



(51) International Patent Classification:
H04R 25/00 (2006.01)

(21) International Application Number:
PCT/EP2011/051380

(22) International Filing Date:
1 February 2011 (01.02.2011)

(25) Filing Language: English

(26) Publication Language: English

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(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, 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, PE, PG, PH, PL, PT, RO, RS, RU, 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, SD, SL, SZ, TZ, UG,
ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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,
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).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

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

(54) Title: HEARING DEVICE WITH A RECEIVER MODULE AND METHOD FOR MANUFACTURING A RECEIVER
MODULE

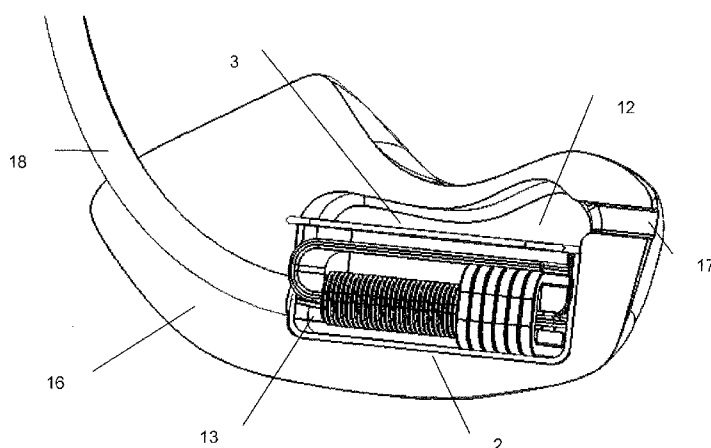


Fig. 4

(57) Abstract: The present invention proposes a hearing device with a housing and a receiver module which comprises a shell (16) with a cavity (15) having an opening (17), wherein at least part of the shell (16) forms part of the housing, and wherein an electro-acoustic transducer, comprising a motor assembly (2) and an acoustic assembly (3) including a membrane (10), is arranged within the cavity (15), the acoustic assembly (3) being disposed within the shell (16) such that the cavity (15) is divided into a front chamber (12) and a back chamber (13), the motor assembly (2) being disposed within the back chamber (13) and being drivingly connected to the membrane (10), and the front chamber (12) being in acoustic communication with the exterior of the shell (16) via the opening (17). Furthermore, a method for manufacturing such a receiver module is presented.



- 1 -

**HEARING DEVICE WITH A RECEIVER MODULE AND METHOD FOR
MANUFACTURING A RECEIVER MODULE**

5 TECHNICAL FIELD

The present invention is related to the technical field of hearing devices employing a miniature loud speaker, which is often also referred to as a receiver. The present
10 invention especially pertains to a receiver module of a hearing device as well as to a method for manufacturing such a receiver module.

BACKGROUND OF THE INVENTION

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Small electronic hearing devices for being worn at an ear or within an ear canal of a user are becoming increasingly popular. Examples of such devices are earphones, for instance used in conjunction with personal audio/video
20 players, gaming units and mobile phones, ear-level communication devices, active hearing protection devices, in-ear monitors as well as hearing aids, sometimes also referred to as hearing instruments or hearing prostheses. Such devices are available in a number of different form
25 factors depending on how they are worn, for instance as behind-the-ear (BTE), in the crest of the cymba, in-the-ear (ITE), in-the-canal (ITC), completely-in-canal (CIC) or

- 2 -

hybrid BTE/ITE devices. In many applications it is preferred that the device is as inconspicuous as possible, e.g. for reasons of aesthetics and wearing comfort. This is frequently achieved by placing the device into the ear canal of the user, either partly or fully. Alternatively, the devices are designed to be small enough to fit into the crest of the cymba or to be worn entirely behind the pinna.

In order to provide an audio signal to the ear drum of the user all the mentioned devices require a receiver, i.e. a unit that converts an electrical signal conveying the audio signal into acoustic energy in the form of sound waves. Such receivers need to be very small, especially in order to fit into the ear canal of a person. Smaller receivers allow to design hearing devices which can be inserted deeper into the ear canal, e.g. into the bony portion, which provides the benefit of reduced occlusion effect. This particularly enables the design of deep-fitted CIC devices. Moreover, smaller receivers allow to design hearing devices that occlude the ear canal to a lesser extent, i.e. that leave the ear canal more open when the hearing device is inserted, providing the benefit of increased wearing comfort as well as a more natural sound perception. Especially open-fitted hybrid BTE/ITE devices, popularly referred to as receiver-in-canal (RIC) or receiver-in-the-ear (RITE) devices, benefit from such small receivers. Furthermore, also BTE devices and devices worn in the crest of the cymba profit from small receivers since

- 3 -

it is mainly the size of the receiver that determines the degree of miniaturisation achievable for these devices.

An example of such a miniature receiver is disclosed in EP 0 851 710 A1. Such receivers typically have the shape of a rectangular cuboid, which is especially not optimal in view of the oval-shaped cross-section of the ear canal.

Alternatively shaped receivers are shown in EP 1 209 948

A2. A receiver with reduced thickness is described in US

5,960,093. In all of these publications the acoustic membrane, also called diaphragm, is arranged longitudinally within the receiver casing in order to maximise the size of the diaphragm and thus to achieve a high output sound

pressure level. Contrary to this EP 0 548 580 A1 proposes

a cylindrical receiver for in-the-ear applications where the diaphragm is arranged laterally with respect to the cylinder axis at an open end of the cylinder. However, this design constrains the size of the diaphragm to that of the ear canal cross-section which has the disadvantage of limiting the achievable output sound pressure level relative to the designs mentioned previously.

SUMMARY OF THE INVENTION

The object of the present invention is to provide smaller hearing devices than presently possible. It is a further object of the present invention to propose a receiver module that can be tailored to the specific needs of an

- 4 -

individual or to the specific requirements of a hearing device model.

At least these objects are achieved by the hearing device with the receiver module according to claim 1. Various exemplary embodiments thereof as well as a method for manufacturing such a receiver module are given in the further claims.

10 The present invention provides a hearing device with a housing and a receiver module, the receiver module comprising a shell with a cavity having an opening, wherein at least part of the shell forms part of the housing, and wherein an electro-acoustic transducer, comprising a motor assembly and an acoustic assembly including a membrane, is
15 arranged within the cavity, the acoustic assembly being disposed within the shell such that the cavity is divided into a front chamber and a back chamber, the motor assembly being disposed within the back chamber and being drivingly
20 connected to the membrane, and the front chamber being in acoustic communication with the exterior of the shell via the opening.

By directly incorporating the electro-acoustic transducer
25 into the shell of a receiver module, where at least part of the shell constitutes part of the housing of the hearing device, and thereby replacing the conventionally used receiver casing with part of the shell a much more flexible

- 5 -

design of the receiver module is achievable both in terms of its size and shape as well as in terms of its acoustic properties. By no longer being constrained to the shape and dimensions of the receiver casing, which is typically a rectangular cuboid, small receiver modules can be designed and hence overall small hearing devices can be realised. Moreover, since a larger degree of design freedom is provided when the electro-acoustic transducer is directly arranged within a cavity of the shell instead of within a receiver casing which has to be disposed in the housing of the hearing device, a larger electro-acoustic transducer capable of providing a higher maximum output sound pressure level can often be employed. Furthermore, the acoustic properties of the receiver module can be optimised to meet desired target parameters, such as a certain frequency response, acoustic impedance, resonant frequency, etc. The acoustic properties can be varied by changing the shape and volume of the front and rear chamber, e.g. by altering the size and shape of the cavity as well as the arrangement of the acoustic assembly. These advantages apply to all styles of miniature hearing devices, i.e. to BTE, ITE, CIC and hybrid versions such as RITE hearing devices.

In an exemplary embodiment of the hearing device the shell has an outer surface individually shaped according to the measured inner shape of a section of the user's ear canal. In this way the specific size and shape of a user's individual ear canal is taken into account, thus allowing to provide a receiver module that can be inserted deeper

- 6 -

into the ear canal of the user or alternatively that blocks the ear canal to a lesser extent.

In a further exemplary embodiment of the hearing device a wall of the cavity is shaped substantially according to the measured inner shape of at least part of the section of the user's ear canal. By adapting parts of the cavity to the shape of the user's ear canal the space available within the shell can be optimally utilised.

10

In a further exemplary embodiment of the hearing device the motor assembly and the acoustic assembly are resiliently attached to the shell. By supporting the motor assembly and the acoustic assembly within the shell with elastic, vibration and shock absorbing means, vibrations from the electro-acoustic transducer are not transferred to the shell and conversely shocks impacting on the shell are not transferred to the electro-acoustic transducer. The former reduces acoustic feedback in configurations where a

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microphone is also located within the shell, as for example in ITE/ITC/CIC-type hearing aids or active hearing protection devices. The latter ensures that the electro-acoustic transducer is protected against shocks affected on the hearing device from the outside, such as when it is dropped and falls on the ground.

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- 7 -

In a further exemplary embodiment of the hearing device the motor assembly and the acoustic assembly are attached to the shell via elastic braces or brackets.

- 5 In a further exemplary embodiment of the hearing device the acoustic assembly further comprises a rigid frame to which the membrane is mounted at its periphery. Mounting the membrane in a rigid frame makes it easier to handle during manufacturing of the hearing device. Additionally, this
10 provides a stable structure for attaching the acoustic assembly to the shell. Furthermore, the acoustic properties of the membrane are strongly influenced by the way in which it is held at its periphery, since this affects its oscillation behaviour, hence defining the
15 fixture of the membrane by means of a frame helps to achieve the desired acoustic performance.

- In a further exemplary embodiment of the hearing device the membrane is integrally formed with the shell. Such an
20 implementation is attractive when employing an additive manufacturing technology such as 3D printing where the shell is created by laying down successive layers of material. 3D printers allow to print parts and assemblies made of several materials with different mechanical and
25 physical properties in a single build process. Alternative additive manufacturing technologies include selective laser sintering (SLS), fused deposition modelling (FDM), digital light projection (DLP) and stereolithography (SL). Forming the membrane together with the shell in a single

- 8 -

manufacturing step saves the step of having to assemble the two and provides a further degree of freedom in customising the receiver module to the requirements of the user by being able to optimise the membrane in terms of its
5 physical dimension, its deployment within the cavity and its acoustic properties.

In a further exemplary embodiment of the hearing device a layer of magnetic shielding material, such as for instance
10 mu-metal, is disposed on the surface of the cavity. By lining the surface of the cavity with a material having a very high magnetic permeability, such as mu-metal, the electro-acoustic transducer is very effectively shielded against static or low-frequency magnetic fields from the
15 outside which could otherwise be picked up by a coil of the motor assembly and thus influence the acoustic output of the electro-acoustic transducer.

In a further exemplary embodiment of the hearing device the
20 receiver module further comprises additional functional units - apart from the electro-acoustic transducer -, such as for instance one or more microphone modules, an amplifier, a processing unit, a wireless transceiver, an antenna, a power supply, wherein at least one of these
25 additional functional units is disposed within the back chamber. In those cases where the receiver module includes additional functional units, such as for instance a wireless receiver for providing an acoustic signal from a personal audio player to the hearing device, these units

- 9 -

can either be disposed in a further cavity within the shell or alternatively, one or more of the units can be disposed in the back chamber of the cavity containing the electro-acoustic transducer. This can for example be the case when
5 the volume of the back cavity needs to be increased, e.g. in order to optimise the low frequency response of the electro-acoustic transducer. To achieve this, the size of the further cavity with the additional functional units and the size of the cavity with the electro-acoustic transducer
10 are traded-off, so that the back chamber obtains a desired volume and shape. As part of this space optimisation process certain of the further functional units may also have to be shifted from the further cavity to the back chamber. Often, it is desirable to maximise the volume of
15 the back cavity, so that no further cavity is formed but all further functional units are deployed in the back chamber, where the back chamber then essentially consumes the entire volume of the shell together with the front chamber.

20

In a further exemplary embodiment the hearing device comprises one or more microphone modules each having a microphone membrane, wherein the microphone membrane of at least one of the microphones is substantially perpendicular
25 to the membrane of the acoustic assembly. In devices such as hearing aids, which incorporate both a microphone and a receiver within the same shell, acoustic feedback from the receiver to the microphone is a big problem. This problem arises due to the very close proximity of the microphone

- 10 -

and the receiver in such small devices and because the microphone signal is strongly amplified before being applied to the receiver, whereby the high gain supports the build-up of feedback oscillations. In order to minimise the propagation of vibrations from the microphone membrane to the membrane of the acoustic assembly, they should preferably be arranged perpendicularly to one another. This can be achieved with the receiver module according to the present invention, since the arrangement and orientation of the microphone relative to the membrane of the acoustic assembly is defined during the design and customisation of the receiver module according to the requirements of the hearing device.

15 In a further exemplary embodiment of the hearing device the back chamber is acoustically sealed from the exterior of the shell. Whilst the front chamber is in acoustic communication with the exterior of the shell via an opening, usually referred to as sound port, in the form of a spout, the back chamber is substantially sealed from the environment and the front chamber in order to achieve a certain acoustic compliance of the air in the back chamber. This however does not mean that the back chamber is air-tight, since an atmospheric pressure equalisation is necessary, for instance via a perforation in the membrane.

In a further exemplary embodiment of the hearing device the shell is a two-part shell with a first part and a second part. This allows to arrange the motor assembly and the

- 11 -

acoustic assembly as well as any further functional units, such as for example a wireless receiver along with an antenna, within the shell during assembly of the hearing device. Following arranging of the various components within the shell, the two parts of the shell are firmly joined together. This can for instance be achieved by gluing or welding the two parts together. Access to the components within the shell can then only be regained by breaking open the shell.

10

In a further exemplary embodiment of the hearing device the first and the second part are separably connected to one another, for instance by means of quick-connect closures, such as catch pawls, detents or bayonet-type junctions.

15 This allows to access the components within the shell anytime, for instance to replace one or more of them, by simply opening the quick-connect closures and then reclosing them again, e.g. when repair work is completed.

20 In a further exemplary embodiment of the hearing device the first part of the shell includes the front chamber and the second part of the shell includes the back chamber.

In a further exemplary embodiment of the hearing device the
25 acoustic assembly is mounted between the first part and the second part. This makes the deployment of the acoustic assembly within the shell easy during assembly since the acoustic assembly can simply be placed into the opening of

- 12 -

one of the parts before the two parts are joined together. Furthermore, the profile of the openings can be used as supports for the acoustic assembly, thus allowing to position the acoustic assembly quickly and accurately during assembly.

In a further exemplary embodiment the hearing device further comprises a behind-the-ear component shaped to fit behind the ear of the user, the behind-the-ear component comprising at least one microphone and an amplifier means, wherein the receiver module is mechanically separate from the behind-the-ear component, and wherein the amplifier means is operatively connected to the motor assembly. The behind-the-ear component can be a generic part intended for many different users, whereas the receiver module may be custom-made to meet the requirements of an individual user both in terms of its geometrical size and shape as well as in terms of its acoustic properties and performance.

In order to be able to take full advantage of the customisation possibilities of the proposed receiver module especially for tailoring a receiver module to the specific needs of an individual an appropriate method for manufacturing such a customised receiver module is required.

The present invention thus further provides a method for manufacturing a receiver module for being worn at least

- 13 -

partly within the ear canal of a user, the receiver module comprising a shell, with a cavity having an opening, and an electro-acoustic transducer, disposed within the cavity and including a motor assembly and an acoustic assembly, the

5 method comprising the steps of:

- measuring the inner shape of at least a section of the user's ear canal (this step subsequently being referred to as "the step of measuring");

10 - generating a three-dimensional computer model of the shell, such that the shell has an outer surface individually shaped according to the measured inner shape of the section of the user's ear canal, and of the arrangement of the motor assembly and the acoustic assembly within the cavity, such that the acoustic
15 assembly divides the cavity into a front chamber and a back chamber, whereby the motor assembly is disposed within the back chamber and is drivingly connected to the acoustic assembly, and the front chamber is in acoustic communication with the exterior of the shell
20 via the opening (this step subsequently being referred to as "the step of generating");

- computing acoustic properties of the electro-acoustic transducer including the front and back chambers based on the generated three-dimensional computer model (this
25 step subsequently being referred to as "the step of computing").

The step of measuring provides a three-dimensional (3D) computer model of at least part of the user's ear canal, namely of the part of the ear canal where the receiver module is intended to be worn, i.e. where it is to be
5 positioned within the ear canal. The step of generating establishes a 3D computer model of the shell based on the 3D computer model of at least part of the user's ear canal as well as 3D computer models of the components, e.g. the motor assembly and the acoustic assembly to be arranged
10 within the cavity of the shell. The resulting 3D computer model of the shell comprises the cavity and the arrangement of the individual components within the cavity, thus yielding all geometric data necessary for determining the acoustic properties of the electro-acoustic transducer in
15 the step of computing.

In an exemplary embodiment the manufacturing method further comprises the step of modifying the three-dimensional computer model of the shell and the arrangement of the
20 motor assembly and the acoustic assembly within the cavity if the computed acoustic properties deviate from desired acoustic properties (this step subsequently being referred to as "the step of modifying"). Hereby, the shape and size of the shell itself as well as the shape, size and location
25 of the cavity within the shell and the arrangement of the components within the cavity can be changed. This yields a modified 3D computer model of the shell including the cavity and the arrangement of the components therein, the modified computer model having modified acoustic

properties, which preferably match desired acoustic properties which are based on the individual requirements of the specific user, e.g. in terms of acoustic performance and wearing comfort.

5

In a further exemplary embodiment of the manufacturing method the step of modifying and the step of computing are repeated until the computed acoustic properties (i.e. those determined in the step of computing) match the desired
10 acoustic properties. Thus the desired acoustic properties are gradually approached by repeatedly modifying the 3D computer model of the shell including the cavity and the arrangement of the components therein, computing the resulting acoustic properties and comparing these with the
15 desired acoustic properties specified as design target for the receiver module.

In a further exemplary embodiment of the manufacturing method the shape and/or the volume of the front and/or the
20 back chamber is modified as part of the step of modifying. Since the acoustic properties of the receiver module are largely dependent on the shape and volume of the front and back chambers, focusing modifications on these quantities will have the largest impact on the acoustic properties,
25 and thus will result in a rapid convergence of the 3D computer model of the shell including the cavity and the arrangement of the components therein towards a design of the receiver module which exhibits the desired acoustic properties.

- 16 -

In a further exemplary embodiment of the manufacturing method the computed acoustic properties include one or more of an acoustic impedance, an acoustic compliance, a
5 frequency response, a resonant frequency, a power conversion efficiency, an output sound pressure level. Based on these acoustic properties the acoustic performance of the receiver module can be determined for a situation where the user is wearing the receiver module at least
10 partly within the ear canal as intended during its use.

In a further exemplary embodiment the manufacturing method further comprises the step of forming the shell according to the three-dimensional computer model by a rapid
15 prototyping process such as for instance selective laser sintering, stereolithography, photopolymerisation, fused deposition modelling or 3D printing. This allows a very cost effective and quick production of customised shells for the receiver module, and even makes it possible to
20 integrally form components such as for instance the membrane of the electro-acoustic transducer as part of the shell, as indicated above, thus further simplifying production since separate assembly of the acoustic assembly is not required.

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It is explicitly to be noted that the mentioned method of manufacturing a receiver module can also be similarly applied to manufacturing receiver modules that are tailored to the specific requirements of a hearing device "model".

- 17 -

Such a hearing device model can be either a BTE or an ITE hearing device, which is not adapted to a certain individual, e.g. is not shaped according to the individual's ear canal, but more generically designed to meet the requirements of most user's by providing a hearing device model with a very specific shape and/or size and/or acoustic properties that cannot be achieved with an off-the-shelf receiver provided for instance in a standard rectangular cuboid shaped casing as a separate unit to be built into a hearing device. For such an application the proposed method for manufacturing a receiver module would be adapted to comprise:

- providing a desired shape and size of a receiver module for being used as part of a hearing device worn at the ear or in the ear canal;
- generating a three-dimensional computer model of the shell taking into account the provided shape and size of the receiver module; and
- computing acoustic properties in accordance with the previously proposed method for manufacturing a receiver module.

It is expressly pointed out that any combination of the above-mentioned embodiments, or combinations of combinations, is subject of a further combination. Only those combinations are excluded that would result in a contradiction.

BRIEF DESCRIPTION OF THE DRAWINGS

Subsequently, the present invention is further explained with the help of exemplary embodiments and with reference to the following accompanying drawings:

Fig. 1 is a schematic side-sectional view of a known (i.e. prior art) receiver;

Fig. 2 is a schematic side-sectional representation of a known (i.e. prior art) receiver arranged within a shell inserted in an ear canal a) at a large distance d from the ear drum, and b) at a short distance d' from the ear drum;

Fig. 3 is a schematic side-sectional representation of a receiver module according to the present invention positioned within an ear canal; and

Fig. 4 is a sectional view of an exemplary embodiment of a receiver module according to the present invention for use within a user's ear canal in connection with a BTE component (not shown).

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a schematic side-sectional view of a commonly employed balanced-armature type of magnetic receiver 1.

This type of receiver 1 is capable of a very efficient conversion of electrical energy into sound energy. The known receiver 1 in Fig. 1 basically consists of a motor

- 19 -

assembly 2 and an acoustic assembly 3 (together referred to as an electro-acoustic transducer) which are disposed in a casing 4. The motor assembly 2 comprises a coil 5 and a pair of permanent magnets 6, 6' through and between which a U-shaped armature 7 extends. An electric current passing through the coil 5 introduces a magneto motive force in the armature 7. As a result, the tip of the armature 7 is attracted more by one of the permanent magnets 6, 6' and less by the other, depending on the direction of the electric current, which bends the armature 7. A drive pin 8 connected to the armature 7 and to a membrane 9 (also referred to as a diaphragm) of the acoustic assembly 3, is thus moved dependent on the electrical signal applied to the coil 5 through a terminal 9 causing the membrane 10 to vibrate and generate sound waves, which exit the casing 4 via a spout 11. The acoustic properties of the receiver 1 are dependent on the air volumes in front of and behind the membrane 11 (referred to as front and back volumes), i.e. in the front chamber 12 and back chamber 13, where the motor assembly 2 is located in the back chamber 13. Typically a rectangular cuboid casing 4 is used to encapsulate the motor and acoustic assemblies 2, 3 as well as the front and back volumes.

Fig. 2 a) depicts a standard receiver 1 arranged within a shell 16 which is inserted into the outer end of an ear canal 14 such that the inner end of the shell 16 is located at a relatively large distance d from the ear drum. As schematically shown in Fig. 2 b) the rectangular casing of

- 20 -

a standard receiver 1 often does not fit into a deeply located inner section of the ear canal 14, i.e. at a relatively short distance d' from the ear drum, and hence cannot be arranged in the shell 16 of a hearing device to be inserted into the ear canal 14 at such a location. This is evident from the casing 4 extending beyond the contour of the shell 16 and beyond the wall of the ear canal 14 in Fig. 2 b).

In order to overcome this problem the present invention proposed to dispose the electro-acoustic transducer comprising the motor assembly 2 and the acoustic assembly 3 directly into a cavity 15 of the shell 16 without the casing 4. A receiver module according to the present invention is schematically illustrated in Fig. 3. Here the cavity 15 is formed in such a way in the shell 16, intended to be worn within a deeply located inner section of the ear canal 14, that the motor assembly 2 and the acoustic assembly 3 can be arranged closer to the opening 17, which constitutes a sound port to the exterior of the shell 16. The front and back volume of the receiver module has been maintained equivalent to that of the solution using a standard receiver 1 with a casing 4, but the shape and volume of the cavity 15 and the arrangement of the acoustic membrane 10 has be adapted such that the front chamber 12 and the back chamber 13 provide the necessary free space for the front and back volumes of air.

- 21 -

The front chamber 12 is in acoustic communication with the exterior of the shell 16 via the opening 17, also referred to as sound port, whilst the back chamber 13 is substantially sealed from the environment and the front chamber 12. However, a means for allowing atmospheric pressure equalisation within the back chamber 13, such for instance a perforation in the membrane 10 or a vent with a very small diameter connecting the back chamber 13 with the exterior of the shell 16, is provided.

10

As already indicated earlier, a small receiver module is often desired in order to be able to insert the receiver module deeply into the bony portion of the ear canal 14, where it is seated in a sealing manner. This is referred to as a closed "deep-fitting", which offers a reduced occlusion effect in comparison to a less deep fitting located within the cartilaginous region of the ear canal 14. Alternatively, it is sometimes desirable to be able to arrange the receiver module in the form of an "open-fitting" within an outer section of the ear canal 14, whereby the receiver needs to be small in order not to occlude the ear canal 14 and leave its cross-section as open as possible. In both cases a receiver module according to the invention will be of use due to its reduced size relative to one incorporating a standard receiver 1 with a casing 4.

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To be able to mount the electro-acoustic transducer within the cavity 15 of the shell 16, the shell 16 is for instance

- 22 -

made of two parts. The first and second part of the two-part shell can be formed as two separate parts or as a single part which is subsequently cut into two parts. Once the electro-acoustic transducer has been arranged within the cavity 15 the two parts of the shell can be firmly joined together. This can for instance be achieved by gluing or welding the two parts together, or especially in the case where the first and second part of the two-part shell were formed as two separate parts this can be achieved by separably connecting the two parts to one another, for instance by means of quick-connect closures, such as catch pawls, detents or bayonet-type junctions.

The motor assembly 2 and the acoustic assembly 3 are resiliently attached to the shell 16 within the cavity 15 in order to minimise the transfer of acoustic vibrations from the electro-acoustic transducer to the shell 16 and on the other hand to protect the electro-acoustic transducer from shock impacts imposed on the receiver module from the outside. Hereby, the motor assembly 2 and the acoustic assembly 3 are attached to the shell 16 via elastic braces or brackets.

The membrane 10 is for instance mounted at its periphery to a rigid frame. This provides a stable structure for attaching the acoustic assembly 3 to the shell 16. The frame can for instance be positioned between the first and second part of the shell 16 and the profile of their openings can be used as supports for the frame, thus

- 23 -

allowing to position the membrane 10 quickly and accurately during assembly. In this case the first part of the shell 16 includes the front chamber 12 and the second part of the shell 16 includes the back chamber 13. In applications
5 where the shell 16 also contains a microphone, the plane of the membrane 10 of the electro-acoustic transducer and the plane of the membrane of the microphone are preferably to be oriented perpendicularly to each other.

- 10 To provide magnetic shielding of the electro-acoustic transducer the entire surface of the cavity 15 is lined with a material having a very high magnetic permeability, such as mu-metal.
- 15 For certain applications further functional units, such as for instance one or more microphone modules, an amplifier, a processing unit, a wireless transceiver, an antenna, a power supply, are arranged within the shell 16, either in a separate cavity or within the back chamber 13.

20

As exemplified in Fig. 4 the receiver module according to the present invention can be used in conjunction with a hybrid-type hearing device, comprising a component (not shown) worn outside of the ear canal, such as for instance
25 a behind-the-ear (BTE) component having a housing shaped to fit behind the ear of the user, and the receiver module worn at least partly within the ear canal, where the two are connected to one another via a flexible connecting

- 24 -

means 18, for example a thin tube including wires to provide an electrical signal from the BTE component to the receiver module, i.e. from an amplifier means (not shown) to the motor assembly 2.

5

In order to be able to design receiver modules which take into account the specific shape of the user's ear canal and for example also the specific acoustic requirements of the user a manufacturing method needs to be available which
10 allows custom design and manufacturing of individual receiver modules. According to the invention such a manufacturing method for instance comprises the steps indicated in the following.

15 In a first step the inner shape and size of the user's ear canal 14 is measured. This can be achieved by taking an imprint of the user's ear canal 14 and then scanning the imprint with a 3D object scanner, or alternatively by
20 directly scanning the ear canal 14 of the user with the help of an appropriate probe. In either case a 3D computer model of the user's ear canal 14 or part thereof is generated.

In a second step performed with the aid of an appropriate
25 shell modelling software, the shell 16 is designed based on the type of receiver module required by the user, whereby the shell design software uses the 3D computer model of user's ear canal 14 to individually shape the outer surface

- 25 -

of the shell 16, as well as 3D computer models of the components, such as the motor assembly 2 and the acoustic assembly 3, to form the cavity 15 within the shell 16 and arrange the components therein. When forming the cavity 15 and arranging the acoustic assembly 3 therein, special attention is given to achieving appropriately sized front and back chambers 12 & 13, respectively, having a sufficiently large front and back volumes, respectively, for the air to generate sound waves. The result of this design is a 3D computer model of the shell 16 including the cavity 15 with the front and back chambers 12 & 13 as well as the arrangement of all components within the shell 16, i.e. a 3D computer model of the complete receiver module.

In a third step, acoustic properties of the receiver module are computed using an acoustic analysis software based on geometric data extracted from the 3D computer model of the complete receiver module. The acoustic properties determined in this step are then compared with desired target acoustic properties. If these target acoustic properties are achievable with the present design according the 3D computer model of the complete receiver module, the design is ready to be produced, otherwise the design is modified in a fourth step.

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In a fourth step a design resulting from the second step which is acoustically insufficient, i.e. does not match the target acoustic properties, is modified by making changes to any of the shell shape and size, the positioning within

- 26 -

the shell 16 and shape and size of the cavity 15, and the arrangement of the components within the cavity 15, yielding a modified 3D computer model of the complete receiver module.

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Subsequently, the acoustic properties of the modified receiver module are determined according to the third step. The cycle of modifying the design according to the fourth step and determining the acoustic properties of the thus modified receiver module according to the third step is repeated until the determined acoustic properties match the desired target acoustic properties, at which point the design is ready to be produced.

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Finally, the shell 16 of the receiver module is formed employing an additive manufacturing process, such as for instance selective laser sintering (SLS), fused deposition modelling (FDM), digital light projection (DLP), stereolithography (SL) or 3D printing, whereby the shell is created by laying down successive layers of material. 3D printers for example allow to print parts and assemblies made of several materials with different mechanical and physical properties in a single build process. Such a production process also allows to integrally form the membrane 10 of the electro-acoustic transducer together with the shell 16 in a single production step, thus saving the step of having to assemble the two and furthermore providing an extra degree of freedom to customise the receiver module to the requirements of the user by being

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- 27 -

able to optimise the membrane in terms of its physical dimension, its deployment within the cavity and its acoustic properties.

- 5 A similar manufacturing method may be applied to provide a receiver module tailored to a hearing device model having specific requirements in terms of shape and/or size and/or acoustic properties, which is suitable to fulfil the needs of a large number of users, i.e. which is not fully
10 customised according to the individual needs of a single person. To obtain such "one-size-fits-all" types of BTE, ITE and/or RITE hearing devices, their specific requirements are provided as inputs in the previously described manufacturing method instead of the individual
15 data related to a certain user.

In both the case of an individualised hearing device and of a hearing device model having one or more of the above listed specific requirements the shell 16 of the receiver
20 module may be implemented as a separate part of the housing of the hearing device or as an integral part of the housing of the hearing device.

CLAIMS

1. A hearing device with a housing and a receiver module,
the receiver module comprising a shell (16) with a cavity
5 (15) having an opening (17), wherein at least part of the
shell (16) forms part of the housing, and wherein an
electro-acoustic transducer, comprising a motor assembly
(2) and an acoustic assembly (3) including a membrane (10),
is arranged within the cavity (15), the acoustic assembly
10 (3) being disposed within the shell (16) such that the
cavity (15) is divided into a front chamber (12) and a back
chamber (13), the motor assembly (2) being disposed within
the back chamber (13) and being drivingly connected to the
membrane (10), and the front chamber (12) being in acoustic
15 communication with the exterior of the shell (16) via the
opening (17).

2. The hearing device according to claim 1, wherein the
shell (16) has an outer surface individually shaped
20 according to the measured inner shape of a section of a
user's ear canal (14).

3. The hearing device according to claim 1 or 2, wherein
the motor assembly (2) and the acoustic assembly (3) are
25 attached to the shell (16) via elastic braces or brackets.

4. The hearing device according to one of the claims 1 to
3, wherein the acoustic assembly (3) further comprises a

- 29 -

rigid frame to which the membrane (10) is mounted at its periphery.

5 5. The hearing device according to one of the claims 1 to 4, wherein the receiver module further comprises functional units, such as for instance one or more microphone modules, an amplifier, a processing unit, a wireless transceiver, an antenna, a power supply, wherein at least one of these functional units is disposed within the back chamber (13).

10

6. The hearing device according to one of the claims 1 to 5, wherein the shell (16) is a two-part shell with a first part and a second part.

15 7. The hearing device according to claim 6, wherein the first part includes the front chamber (12) and the second part includes the back chamber (13).

20 8. The hearing device according to claim 6, wherein the acoustic assembly (3) is mounted between the first part and the second part.

25 9. The hearing device according to one of the claims 1 to 8, further comprising a behind-the-ear component shaped to fit behind the ear of the user, the behind-the-ear component comprising at least one microphone and an amplifier means, wherein the receiver module is

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mechanically separate from the behind-the-ear component, and wherein the amplifier means is operatively connected to the motor assembly (2).

- 5 10. A method for manufacturing a receiver module for being worn at least partly within the ear canal (14) of a user, the receiver module comprising a shell (16), with a cavity (15) having an opening (17), and an electro-acoustic transducer, disposed within the cavity (15) and including a
- 10 motor assembly (2) and an acoustic assembly (3), the method comprising the steps of:
- measuring the inner shape of at least a section of the user's ear canal (14);
 - generating a three-dimensional computer model of the

15 shell (16), such that the shell (16) has an outer surface individually shaped according to the measured inner shape of the section of the user's ear canal (14), and of the arrangement of the motor assembly (2) and the acoustic assembly (3) within the cavity (15), such that

20 the acoustic assembly (3) divides the cavity (15) into a front chamber (12) and a back chamber (13), whereby the motor assembly (2) is disposed within the back chamber (13) and is drivingly connected to the acoustic assembly (3), and the front chamber (12) is in acoustic

25 communication with the exterior of the shell (16) via the opening (17);

 - computing acoustic properties of the electro-acoustic transducer including the front and back chambers (12,

- 31 -

13) based on the generated three-dimensional computer model.

11. The method according to claim 10, further comprising
5 the step of modifying the three-dimensional computer model of the shell (16) and the arrangement of the motor assembly (2) and the acoustic assembly (3) within the cavity (15) if the computed acoustic properties deviate from desired acoustic properties.

10

12. The method according to claim 11, wherein the steps of modifying and computing are repeated until the computed acoustic properties match the desired acoustic properties.

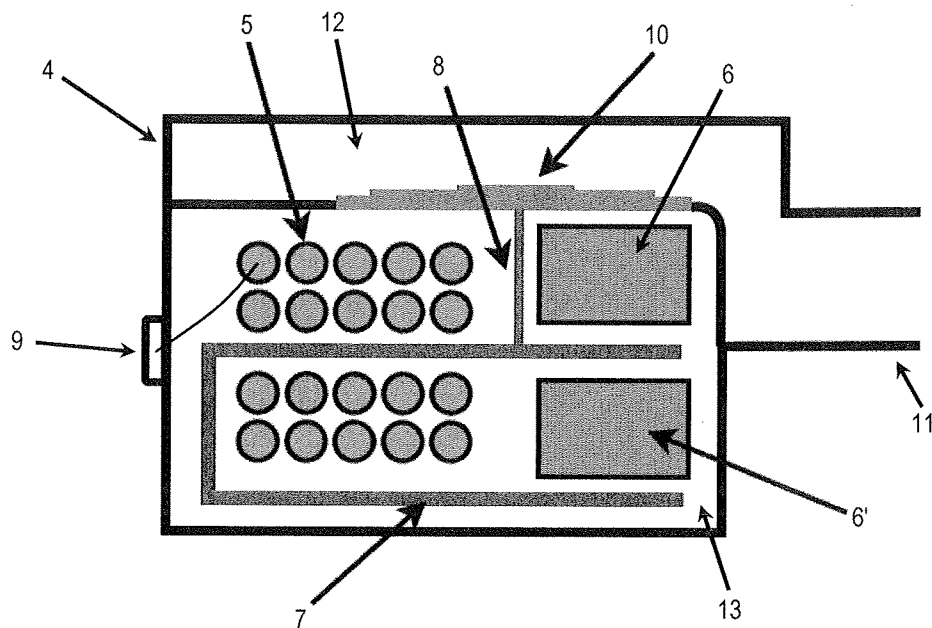
15 13. The method according to claim 11 or 12, wherein as part of step of modifying, the shape and/or the volume of the front and/or the back chamber (12, 13) is modified.

14. The method according to one of the claims 10 to 13,
20 wherein the computed acoustic properties include one or more of an acoustic impedance, an acoustic compliance, a frequency response, a resonant frequency, a power conversion efficiency, an output sound pressure level.

25 15. The method according to one of claims 10 to 14, further comprising the step of forming the shell (16) according to the three-dimensional computer model by a

- 32 -

rapid prototyping process such as for instance selective laser sintering, stereolithography, photopolymerisation, fused deposition modelling or 3D printing.



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Fig. 1

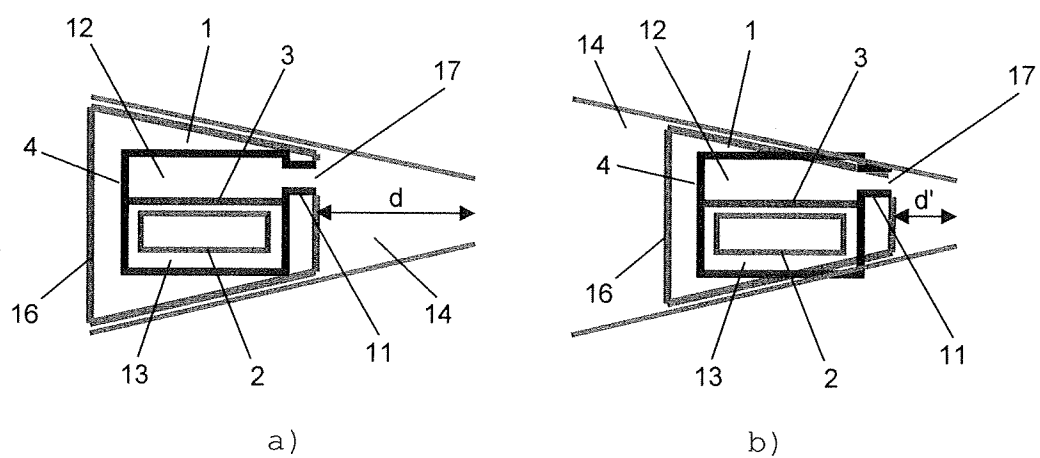


Fig. 2

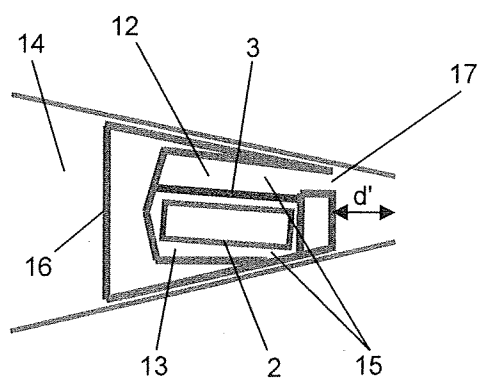


Fig. 3

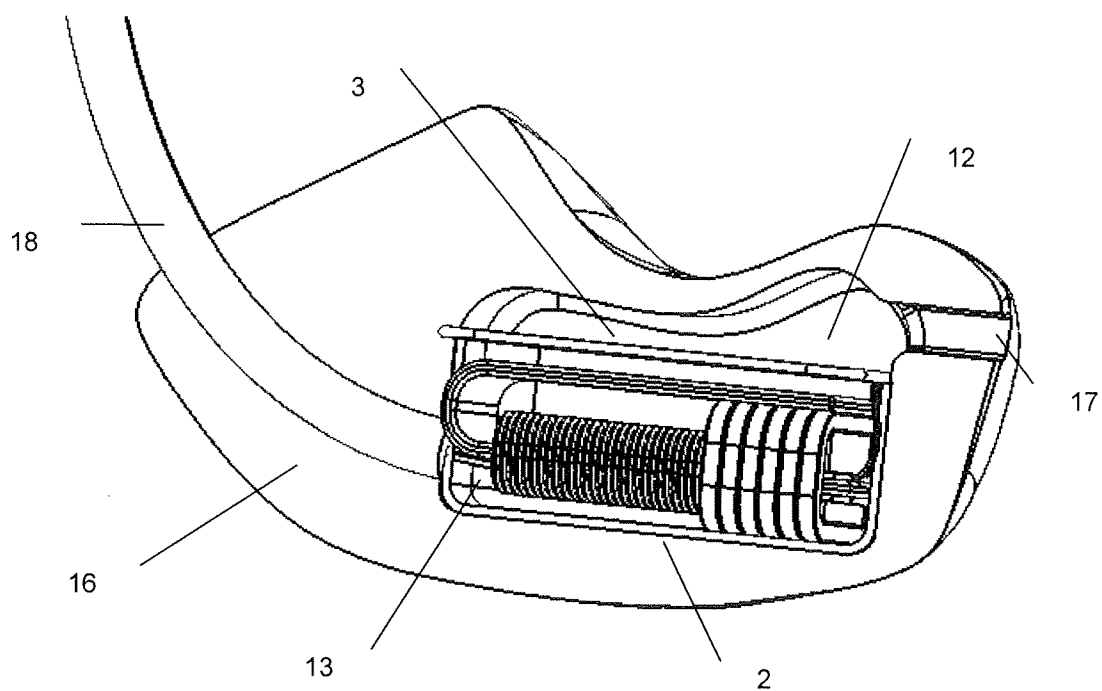


Fig. 4

International application No
PCT/EP2011/051380

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

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 practical, search terms used)

EP0-Internal, WPI Data

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X	W0 2007/140403 A2 (KNOWLES ELECTRONICS LLC [US]; WARREN DANIEL MAC [US]; MILLER THOMAS ED) 6 December 2007 (2007-12-06)	1-4,6-9
Y	paragraphs [0028], [0036] - [0040] figures 7A-7C -----	10-15
Y	EP 1 246 506 A1 (WIDEX AS [DK]) 2 October 2002 (2002-10-02) paragraphs [0010], [0016], [0018] - [0019] ----- -/--	10-15

☒ Further documents are listed in the continuation of Box C.

X See patent family annex.

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Date of the actual completion of the international search

15 September 2011

Date of mailing of the international search report

26/09/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2011/051380

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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