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(54) Title: PARTIALLY IMPLANTABLE HEARING INSTRUMENT

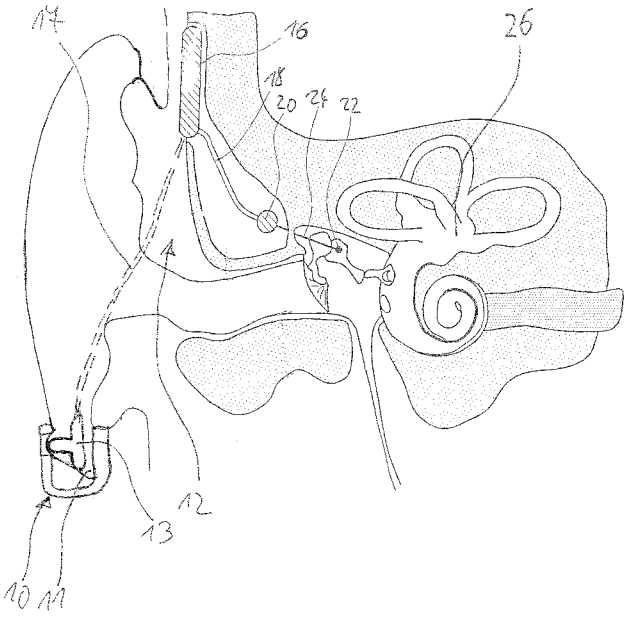

Fig. 1

(57) Abstract: The invention relates to a hearing instrument comprising an external unit (10, 110) comprising an audio signal source (30), an audio signal processing unit (36) for processing the audio signals provided by the audio signal source, a power source (50) and means (38, 40, 52, 54) for transmitting the processed audio signals and power from the power source via a transcutaneous wireless link (42, 56), the transmitting means comprising at least one transmission coil (40, 54), and an implantable assembly (12) comprising means (44, 46, 58, 60) for receiving audio signals and power via the transcutaneous wireless link from the external unit and an actuator (20) for stimulating a middle ear or inner ear component (22) of the hearing of a patient according to the processed audio signals, wherein the means for receiving audio signals and power from the external unit comprises a receiving coil assembly (13, 113) to be implanted within an earlobe (11) of a patient and wherein the external unit comprises fixation means (62, 64, 66, 174, 176) for clipping the external unit to the earlobe in a detachable manner.

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Partially implantable hearing instrument

The present invention relates to a partially implantable hearing instrument comprising an external unit including an audio signal source (typically a microphone), an audio signal processing unit for processing the audio signals provided by the audio signal source, a power source and means for transmitting the processed audio signals and power from the power source via a transcutaneous wireless link, and an implantable assembly comprising means for receiving audio signals and power via the transcutaneous wireless link from the external unit and an actuator for stimulating a middle ear or inner ear component of the hearing of a patient according to the processed audio signals.

Typically, the transcutaneous wireless link is realized as an inductive link used for transmitting both audio signals and power, with the external unit comprising a transmission coil and the implantable unit comprising a receiving coil. Typically, the receiving coil is implanted in an artificial cavity created in the mastoid region, and the external unit has a disc-like or button-like shape and is attached to the patient's head in a detachable manner at a position opposite to the implanted receiving coil in order to align the coils. The external unit typically includes at least one magnet which cooperates with an implanted magnet in order to keep the external unit at the correct position. An example of such a partially implantable hearing aid comprising an electromechanical output transducer is described in WO 2005/101903 A2.

However, such fixation of the external unit via magnetic forces causes a relatively high weight of the external unit (the magnet of the external unit may contribute almost half of the total weight of the external unit) and also a relatively large size of the external unit; in addition, the implanted magnet has to be surgically removed in case of MRI (Magnetic Resonance Imaging). Moreover, since the attractive forces between the magnets are limited, the external unit may move from the desired position and even fall down as a result of fast movements of the head (for example, when the patient jumps).

WO 2009/056167 A1 relates to a cochlea implant having an external microphone module which is connected to the implantable part of the hearing aid via a wireless interface for

transmitting audio signals/data from the microphone to the implantable part and for transmitting power from the implantable part to the microphone module. The signal/power transmission may be inductive, with a wireless interface of the implant cooperating with a wireless interface of the microphone module; the interfaces comprise cooperating inductive coils. The coil of the implant interface may be implanted within the pinna in such a manner that it surrounds a hole made into the pinna for inserting the microphone module. Such hole may be provided in the earlobe part of the pinna.

US 2003/0055311 A1 and WO 97/30565 A1 relates to fully implantable hearing aids, wherein the microphone is implanted in the earlobe.

US 2004/0138723 A1 relates to a communication system including an external control device which may have the appearance of an ear ring which is clipped to the earlobe of the user.

It is an object of the invention to provide for a partially implantable hearing aid, wherein the external unit is of small size and low weight and can be detachably fixed at the patient's head in a reliable manner.

According to the invention, this object is achieved by a hearing instrument as defined in claim 1.

The invention is beneficial in that, by providing the implantable unit with a receiving coil assembly to be implanted within the earlobe of the patient and by providing the external unit with fixation means for clipping the external unit to the earlobe in a detachable manner, the external unit can be fixed at the patient's head in a reliable and safe manner, while the need for using fixation magnets in the external unit and the implantable unit is eliminated, so that the external unit can be made of small size and of low weight.

Preferred embodiments of the invention are defined in the dependent claims.

Hereinafter examples of the invention will be illustrated by reference to the attached drawings, wherein:

Fig. 1 is a cross-sectional view of the pinna, the mastoid region, the middle ear and the inner ear of a patient after implantation of an example of a hearing instrument according to the invention, with the hearing instrument being shown schematically;

Fig. 2 is an example of a block diagram of the system of Fig. 1;

Fig. 3 is a view of an example of the implantable part of a hearing instrument according to the invention prior to implantation;

Fig. 4 is a view like Fig. 3, with an alternative embodiment being shown;

Fig. 5 is a perspective view of how an example of the external unit of a hearing aid according to the invention cooperates with the receiving coil assembly of the implantable part shown in Fig. 3 or 4;

Fig. 6 is a perspective view of an alternative embodiment of the receiving coil assembly of the implantable part; and

Fig. 7 is a cross-sectional view of the receiving coil assembly of Fig. 6 when cooperating with a mating external unit.

Fig. 1 shows a cross-sectional view of the pinna, the mastoid region, the middle ear and the inner ear of a patient after implantation of an example of a hearing instrument according to the invention, wherein the hearing instrument is shown only schematically. The hearing instrument comprises an external unit 10 which is worn at the patient's earlobe 11 and an implantable assembly 12 comprising a receiving coil assembly 13, an electronics unit 16 and an electromechanical actuator 20. The receiving coil assembly 13 is implanted within the earlobe 11 and is connected via a first electrical cable 17 to the electronics unit 16 which is implanted under the patient's skin, usually in an artificial cavity created in the patient's mastoid and which is connected via a second electrical cable 18 to the electromechanical actuator 20. The actuator 20 is coupled via a coupling rod 24 to a middle ear or inner ear

component of the hearing of the patient, such as an ossicle 22, the stapes footplate, the oval window or the round window of the cochlea 26 in order to stimulate the patient's hearing. As an alternative, the actuator 20 could act directly on the perilymph, or it could be a cochlea implant electrode (not shown in Fig. 1).

An example of a block diagram of the system of Fig. 1 is shown in Fig. 2. The external unit 10 includes a microphone arrangement 30 which typically comprises at least two spaced-apart microphones 32 and 34 for capturing audio signals from ambient sound, which audio signals are supplied to an audio signal processing unit 36, wherein they undergo, for example, acoustic beam forming. The processed audio signals are supplied to a transmission unit 38 connected to a transmission antenna 40 in order to enable transcutaneous transmission of the processed audio signals via an inductive link 42 to the implantable assembly 12 which comprises a receiving antenna 44 connected to a receiver unit 46 for receiving the transmitted audio signals. The received audio signals are supplied to a driver unit 48 which drives the actuator 20.

The external unit 10 also comprises a power supply 50 which may be a replaceable or rechargeable battery, a power transmission unit 52 and a power transmission antenna 54 for transmitting power to the implantable unit 12 via a wireless power link 56. The implantable unit 12 comprises a power receiving antenna 58 and a power receiving unit 60 for powering the implanted electronic components with power received via the power link 56.

In order to achieve a particularly simple design, the antennas 40 and 54 and the antennas 44 and 58 could be physically formed by a single coil, respectively. However, if efficiency of the audio signal link 42 and of the power link 56 is to be optimized, the audio signal antennas 40, 44 may be separated from the power antennas 54 and 58.

In the example of Fig. 1, the receiving antennas 44, 58, preferably as a single coil, are included within the receiving coil assembly 13, and the driver unit 48, and optionally also the audio signal receiver unit 46 and the power receiver unit 60, may form part of the electronics unit 16. However, in the example shown in Fig. 1, not only the receiving antennas 44, 58 but

also driver unit 48, the audio signal receiver unit 46 and the power receiver unit 60 are shown as being included in the receiving coil assembly.

The external unit 10 comprises fixation means for clipping the external unit 10 to the earlobe 11 in a detachable manner. In the example shown in Figs. 1 and 5, the housing of the external unit 10 has a clamp-like shape having a first leg 62 and a second leg 64 (i.e. the housing has a substantially U-shaped cross-section), with the transmission coil(s) 40, 54 being located in the second leg 64 and with the first leg 62 comprising an opening 66 (alternatively, the opening 66 could be replaced by a corresponding recess in the first leg 62).

The receiving coil assembly 13 comprises positioning means cooperating with the fixation means of the external unit 10 in a manner so as to position the external unit 10 relative to the receiving coil assembly 13. In particular, the positioning means and the fixation means serve to align the transmission coil(s) 40, 54 and the receiving coil(s) 44, 58. According to the example shown in Figs. 1 and 5, the receiving coil assembly 13 comprises a central axially extending projection 68 which cooperates with the opening 66 provided in the external unit 10. When the external unit 10 is clipped to the earlobe 11, the receiving coil assembly 13 is located between the first leg 62 and the second leg 64, with the projection 68 of the receiving coil assembly 13 extending towards or into the opening 66 of the external unit 10. Since the receiving coil assembly 13 is implanted within the earlobe 11, the opening 66 and the projection 68 have to be designed in such a manner that there is enough space for the skin 14 covering the projection 68 between the tip of the projection 68 and the opening 66. For example, the diameter of the opening 66 should be sufficiently larger than the diameter of the tip of the projection 68, and the length of the projection 68 has to be selected such that the tip of the projection 68 does not extend too far into the opening 66.

As shown in Fig. 1, the first leg 62 may be located at the ventral side of the earlobe 11 and the second leg 64 may be located at the dorsal side of the earlobe 11, so that the second leg 64, which includes the transmission coil(s) 40, 54 and hence usually will be larger than the first leg 62, is at least partly concealed behind the earlobe 11. However, also an orientation opposite to that shown in Fig. 1, with the ventral and dorsal position of the first and second leg being interchanged, is possible.The patient may be asked before the operation which

orientation of the external unit 10 he prefers, so that the receiving coil assembly can be implanted in the respective orientation in which the antennas match best.

According to the embodiment shown in Figs. 1 and 3, an electronics unit 16, i.e. an implant casing housing electronic circuitry forming the driver unit 48, and optionally also electronic circuitry forming the audio signal receiver unit 46 and/or the power receiving unit 60, is provided between the transmission coil assembly 13 and the actuator 20. According to an alternative embodiment shown in Fig. 4, the electronics unit 16 may be eliminated by integrating the electronic circuitry contained in the electronics unit 16 within the housing of the receiving coil assembly 13. In this case the receiving coil assembly 13 is directly connected to the actuator 20 via a cable 19.

An alternative embodiment of the fixation means of the external unit 10 and the positioning means of the receiving coil assembly 13 is shown in Figs. 6 and 7, wherein the receiving coil assembly 113 is provided with a central opening 170, and wherein the housing of the external unit 110 comprises a base portion 172 containing the transmission coil(s) 40, 54 and a projection 174 which extends from the base portion 172 through the central opening 170 of the receiving coil assembly 113 and also through a hole provided in the earlobe 11 (such hole in the earlobe 11 has to be created at the position of the central opening 170 of the receiving coil assembly 113 after implantation). The tip of the projection 174 is provided with a removable end cap 176 for securing the projection 174 within the central opening 170 of the receiving coil assembly 113. According to Fig. 7, the end cap 176 is located at the ventral side of the earlobe 11 and the base portion 172 is located at the dorsal side of the earlobe 11. However, as in the embodiment of Figs. 4 and 5, alternatively the orientation with regard to the ventral and dorsal side may be interchanged.

Compared to partially implantable hearing instruments wherein the external unit is fixed by magnets at the skin of the patient's head above the ear, the present invention provides for the following benefits: the size and the weight of the external unit can be reduced, since no magnet is necessary for fixation; a more reliable fixation of the external unit can be achieved so that the patient's head may move more freely (in particular the risk that the external unit will move from its desired position or even falls down is significantly reduced); there is no

problem of hair growing at the position where the external unit is fixed; and the external unit is less apparent to other persons, so that there is a less obvious perception of a handicap.

Claims

1. A hearing instrument comprising

an external unit (10, 110) comprising an audio signal source (30), an audio signal processing unit (36) for processing the audio signals provided by the audio signal source, a power source (50) and means (38, 40, 52, 54) for transmitting the processed audio signals and power from the power source via a transcutaneous wireless link (42, 56) , the transmitting means comprising at least one transmission coil (40, 54), and

an implantable assembly (12) comprising means (44, 46, 58, 60) for receiving audio signals and power via the transcutaneous wireless link from the external unit and an actuator (20) for stimulating a middle ear or inner ear component (22) of the hearing of a patient according to the processed audio signals,

wherein the means for receiving audio signals and power from the external unit comprises a receiving coil assembly (13, 113) to be implanted within an earlobe (11) of a patient and wherein the external unit comprises fixation means (62, 64, 66, 174, 176) for clipping the external unit to the earlobe in a detachable manner.

2. The hearing instrument of claim 1, wherein the receiving coil assembly (13, 113) comprises positioning means (68, 170) cooperating with the fixation means (62, 64, 66, 174, 176) in a manner so as to position the external unit (10, 110) relative to the receiving coil assembly.

3. The hearing instrument of claim 2, wherein the positioning means (68, 170) and the fixation means (62, 64, 66, 174, 176) are for aligning the transmission coil (40, 54) and the receiving coil assembly (13, 113).

4. The hearing instrument of one of the preceding claims, wherein the receiving coil assembly (13) comprises an axially extending projection (68) and wherein the external unit comprises a cooperating opening (66) or recess for receiving the projection.

5. The hearing instrument of claim 4, wherein the housing of the external unit (10) has a clamp-like shape having a first leg (62) and a second leg (64), wherein the receiving coil assembly (13) is to be located between the first leg and the second leg, wherein the

cooperating opening (66) or recess forms part of the first leg, and wherein the transmission coil (44, 58) forms part of the second leg.

6. The hearing instrument of claim 5, wherein the first leg (62) is to be located at the ventral side of the earlobe (11) and wherein the second leg (64) is to be located at the dorsal side of the earlobe.

7. The hearing instrument of one of claims 1 to 3, wherein the receiving coil assembly (113) comprises a central opening (170), and wherein the housing of the external unit (110) comprises a base portion (172) containing the transmission coil (40, 54) and a projection (174) for extending from the base portion through said central opening and through the earlobe (11), and wherein the projection of the external unit comprises an end cap (176) for securing the projection within the central opening.

8. The hearing instrument of claim 7, wherein the end cap (176) is to be located at the ventral side of the earlobe (11) and wherein the base portion (172) is to be located at the dorsal side of the earlobe.

9. The hearing instrument of one of the preceding claims, wherein the implantable assembly (10, 110) comprise an electronics unit (16) comprising electronic circuitry (48) for driving the actuator (20), and wherein the electronics unit is connected to the receiving coil assembly (13) via an electrical cable (17).

10. The hearing instrument of one of claims 1 to 9, wherein the housing of the receiving coil assembly (13, 113) contains electronic circuitry (48) for driving the actuator (20).

11. The hearing instrument of one of the preceding claims, wherein the actuator (20) is an electromechanic actuator to be coupled to an ossicle (22), the round or oval window or to the cochlea wall or to act directly on the perilymph.

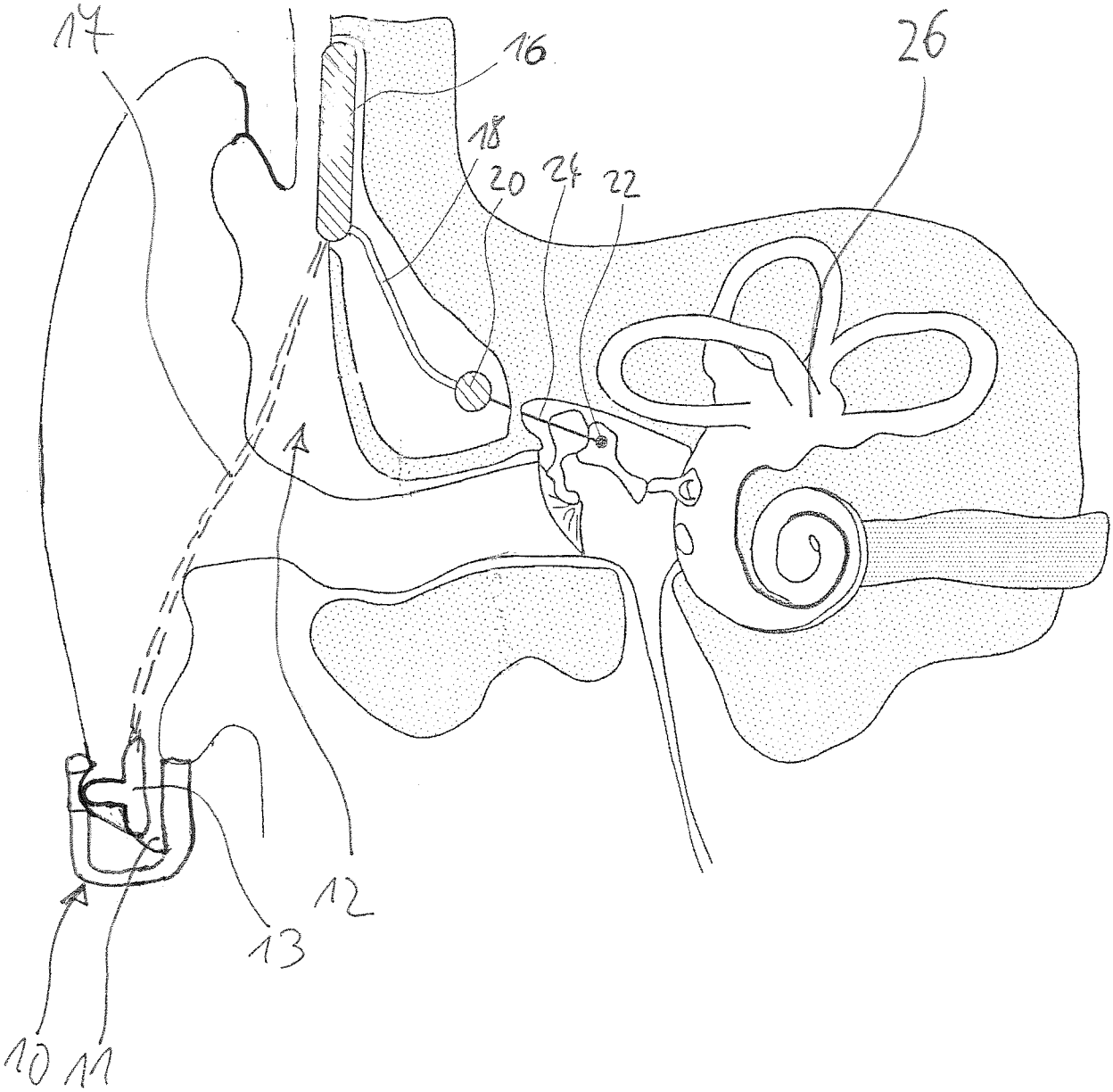

Fig. 1

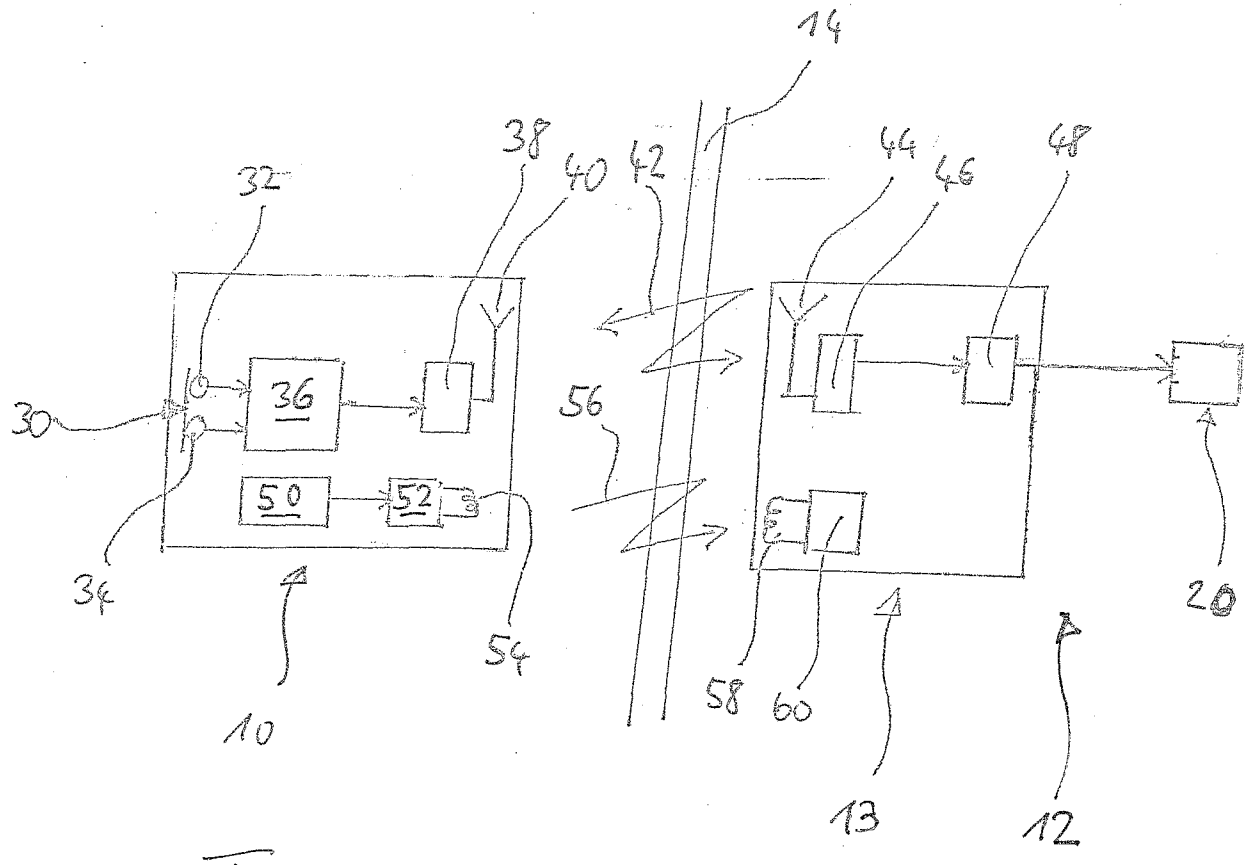

Fig. 2

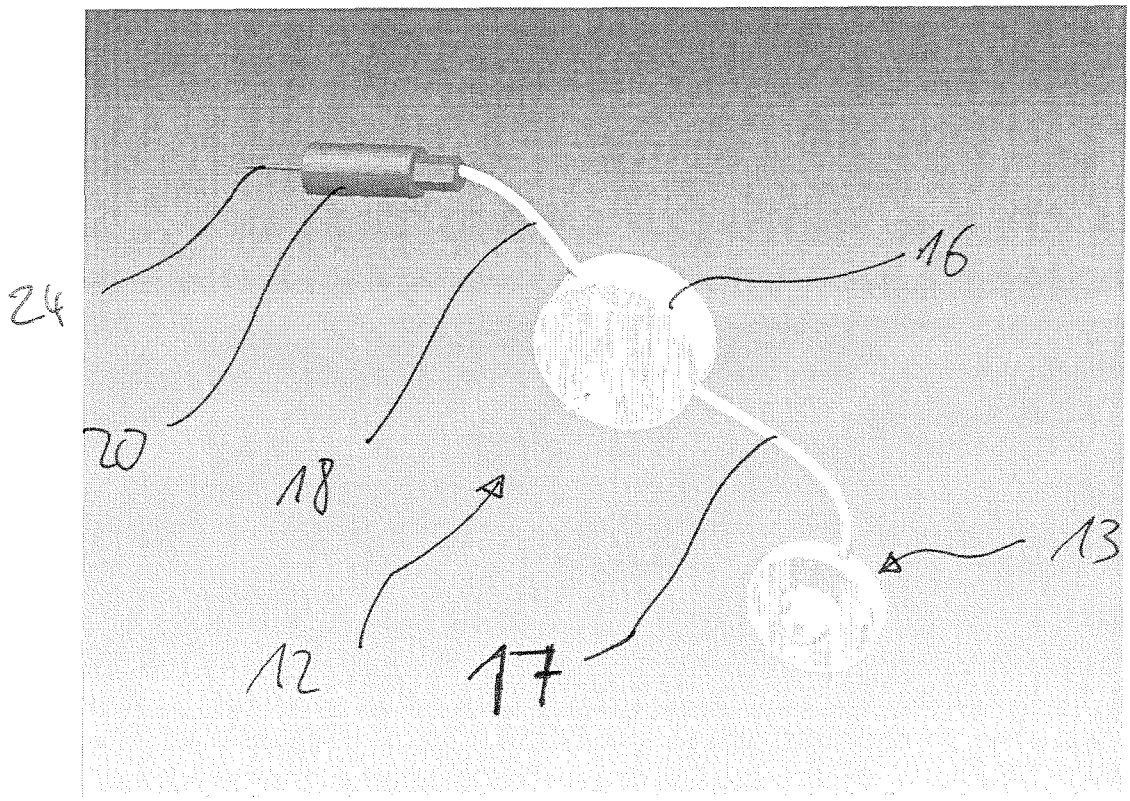

Fig. 3

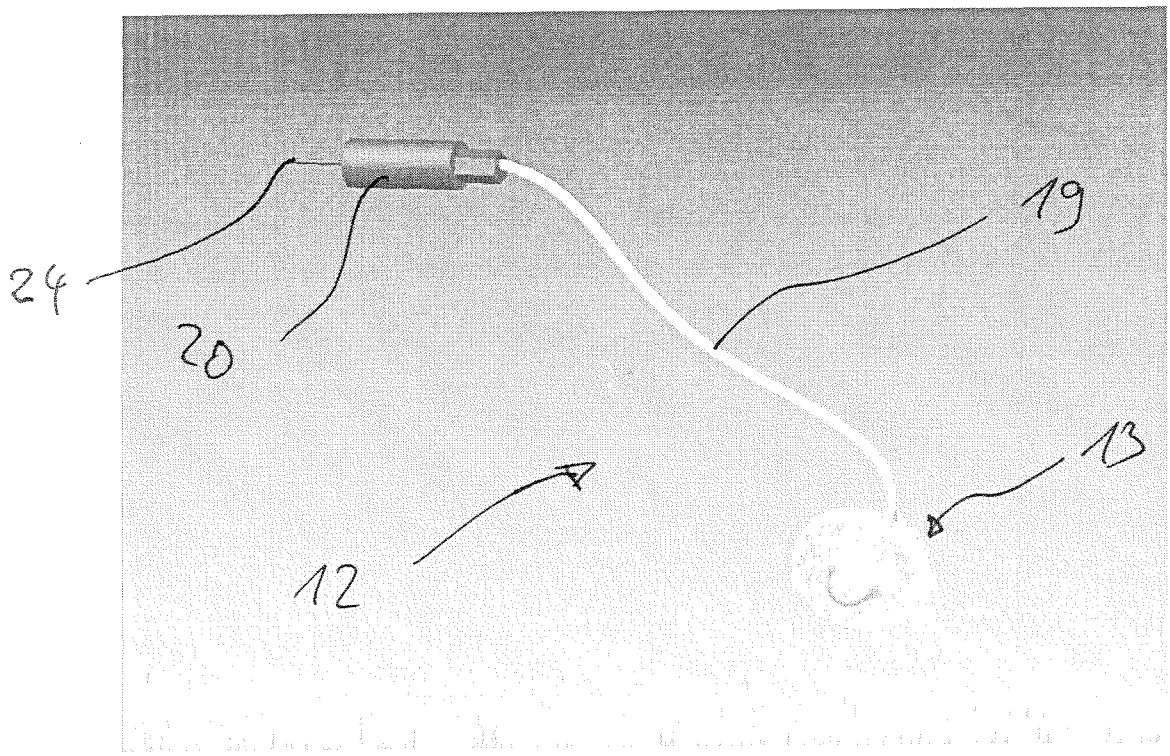

Fig. 4

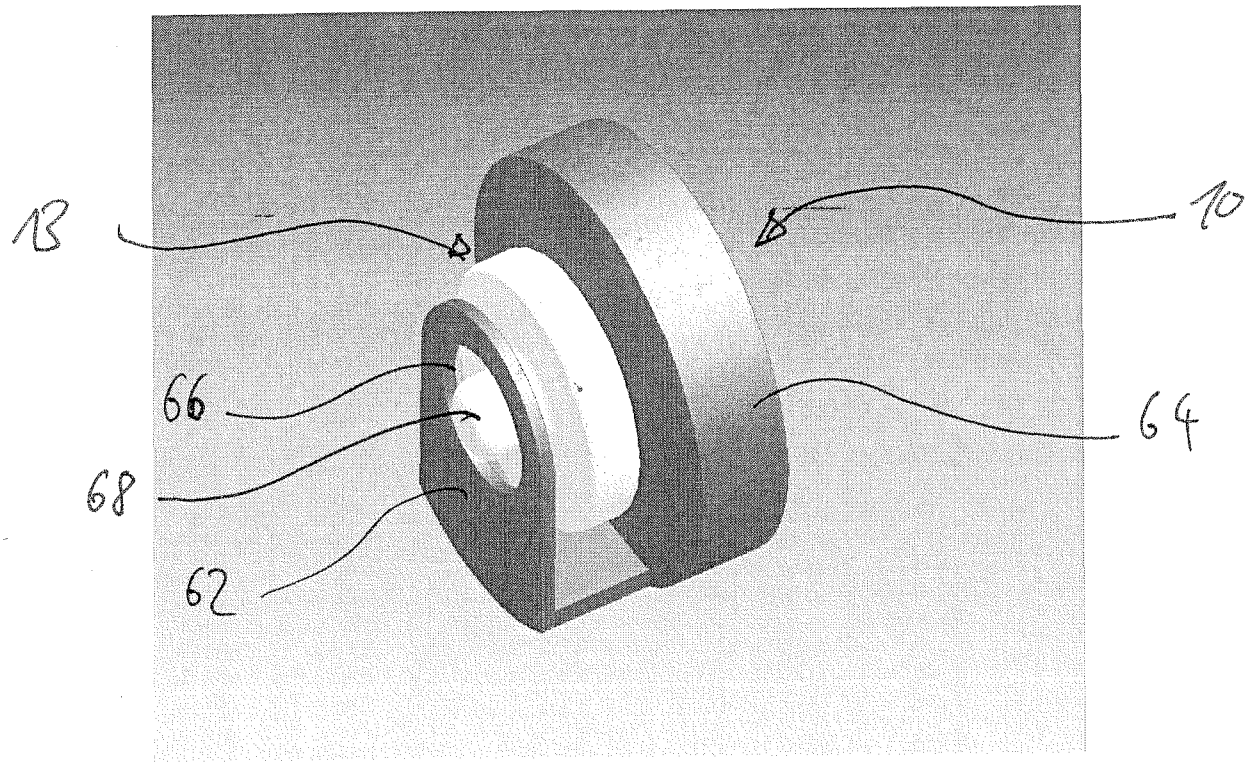

Fig. 5

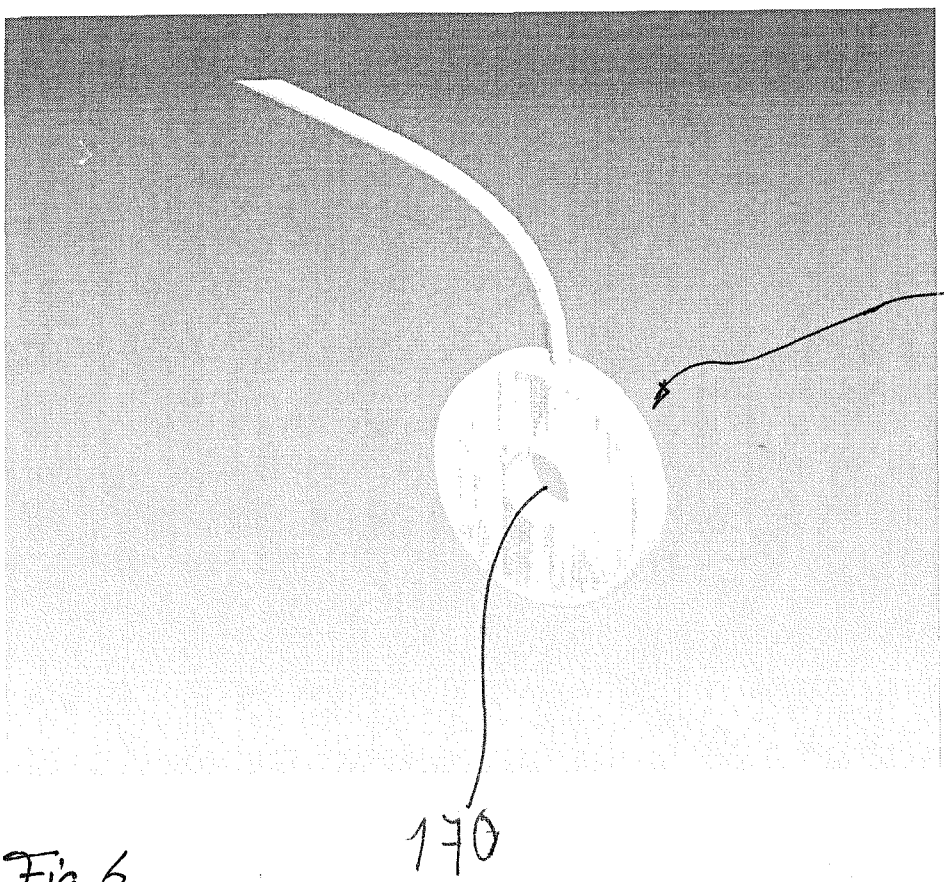

Fig. 6

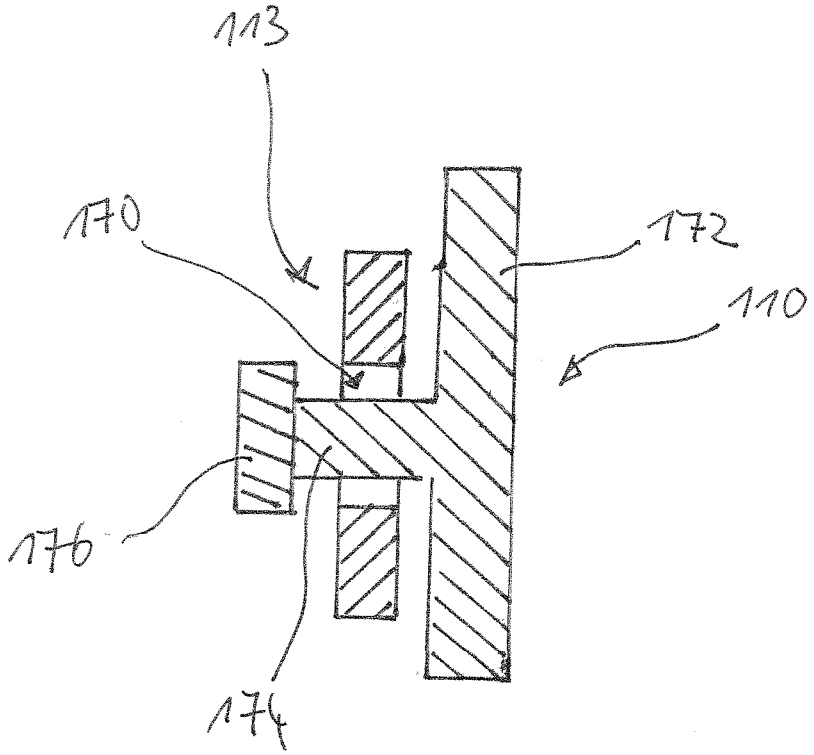

Fig. 7