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(71) Applicant: **Phonak AG**
8712 Stäfa (CH)

(72) Inventors:
• **von Dombrowski, Sven**
5430 Wettingen (CH)

• **Leysieffer, Hans**
8706 Meilen (CH)
• **Gabathuler, Bruno**
8712 Stäfa (CH)

(74) Representative: **Frei Patent Attorneys**
Frei Patentanwaltsbüro
Postfach 1771
8032 Zürich (CH)

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(54) **Hearing instrument**

(57) According to the invention, a hearing instrument with at least one microphone and signal processing comprises at least two receivers having a different frequency

response. At least a first one of the receivers is placed outside the ear canal, for example in a behind-the-ear component.

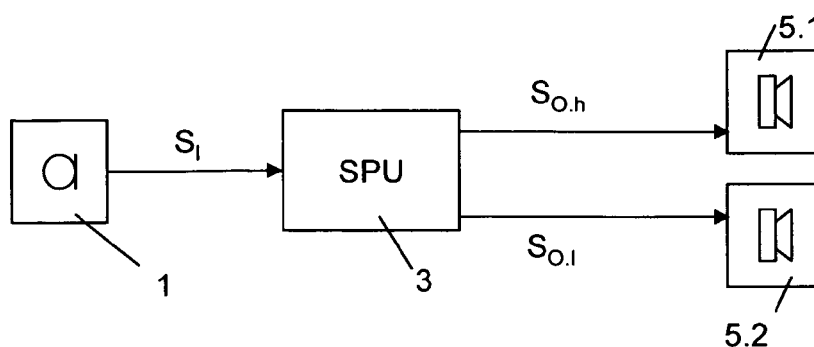


Fig. 1

Description

FIELD OF THE INVENTION

[0001] The invention relates to hearing instruments, in particular hearing aids.

BACKGROUND OF THE INVENTION

[0002] State of the art hearing instruments are usually either behind-the-ear (BTE) hearing devices, in-the-ear (ITE) hearing devices, in-the-canal (ITC) hearing devices or completely-in-the-canal (CIC) hearing devices. BTE hearing devices offer, due to the available space and the resulting possibility to use receivers of larger dimensions, and the opportunity to provide a rather high amplification and to obtain a usually satisfying sound quality. The sound transmission from the BTE device into the user's ear canal has to be done by a sound conduction tube which modifies the sound impression since the signal transmission characteristic is not homogeneous over the entire frequency range. Some of these modifications are wanted, others are unwanted and, if possible, are eliminated by means of acoustic filters in the sound conduction tube. ITE, ITC and CIC hearing devices, in contrast, have a shorter sound conduction tube or none at all. Also, ITC and especially CIC devices are barely visible from the outside and are therefore preferred by many users. However, they have the drawbacks of limited maximum amplification, limited battery lifetime and limited receiver quality, all due to the limited space available. Also the space in the ear canal has to be used efficiently and the ear canal essentially has to be closed by the device so as to minimise acoustic feedback due to the proximity of the sound outlet of the receiver and the sound inlet of the microphone. This plugging of the ear canal may cause undesirable effects, known as occlusion effect which has an impact on the perception of the wearer's own voice and on the wearing comfort.

[0003] In order to combine the advantages of BTE devices and of ITC and CIC devices, approaches have been proposed in which a BTE component is combined with an external component to be placed in the ear canal. The external component comprises the receiver.

[0004] The quality of the acoustic signal transmission path of a hearing aid depends on four factors: The sensitivity of the acoustic-to-electric transducer (microphone), the performance of the signal processing unit, the response of the electric-to-acoustic transducer and the acoustic coupling between the electric-to-acoustic transducer output and the ear drum. Electric-to-acoustic transducers ("speakers") in hearing instruments are often termed "receivers", which term is used in the following for electric-to-acoustic transducers in or for hearing instruments of all kinds.

[0005] Microphones typically used in hearing aids have a sensitivity that is more or less flat within 10 dB in a frequency range between 100 Hz and 6 kHz. Variations

from flat response occur both intentionally or undesired. At higher frequencies, there is often a rapid sensitivity deterioration, typically around 10 kHz, depending on the model. Typical receivers for hearing aids show frequency response curves with very characteristic structures due to the construction of the receiver (size, spout dimensions, etc.). Above 6 kHz typical receivers exhibit a significant fall off of the response curve.

[0006] For high quality sound perception, however, the ideal frequency response curve should mimic the natural acoustics of the ear in the range between 20 Hz and about 10 kHz, preferably even between 20 Hz and 16 kHz.

[0007] The German patent application publication DE 19634984 describes a hearing aid with several receivers integrated in the otoplastics (the component of the hearing aid which is specifically fit to the ear shape of the wearer and is worn in the ear canal or which at least protrudes into the ear canal). The multiple receivers are supposed to provide an improved sound quality. This hearing aid, however, has the drawback that a special new receiver technology has to be applied (multilayer foil technology) in order to fit the multiple receivers into the ear canal. This receiver technology has not proven to provide sufficient loudness and sound quality at all relevant frequencies and accordingly has not prevailed on the market.

[0008] Current hearing aids, therefore, still use mainly one receiver for sound production. The acoustical performance is limited by the construction and size of the receiver, making it difficult to provide a high quality sound over a wide frequency range.

SUMMARY OF THE INVENTION

[0009] It is a **first object** of the invention to provide a hearing instrument, especially a hearing device, overcoming drawbacks of existing hearing instruments which especially is suited for providing a high quality sound perception. Preferably, the hearing instrument should maintain the possibility to use high quality receivers, which especially in view of the sound quality at low frequencies, have to have a certain minimal size.

[0010] According to the first aspect of the invention, a hearing instrument with at least one microphone and signal processing means (usually comprising an amplification functionality) comprises at least two receivers having a different frequency response. At least a first one of the receivers is placed outside the ear canal, for example in a behind-the-ear component.

[0011] A different frequency response of two receivers may be achieved by a variety of measures, such as different receiver sizes, different geometries, different materials, different wirings, different passive and active electrical components (for example different coils if the receivers are of an inductive type), different physical principles (for example an inductive receiver and a capacitive receiver, or an inductive receiver and a piezoelectric receiver may be used), different outcoupling, combinations

of these, etc.

[0012] Preferably, the signal processing means are configured so as to feed output signals of different frequencies to the at least two receivers. For example one receiver may be fed with a first output signal, the frequency spectrum of which is such that it essentially comprises signal proportions between 0 and a certain splitting frequency, whereas the other receiver is fed with a second output signal with a frequency spectrum essentially starting at the splitting frequency. In other words, the signal processing means as a whole have implemented the function of a frequency separating filter.

[0013] The hearing instrument preferably also comprises a sound conduction element, such as a sound conduction tube connecting the first receiver with the ear canal.

[0014] The concept according to the first aspect of the invention features the substantial advantage that it makes an improved overall sound quality possible. Specific receiver designs may be used, for example one receiver optimised for high frequency sounds, and another one for low frequency sounds. This provides the possibility of enhancing the range with a largely flat frequency response. Nevertheless, receivers of the known kind with the known sizes may be used. Further, the invention provides the possibility of reducing the instrument's power consumption and to reduce unwanted sound modification effects, since receivers and/or sound conducting elements may be operated closer to their resonance frequencies than if only one receiver covering the whole frequency range is used.

[0015] Besides the fact that at least two receivers are suited to obtain a wider frequency response, such a solution may also be advantageous in the case where negative impacts on the performance of the hearing instrument due to mechanical vibrations produced by any of the receivers can be reduced by an adequate design which places the components at the most beneficial locations.

[0016] In an especially preferred first embodiment, a second one of the receivers is placed in the ear canal. In this embodiment, the sound conduction tube may also comprise an electrical connection from the outside-the-canal (preferably behind-the-ear) component to the second receiver. In a first variant of this embodiment, the first receiver (the one outside the ear canal) is used as a receiver for high frequency sounds (a "tweeter"), whereas the second receiver serves as a receiver for low frequencies (a "woofer"). However, it is also possible that the first receiver (the one outside the ear canal) is operated as a woofer and the second one as a tweeter. This second variant is especially preferred in cases where available space is an issue since woofers are usually of larger dimensions than tweeters and hence tweeters can more easily be placed in the ear canal. Additionally, thin diameter sound conduction tubes can be used for the transmission of low frequency sounds. In contrast, high frequency sounds would negatively be affected by small-

er diameters due to the acoustic transmission characteristic of a sound conduction tube. This second variant may consequently also be preferred in cases where a high amplification at high frequencies is desired. The second variant may also be preferred where the used sound conduction elements have wanted resonant frequencies at low frequencies.

[0017] This first embodiment features the substantial advantage that limited space is used in both, the ear canal and the behind-the-ear component. The required size in the behind-the-ear component is especially small if the high frequency receiver (the "tweeter") is located in the behind-the-ear component.

[0018] In another embodiment, both receivers are placed outside the ear canal, for example in the behind-the-ear component. The sound is preferably delivered through a sound conduction channel or through at least two sound conduction channels to the ear canal. In the case of more than one sound conduction channels, the channels may be mechanically coupled to each other. They may for example be formed as two bores in a single sound conduction tube. As an alternative, there may be two separate sound tubes.

[0019] In this entire text, "in-the-ear-canal" or "in-the-canal" includes any arrangement where the elements concerned are at least partially placed in the ear canal of a user, including the classical "in-the-canal" (ITC) and "completely-in-the-canal" (CIC) arrangements. "Outside-the-canal" or "outside-the-ear-canal" subsumes elements that are primarily located outside the ear canal and includes behind-the-ear elements, elements placed in the concha or elements at places more remote to the ear canal. An "external" component is a component that is placed outside the housing of a main component of a hearing instrument, such as a component placed outside the BTE component housing. The main component in this respect is usually the component that comprises a better part of the signal processing means (such as a digital signal processor) and a battery compartment.

[0020] It is a **second object** of the invention to provide a hearing device with an external receiver that overcomes drawbacks of prior art hearing devices with external receivers and that provides mechanical stability, variability and does not require an abundance of parts to be delivered with the device.

[0021] According to the second aspect of the invention, a hearing instrument comprising at least one acoustic-to-electric input converter (a microphone), a signal processing unit, which preferably includes an amplification functionality and an output converter (a receiver) is provided. At least the signal processing unit - and preferably also a battery compartment and possibly also the at least one microphone - is contained in a behind-the-ear component which fits behind a user's ear. The behind-the-ear component may also comprise a detachable or non-detachable hook. The hearing instrument further comprises an external component for being placed in the user's ear canal or in the user's ear and which comprises

at least one receiver, and a connection link between the behind-the-ear component and the external component, the connection link comprising at least two electrical contact lines. The connection link is reversibly pluggable to the behind-the-ear component and/or the in-the-ear-canal component and has a length that is reversibly adjustable. The hearing instrument also comprises fixation means for reversibly fixing the adjusted length of the connection link.

[0022] "Reversible" in the context of this text means that a fixation may be released destruction free and preferably be re-fit a plurality of times.

[0023] Preferably, the external component is an in-the-ear-canal component. The in-the-ear-canal-component may be free of parts protruding from the ear canal and thus be a completely-in-the-canal component.

[0024] Due to the concept of the invention, the in-the-ear-canal component can be detached from the housing of the behind-the-ear component without the need to open the behind-the-ear component in a manner that sensitive electronics is exposed.

[0025] In a first embodiment of the invention, the connection link is formed by a connection element which on one end is pluggable to the external component and on the other end is fixedly connected with the behind-the-ear component and is insertable into a cavity of the behind-the-ear component to varying extents. In the present text, an optional "hook" is part of the behind-the-ear component. Of course, the mentioned cavity may also be present in the hook instead of a main part of the BTE component.

[0026] According to an alternative, preferred principle of the second aspect of the invention, a connection element for forming the connection link has one end with at least two electrical contacts which cooperate with corresponding electrical contacts of the behind-the-ear component or the external component so as to form a position variable contact. Position variable contacts in this text are contacts between two elements which can be brought in contact with each other in a range of relative positions or in plurality of discrete relative positions. An example of a position variable contact is a slider contact. However, also other kinds of position variable contacts may be envisaged. A first example of such on other kind of position variable contacts comprises threaded contacts, where a threaded shaft and its inside thread counterpart have at least a first and a second electrically conducting section forming the first and second electrical contacts and an electrically insulating section therebetween. A second example is based on electrical contacts that have a geometrical structure that allows them to be snapped on each other in a plurality of possible discrete positions. Such a geometrical structure may comprise at least one protrusion of one electrical contact co-operating with one of a plurality of corresponding indentations of the corresponding electrical contact. This first and second example feature the advantage that the contacting functionality may be combined with the fixation functionality.

[0027] The concept of the position variable contact has several advantages. For example, there is no need to deform a terminal proportion of a connection element in order to vary the length of the connection element, as is the case in the first embodiment, where the length of a connection element proportion in a given cavity is varied with a fixed end. Such deformations, given the dimensions present in a behind-the-ear component may cause substantial stress on the connection element and its electrical leads. In contrast, the concept of the position variable contacts allows the connection element to be relatively stiff, especially at a terminal portion carrying the electrical contacts. Also, a relatively large range of position variations is possible. Nevertheless, the first and second electrical contacts may be protected in their entire range by being placed in a cavity of the behind-the-ear component (or possibly the external component if the external component is large enough).

[0028] In embodiments of this preferred principle, the length of the connection link can be varied by inserting the connection element in the behind-the-ear component (or possibly the external component) to varying extents. The connection element can be fixed with regard to its longitudinal position (i.e. the extent of its introduction in the behind-the-ear component or the in-the-ear-canal component) and possibly also with regards to its angular position by the locking means. The locking means may be separate locking means or may, as previously mentioned, be a functionality of special embodiments of the position variable contact. The connection element may be fixedly connected to the other component, i.e. to the external (in-the-ear-canal or in-the-concha) component or the behind-the-ear component, respectively.

[0029] In most embodiments, due to the limited space in the in-the-ear-canal component, the position variable contact is formed between the connection element and the behind-the-ear component, whereas the connection element is fixedly connected to the in-the-ear-canal component.

[0030] A slider contact between first and second electrical contacts may be based on the following principle: The first electrical contacts have a surface with a certain extension in a longitudinal direction (the longitudinal direction - except for a possible bending - for example corresponding to the insertion direction of the connection element), whereas the second contacts exert a contact force on the first electrical contacts so that an electrical contact is made. As an alternative, the first contacts - comprising the surface that is extended in the longitudinal direction - may be spring contacts exerting the contact force.

[0031] Another principle is that the first and second contacts are both threaded. The at least two different first and second contacts or different polarities, respectively, are arranged with respect to each other at a distance in the longitudinal direction. Corresponding electrical contacts of different polarities are in this context for example contacts for "positive" and "negative" or for "signal" and

"neutral", etc.; more than two "polarities" may be present.

[0032] The concept of preferred embodiments with a position variable contact may also be used in hearing instruments where the external receiver is arranged in a component to be placed in the concha instead of in the ear canal. Also in this case, the slider contact is preferably formed between the connection element and the behind-the-ear component, whereas the connection element is fixedly connected to the in-the-ear component.

[0033] Especially preferred embodiments are based on a combination of the first aspect of the invention with a second aspect of the invention. In this case an output of the receiver in the behind-the-ear-component could be acoustically coupled to the cavity in the BTE component, from where the sound couples into the bore of the sound conduction tube, which may be introduced into the cavity to varying extents. In embodiments where the cavity is present in the hook of the BTE component, the receiver may be mounted in the BTE component in a state-of-the-art manner.

[0034] In alternative embodiments, the external component comprises the sole receivers or all of a plurality of receivers of the hearing instruments.

[0035] It is a **fourth object** of the invention to provide a hearing instrument which comprises a component that is placed in the ear canal and fixation means for fixing said component in the ear canal, which fixation means overcome drawbacks of prior art fixation means and which especially provide a solution letting the ear canal open and has well-defined acoustic coupling characteristics, high comfort and secure fit. Preferred embodiments should especially be suited for in an outer portion of the ear canal, i.e. between the first bend and the isthmus. Further preferred embodiments should ensure a detachable connection between the in-the-ear-canal component and the fixation means.

[0036] According to the fourth aspect of the invention, a hearing instrument is provided which comprises an in-the-ear-canal component to be placed in a user's ear canal and fixation means for fixing it in the ear canal. The fixation means comprise an outer shell which is shaped to fit (i.e. custom shaped to fit the specific user's ear geometry) in the user's ear canal and a mounting structure for holding the in-the-ear-canal component. The mounting structure is such that the in-the-ear-canal component may have a unitary housing, and that the in-the-ear-canal component is replaceable. The set-up is an open set-up, so that a passage between the ear canal's interior and an outside is maintained. The passage is formed by a clearance between an inner surface of the outer shell and the mounting structure or the in-the-ear-canal component, respectively.

[0037] The shell's thickness is preferably not greater than 1 mm, for example not greater than 0.8 mm, the cross sectional area of the passage in a norm state (in which for example no external force is applied on the outer shell) is at least 3 mm², preferably at least 4 mm². The shell may be circumferential (i.e. form, in a section

along at least one section plane, a closed contour) or partially circumferential (i.e. have, in section, an open contour).

[0038] The outer shell is preferably resilient, i.e. has an elasticity allowing temporal deformation.

[0039] The mounting structure which may be formed as an inner shell at least partially encasing the in-the-ear-canal component. The inner shell may adjoin the outer shell or may be held, by a support structure, at a distance therefrom, for example centrally within the outer shell.

[0040] The mounting structure also may comprise a snap-in locking mechanism for automatically locking the connection between the in-the-ear-canal component and the mounting structure when the in-the-ear-canal component is inserted in the ear canal component. The snap-in locking mechanism may be releasable, in a first variant, by a small tool or a fingernail when the in-the-ear-canal component with the fixation means is not in the ear canal. Alternatively, the locking mechanism may be a snap-in-twist-off mechanism where the in-the-ear-canal component may be removed by being twisted relative to the fixation means. Apart from the locking mechanism - which may be provided by a cantilever-like spring - the locking mechanism does not require any additional tools or parts such as screws, adhesives, etc.

[0041] The size of the passage is preferably large compared to vents of conventional ITE or CIC hearing instruments. For example, the minimum minimal cross section of said passage may be at least 3 mm². It may for example be larger than a third of a cross section of the in-the-ear-canal component (taken in section along a plane perpendicular to a longitudinal axis of the ear canal). Since walls of both the outer shell and the inner shell (or other mounting structure) are preferably thin and resilient, the cross sectional area taken by the fixation means may be held generally small. Thus, if one manages to provide an in-the-ear-canal component with small dimensions, this advantage translates into better venting. This in turn is advantageous because the ear is in a condition close to the natural condition.

[0042] The fixation means is for example manufactured using the rapid prototyping technology which as such is known for manufacturing shells of ITE hearing devices or CIC hearing devices.

[0043] The fourth aspect of the invention combines advantages of both, the universal fit earpiece and custom shaped earpiece approaches. Since the object that is directly adjacent to the skin is a resilient shell, the fixation means is compressible and comfortable. Nevertheless, the custom shaped shell allows a perfect and reliable fit. The risk of walk-out is minimised. Further, in contrast to universal fit earpieces the shape of the fixation element when it is introduced in the ear canal is known, and so is the shape of the at least one passage. This makes possible that a programming software of the hearing instrument may calculate the acoustic coupling based on the exact geometry of the fixation element with the as-

sembled in-the-ear-canal component and determine the settings of the hearing instrument based on the correct acoustic coupling values (and not just based on some mean value as in the universal fit earpieces). In an initial fitting process, the geometry data may for example be delivered electronically to the hearing professional, such that the programming software may use the data directly, or the geometry data may be delivered as an abstract code or as specific dimensional numbers which may be entered into the programming software by the hearing professional.

[0044] A method of fabricating a customised hearing instrument, therefore, comprises the steps of

- scanning the user's ear canal, or the user's ear impression,
- manufacturing a fixation means with an outer shell shaped to fit in the user's ear canal and with a mounting structure mechanically coupled to the outer shell and being shaped to hold an in-the-ear-canal component of the hearing instrument, the fixation means being shaped so as to maintain a passage from an outside to an interior of the ear canal,
- determining, using data obtained from the scanning of the user's ear canal the in-the-ear-canal component position in the ear canal and the dimensions of the passage obtained therefrom,
- calculating, using the position and dimensions data, an individual amplification characteristics,
- programming a signal processing unit of the hearing instrument so as to have this amplification characteristics.

[0045] Of course, for the calculation of the individual amplification characteristics also further data such as data characterising the hearing loss of the user, are used.

[0046] The in-the-ear-canal-component may be any device or device part of a hearing instrument that is meant to be placed in the ear canal of the user. It may for example be a hearing instrument which as a whole is placed in the ear canal, i.e. a so-called in-the-canal or completely-in-the-canal hearing instrument. It may as an alternative be an external receiver assembly of a hearing instrument which also comprises an outside-the-ear-canal component, for example a behind-the-ear component or a component for being placed in the concha. It may particularly be an in-the-ear-canal component of a hearing instrument according to the first or the second embodiment of the invention.

[0047] Although hearing instruments according to the fourth aspect of the invention may be used in both, set-ups with an in-the-ear-canal component inserted deeply in the canal (beyond the isthmus) and with an in-the-ear-canal component in an outer portion of the canal, they

are especially advantageous for hearing instruments placed in an outer, cartilaginous portion of the canal.

[0048] The term "hearing instrument" or "hearing device", as understood here, denotes on the one hand hearing aid devices that are therapeutic devices improving the hearing ability of individuals, primarily according to diagnostic results. Such hearing aid devices may be Outside-The-Ear hearing aid devices or In-The-Ear hearing aid devices. On the other hand, the term stands for devices which may improve the hearing of individuals with normal hearing e.g. in specific acoustical situations as in a very noisy environment or in concert halls, or which may even be used in context with remote communication or with audio listening, for instance as provided by headphones. In preferred embodiments of all aspects of the invention, however, the amplification of the active system is positive. (The active system comprises the input transducer(s), the signal processing means and the output transducer(s).) In other words, according to these preferred embodiments, the hearing instrument amplifies the incident sound in at least a part of the frequency spectrum and thus is suitable for serving as a hearing aid.

[0049] The hearing devices as addressed by the present invention are so-called active hearing devices which comprise at the input side at least one acoustical to electrical converter, called a microphone, at the output side at least one electrical to mechanical converter (receiver), and which further comprise a signal processing unit for processing signals according to the output signals of the acoustical to electrical converter and for generating output signals to the electrical input of the electrical to mechanical output converter. In general, the signal processing circuit may be an analog, digital or hybrid analog-digital circuit, and may be implemented with discrete electronic components, integrated circuits, or a combination of both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] In the following, principles of the invention are explained by means of a description of preferred embodiments. The description refers to drawings with Figures that are all schematic. The figures show the following:

- Fig. 1 a hearing aid system with two receivers.
- Fig. 2 a hearing aid system with two receivers and two digital signal processing elements.
- Fig. 3 a hearing aid system with two receivers and a frequency separating filter.
- Fig. 4 a further hearing aid system with two receivers.
- Fig. 5 a schematic representation of a hearing aid with two receivers, one of which is placed in the ear canal.

- Fig. 6 a schematic representation of a hearing aid with two receivers, where both are placed outside the ear canal.
 - Fig. 7 cross sections of connection elements between an outside-the-ear-canal (for example behind-the-ear BTE) component and an in-the-canal component.
 - Fig. 8 a cross section of a further connection element.
 - Fig. 9 a sketch of an approach of mechanically coupling a sound conduction tube with an electric connection.
 - Fig. 10 a schematic representation of an assembly of two receivers in a single housing.
 - Fig. 11 a schematic representation of an alternative assembly comprising two receivers in a single housing.
 - Fig. 12 an embodiment of the second aspect of the invention.
 - Fig. 13 a block diagram of a hearing aid device according to the second aspect of the invention.
 - Fig. 14 a schematic representation of the end of a connection element to be inserted in a BTE component (left: front view, right: side view).
 - Fig. 15 a cross section of a cavity within the BTE component for receiving the end of a connection element.
 - Fig. 16 a cross section of a duct of a BTE component with a sealing O-ring.
 - Fig. 17 a set screw placed in the BTE component housing or a (mini) hook.
 - Fig. 18 a contact support part of a connection element with a curvature of constant radius.
 - Fig. 19 a sliding contact assembly.
 - Fig. 20 a variant of a contact support part of a connection element.
 - Fig. 21 a BTE component cavity for co-operating with the connection element of Fig. 20.
 - Fig. 22 a schematic representation of a connection element comprising structures for an interlocking mechanism.
 - Fig. 23 a counterpart for the connection element of Fig. 22.
 - Fig. 24 a view of an interlocking set-up of a BTE component and a connection link.
 - Fig. 25 a schematic representation of a contact support part of a connection element with slider contacts and a threaded sleeve.
 - Fig. 26 a contact support part of a connection element with threaded contacts inserted in a corresponding threaded counterpart.
 - Fig. 27 a contact support part of a connection element with contacts that comprise a structure that form an interlocking mechanism, together with corresponding parts of the BTE component.
 - Fig. 38 an illustration of a typical dependence of the acoustic response on the longitudinal position of a earpiece in an ear canal.
 - Fig. 39 an illustration of a typical dependence of the acoustic response on the diameter of a vent in an earpiece.
 - Fig. 40 a set-up according to the fourth aspect of the invention.
 - Fig. 41 a front view, side view and top view (all in section) of a fixation means of a hearing instrument according to the fourth embodiment of the invention.
 - Fig. 42 an illustration of a possible wall structure for the outer shell.
 - Fig. 43 in illustration of alternative embodiments of the fixation means.
 - Fig. 44 in illustration of another alternative embodiment of the fixation means.
 - Fig. 45 an illustration of yet another alternative embodiment of the fixation means.
 - Fig. 46 an illustration of a snap on/twist off mechanism for fastening and detaching an in-the-ear-canal component in the inner shell of the fixation means.
- [0051]** Same reference numerals in different figures refer to same or analogous elements.
- DESCRIPTION OF THE PREFERRED EMBODIMENTS**
- [0052]** **Figures 1 - 3** show examples of hearing aid systems with more than one output electric-to-acoustic converter 5.1, 5.2, which converters in the following are named "receivers". The two receivers 5.1, 5.2 in the hear-

ing aid systems shown in Figures 1-3 differ from each other in that they have different frequency responses. For example, the first receiver may have smaller dimensions and provide an optimal response to high frequency signals, such as to signals above a particular frequency depending on the application. This frequency may be 500 Hz, 1000 Hz, 2000 Hz, another value between 500 Hz and 2000 Hz or a lower or higher value. The second receiver may be larger and be optimized for signals of lower frequencies, such as signals below the particular frequency.

[0053] The shown examples may be implemented according to the first aspect of the invention, potentially in combination with the second aspect and/or one of the third and of the fourth aspect of the invention.

[0054] A hearing aid system with a single microphone and two receivers is schematically illustrated in **Figure 1**. The system comprises, in a sequence, an input acoustic-to-electric converter (microphone) 1, producing an input signal S_i , a signal processing unit (SPU) 3, transforming the input signal into two output signals, namely a first output signal $S_{o,h}$ with predominating high frequency signal proportions, and a second output signal $S_{o,l}$ with predominant low frequency signal proportions, and the receivers 5.1, 5.2. The signal processing unit may implement the function of an analog-to-digital converter and a digital signal processing stage. It may, depending on the requirements of the receivers, further comprise one or more digital-to-analog transforming stage(s). Such a digital-to-analog transforming stage, however, is not always required, since hearing aid receivers in digital hearing instruments are often driven by a pulse width modulated (PWM) or a pulse code modulated (PCM) digital signal instead of an analog signal.

[0055] Elements of the signal processing unit SPU may be implemented in a single signal processor or may comprise a plurality of physically separate, appropriately connected elements.

[0056] The signal processing unit in all embodiments of the first aspect of the invention preferably includes an amplification functionality. This means that the amplification of the signal processing unit is positive. In other words, the signal strength of the added analog signals fed to the receivers is larger than the signal strength of the analog input signal produced by the input converter (s). However, the first aspect of the invention is also suitable for hearing instruments which do not require a positive amplification, such as active hearing protection devices, for which the signal processing unit provides a negative amplification (damping).

[0057] The digital signal processing stage 3 separates high frequency and low frequency components of the input signal according to the characteristics of the two receivers 5.1, 5.2. Splitting of a signal into high and low frequency signals on a signal processor level as such is known in the art and has been developed and used for audio systems. An example of according audio signal management methods can be found in US 6349285.

[0058] In the shown embodiments, the hearing aid comprises a single microphone. However, there could also be several microphones and/or other input devices - such as a telecoil -, together with according analog-to-digital converting means. For example, dual microphone hearing aids are known which may include a beamforming functionality.

[0059] Also, although in all described embodiments the hearing aid has two receivers, more than two receivers may in fact be used in a hearing aid, for example each receiver for a certain frequency range, or a single receiver for low frequency sounds in combination with a multitude of high frequency receivers, etc.

[0060] The embodiment of **Figure 2** differs from the embodiment of Figure 1 in that it comprises two signal processing stages 3.1, 3.2, one for the high frequency channel (i.e. for providing an input signal for the first receiver 5.1), the other one for the low frequency channel. A control element 6 provides a synchronized input for both digital signal processing stages. The control element may for example either simply split the signal into two (equal) outputs which are fed into the signal processing unit which then overtakes the task of digitally filtering an processing the filtered signal. (In this embodiment, the control element may merely be considered to be a branching of a wiring). Or, the control element itself may comprise a filter element which could preferably be analog if the (for example conventional) SPUs already have a A/D converter implemented. Alternatively, the control element may comprise a digital filter if the SPU possesses a digital input. In this case, an analog-to-digital converter (not shown) will be interposed between the microphone 1 and the control element 6.

[0061] The principle advantage of having to use more than one SPU is that SPUs of conventional single receiver hearing aids may be used. To this end, merely the amplification characteristics of the digital signal processing stages has to be set differently: whereas the first signal processing stage 3.1 amplifies high frequency sounds and attenuates low frequency sounds, the second signal processing stage has an opposite characteristics.

[0062] Yet another embodiment is depicted in **Figure 3**. This embodiment differs from the embodiment of Figure 1 in that the digital signal processing stage only comprises a single output for output signal S_o . The digital signal processing stage may therefore be a processing stage as such known from conventional hearing aids. Frequency splitting is attained, for example, by an analog frequency-separating filter 7 arranged downstream of the - single - digital-to-analog converter 4. The two outputs of the frequency-separating filter are fed to the two receivers 5.1, 5.2.

[0063] As yet another alternative (not shown in the figures) the signal processing unit may produce only one signal which signal is fed to both receivers. This alternative is suitable for receivers the characteristics of which is that sounds of low or high frequencies, respectively, are practically suppressed, so that the receivers them-

selves serve as high pass and low pass filters, respectively.

[0064] In Figure 4, an embodiment is shown where no filter is used at all. In that case the single output of the SPU 3 (with digital or analog signals) is fed into the two receivers 5.1, 5.2 which have by design different response characteristics such one receiver predominantly outputs sound at low frequencies and the other outputs sound at high frequencies.

[0065] Embodiments of the first aspect of the invention are illustrated in Figures 5 and 6. There, dotted lines separate an outside-the-canal-(preferably behind-the-ear)-component 11, an intermediate signal transmission region 12 and an in-the ear (namely in the canal) region 13. The reference numerals 1, 3, 5.1, and 5.2 denote the microphone, the signal processing unit (comprising digital signal processing stage together with the analog-to-digital converters, the digital-to-analog converters and potential other digital or analog signal processing means arranged between the input converter(s) and the receivers), and the first and second receiver, respectively.

[0066] The first, especially preferred embodiment of the first aspect of the invention is shown in Figure 5. The first receiver 5.1 is arranged in the outside-the-canal component 11, whereas the second receiver 5.2 is placed in the ear. The signal transmission between the outside-the-canal component and the in-the-canal component is provided by an (airborne) sound transmission channel 15 from the first receiver 5.1 to the ear canal, and by an electric signal transmission channel 16 from the signal processing unit 14 to the second receiver, respectively.

[0067] According to the embodiment of Figure 6, both receivers are placed in the outside-the-canal component. Two sound transmission channels 17 lead from the receivers 5.1, 5.2 to the ear canal.

[0068] The two channels in the embodiment of Figure 6 need not be physically separated as is illustrated in panel A of Figure 7. Figure 7 shows cross sections of different connection elements between an out-of-the-canal (for example in-the-ear) component and an in-the-canal component of the hearing aid. The connection element of panel A is a sound conduction tube 31 comprising only one bore 32 which is connected, on one side with the outputs of both receivers and on the other side ends in the ear canal. The sound conduction tube 31, thus carries both channels.

[0069] Also the connection element of panel C is suited for the embodiment with both receivers placed outside the ear canal. The sound conduction tube 36 comprises two bores 37, 38 serving as sound conduction bores for the output of the first, and the second receiver, respectively. The bores need not have the same dimensions as in the figure but may rather be adapted so that their resonance frequencies are adapted to the frequency of the signals they conduct. For example, each bore may contain dedicated conventional passive acoustic filters.

[0070] The two bores of the sound conduction tube 40

of panel D, in contrast have different purposes. Whereas the first bore 41 is a sound conduction bore, the second bore 42 contains an electrical wire pair 43 for electrically contacting a receiver placed in the ear canal. The receiver in the ear canal may be placed in a otoplastics which itself has a sound conduction bore that passes the receiver such that the sound outlet of the in-the ear canal receiver is next to the sound outlet from the sound conduction bore, which is coupled to the sound conduction tube and eventually to the receiver in the BTE component. Both sound outlets point inwards to the eardrum.

[0071] The sound conduction tube of panel D, therefore, is suited for the embodiment with one receiver placed in the canal, and another one placed outside the canal. In contrast to the shown embodiments, the electrical wire pair could also be placed inside a (single) sound conduction bore.

[0072] Panels B and E both show cross sections of connection elements comprising a tube 33; 45 with two electrical wire pairs 34.1, 34.2; 46.1, 46.2 for electrically contacting two receivers placed in the ear. In panel B, both wire pairs are placed in a single bore 35, whereas in panel E the tube contains two bores 47, 48 each comprising a wire pair. Other set-ups, for example with wires encapsulated in tube material may be envisaged. Configurations with more than one receiver in the canal are described further below.

[0073] The sound conduction element of Figure 8 is made up of two sound conduction tubes 51, 52 mechanically coupled to each other. The tubes have different sizes and may also have different wall thicknesses and/or be made of different materials having different elasticities. The tube 51 with the larger diameter is preferably used for conducting the low frequency sound signals.

[0074] In the embodiment of Figure 9 the electrical wires 72 are also coupled to the sound conduction tube 71 in an essentially straight manner. Other ways of coupling the wires to a sound conduction tube may be envisaged.

[0075] The above described embodiment of combined sound conduction and electrical signal conduction elements may be coupled to the outside-the-ear (for example behind-the-ear-) component by means of a snap-on mechanism (electrical contacts may be arranged on the inside or the outside of a tube surface), by means of a nipple, using a fastening nut or similar.

[0076] Whereas a mechanical coupling of potentially required wires to sound conduction tubes is advantageous, it is not necessary. Embodiments where electrical wires are guided independently of the sound conduction tube(s) may be envisaged, too.

[0077] Figs. 6-9 relate to the example of two receivers, but the concepts of the shown embodiments may readily be extended to more than two, for example by coupling the outputs of more than one (or more than two) receivers to one sound conducting bores, by providing more bores than shown in the figure, by providing more electrically conducting wires than shown, etc.

[0078] Figures 10 and 11 show - in a very schematical manner - concepts of a combination of two receivers in a single housing. Such concepts may be useful for embodiments of the first aspect of the invention comprising more than two receivers, two of which are placed in the ear canal. They may also be used in situations where two receivers are placed outside the ear canal - for example behind the ear or in the concha - and where it is important to save space. They may, as yet another alternative, be used in hearing aids deviating from the first aspect of the invention, where all of at least two receivers are placed in the ear canal.

[0079] A two-receiver device of the kind described in Figure 10 comprises the following features:

- A housing 71 comprising a diaphragm 72, which may, actuated by an electromagnetic inductive or capacitive drive mechanism, be caused to vibrate and thus generate a first contribution to a sound output.
- A piezoelectric element 73 or a MEMS (Micro-Electro-Mechanical System) element placed within the housing and being operable to vibrate excited by an electrical signal and thus to generate a second contribution to a sound output.

[0080] The embodiment of Fig. 10 is, in other words, characterised in that a low frequency sound producing element (such as the diaphragm) and a high frequency sound producing element (such as a piezoelectric element) are both in the same housing such that their sound producing surfaces are adjacent a common gas filled free volume within the housing.

[0081] In the shown, preferred embodiment, the piezoelectric element 73 is mechanically coupled to the diaphragm 72. More concretely, it is placed on the diaphragm. It is caused to vibrate if an according electrical voltage signal is applied to the high frequency signal contacts 74. The diaphragm's drive mechanism includes for example conventional exciting means 75 such as a coil co-operating with a permanent magnet placed on a tuning fork like armature and means - such as a drive rod - for transferring vibrations from the armature to the diaphragm. The low frequency signal contacts are denoted by 76 in the figure.

[0082] The diaphragm and the piezoelectric element placed thereon both excite sound waves 78 in the gas (typically air) in the free volume 77 of the housing. The sound waves are guided through the opening 79, possibly to a sound conducting tube coupled to it.

[0083] The device of Fig. 10 may be varied in that the piezoelectric element need not be coupled to the diaphragm but may be coupled to the housing and be placed somewhere else adjacent the free volume 77 of the housing (which free volume, of course, may be shaped differently from the shown embodiment).

[0084] The device of Fig. 10 may be used both, as a

double receiver placed in the ear canal or as a double receiver placed in an element outside the ear canal to which a sound conduction tube is coupled.

[0085] The two-receiver device of Figure 11 is also suitable for being placed in the ear canal or outside the ear canal, but it is a preferred embodiment for applications where it is placed in the canal. It comprises:

- A housing 81 with a sound producing element placed therein. The sound producing element is suited for producing high frequency sounds and may be a diaphragm 82 with a corresponding inductive or capacitive first drive mechanism 83 or may be a piezoelectric element.
- A second capacitive or inductive drive mechanism 84 operable to cause a part of the housing to vibrate.

[0086] The part of the housing that may vibrate may be a flexible membrane 85 which forms a part of the housing. In the shown embodiment, the flexible membrane forms an end face of the housing. The end face, if the device is placed in the canal, faces inward, i.e. towards the eardrum. Alternatively, this part may be an outer shell, a combination of an outer shell and an end face, or even the entire housing.

[0087] In the shown embodiment, the membrane 85 comprises a membrane opening for the high frequency sounds caused by the high frequency sound producing element.

[0088] In Figure 12, an embodiment of the second aspect of the invention is very schematically drawn. The hearing instrument shown in Fig. 12 comprises a behind-the-ear component 101 and an in-the-ear-canal component 102. The behind-the-ear component comprises sound acquiring and processing means 103 and a cavity 104 formed in a hook 106 of the behind-the-ear component. The sound acquiring and processing means 103 are connected with the in-the-ear-canal component 102 by means of a pluggable connection link 105. The connection link is implemented by means of a connection element, namely a cable 110 comprising two wires and a plug connector pluggable into a corresponding connector of the in-the-ear-canal component 102. In the figure, very schematically a male plug 111 of the connection element is shown which co-operates with a corresponding female socket 112 of the in-the-ear-canal component 102; however any reversibly pluggable connector could be used. Often, a connector will comprise guiding means for supporting a smooth plugging operation.

[0089] The connection link is adjustable in its length in that the connection element may be inserted in the cavity through an orifice 117 to a variable extent, as indicated by the arrow 116. Sealing means 118 allowing a smooth sliding of the cable with respect to the orifice are also shown in the figure. In contrast to the shown configuration, the cable in the sliding operation may be guided by a tube instead of just an orifice. It may in yet another

configuration by inserted in an inner tube which is slidable inside an outer tube.

[0090] In practice, the behind-the-ear component will often comprise a so-called "hook", which is a dimensionally stable element hooking the behind-the-ear component behind the ear and guiding the connection element towards an interior of the user's concha. In such embodiments the cavity will often be in a transition region between the hook and the sound acquiring and processing means.

[0091] The in-the-ear-canal component is arranged in fixation means (not shown) holding it in its place in the ear canal. Such fixation means may be an otoplastic or a self-adjusting fixation means as such known in the art. It may also be a newly developed fixation means, such as a fixation means according to the third or fourth aspect of the invention as described further below.

[0092] Figure 13 illustrates a hearing aid system that may be implemented according to the second aspect of the invention. The sound acquiring and processing means comprise a microphone 1 (usually comprising pre-amplifier means), the signal processing unit 3 arranged in the behind-the-ear component 101. The receiver 5, however, is placed external component 102, which is for example an in-the-ear-canal-component.

[0093] The behind-the-ear component 102 for example also comprises a compartment for a battery (not shown) for the active elements of the sound acquiring and processing means. The external component is preferably free of any battery means and is only fed by the signal transmission line formed by the connection link.

[0094] The signal transmission between the BTE component and the ITE (including ITC or CIC) component could also be wireless. In that case, the ITE (ITC, CIC) component would require also a battery and the signal processing unit to receive the signal and the drive the receiver.

[0095] Of course, as an alternative to the system illustrated in Fig. 13, a system according to the first aspect and comprising at least one receiver to be placed in the ear canal or another set-up including a signal transmission line between a behind-the-ear component and an in-the-ear-canal component may be used.

[0096] In the following, preferred embodiments of the second aspect of the invention are described, which follow the principle that a position variable contact is formed between the connection element and one of the two components to be connected, preferably between the connection element and the behind-the-ear component.

[0097] In a preferred embodiment, the connection element 131 is made in a main part of a flexible material such as PEBAX and contains two wires connected to the receiver placed in the external component at one end. The opposite end, shown in Figure 14, is the end which is going to be inserted into the behind-the-ear component. It has a contact support part 132, which is made of an insulating material that is preferentially more rigid than the flexible material of the connection link main part. The

left panel of Figure 14 shows a front view of the connection element from the contact support part side. A tip 133 of the contact support part is tapered such as to facilitate the insertion into the duct of the Behind-the-ear (BTE) component. Two electrical contacts 134 are mounted on the contact support part 132 such to enable electrical contact in opposite radial directions of the contact support part. The contacts are in electrical contact with the wires that are connected to the receiver. The electrical contacts 134 are preferentially rigid and do not produce a contact force in radial direction. The contacts are arranged to provide left-right symmetry, meaning that one pole is on the top and the other pole on the bottom of the contact supporting part, or one pole is on the left and the other on the right. This allows either inserting a connection link for a left ear or for a right ear. (For the purpose of the description of this and the following embodiments it is assumed that the receiver is operated in a symmetric mode, i.e. plus and minus poles are labelled simply for easy distinction of the two poles. Of course, the concepts described herein are also suited for non-symmetric modes).

[0098] In this preferred embodiment, the BTE component housing has a cavity 141 with an inner cross sectional dimension large enough to hold the contact support part and partially also the connection link (see Figure 15). The length of the cavity is at such as to allow moving the connection link (with the contact support part) by a sufficiently large amount required by fitting the BTE component with the external receiver to the ear geometry of a user. The cavity has two spring electrical contacts 142 which, when the connection link is inserted into the BTE component housing, are making contact with the electrical contacts on the contact support part of the connection link and which are producing a sufficiently large contact force to provide a reliable electrical connection. Preferably, the contact force is also large enough to provisionally fix the relative position of the connection element and the behind-the-ear component to enable the hearing professional to verify the physical fitting of the hearing device without the need of fixing the position by means of the locking mechanism. To protect the inside of the behind-the-ear component housing from moisture, the orifice or duct 145 of the BTE component housing in which the connection link is inserted may be equipped with a sealing means such as an O-ring 145 (see Figure 16).

[0099] In this preferred embodiment, the fixation of the connection link within the BTE component housing requires a separate fixation means. One possibility is to provide a (metallic) set screw 147 with a conical end 147.1 which penetrates into the softer flexible material of the connection link 131 such as to fix the connection link in longitudinal and angular direction (see Figure 17). A set screw is for example arranged in the duct of the behind-the-ear component, thus for example on the left of the O-ring in Fig. 16 or in the hook. Other fixation means can be applied alternatively; one example is clamping with a fastening nut.

[0100] In an alternative embodiment, the contact support part 132' has a defined curvature with constant radius in its longitudinal direction (see Figure 18). In this way, the cavity within the BTE component and also the duct of the BTE component into which the connection link is inserted, also has a defined curvature with constant radius, approximating the anatomical shape behind the ear just at the location where the BTE component is usually suspended. By doing so, the size of the BTE component can be minimized.

[0101] In a further alternative embodiment, the contact support part has a cross-sectional shape which deviates from cylindrical symmetry and thus defines the angular position of the connection support part and the whole connection element with respect to the BTE component housing. An example of such an assembly is shown in **Figure 19**. Fig. 19 shows an end portion 161 of a BTE component with an inserted contact support part 152 of a connection element 151. In the shown embodiment, the contact support part 152 is essentially plate shaped and for example similar to a flexible print with contacts 154 on the top and the bottom. The corresponding contacts 162 belonging to the BTE component in the drawn embodiment are mounted within a sleeve 163 that is inserted into the duct of the BTE component housing. Also shown in the drawing is a (conventional) hook mounting structure 164 with several nipples. A feature of this kind could also be used as thread to co-operate with a fastening nut in embodiments of the invention.

[0102] A further embodiment of the second aspect of the invention and including a slider contact is shown in **Figures 20 and 21**. Fig. 20 shows an end portion of the connection element 171 including the contact support part 172 in front view (right panel) and in side view (left panel). The electrical contacts 174 fixed on the contact support have the shape of a resilient slab or wire and part are made of highly resilient material such as copper beryllium and are formed such that they are squeezed radially when then the connection link is inserted into the BTE component housing. Within the cavity 181 of the BTE component housing, rigid contact pads 182 as shown in Fig. 21 are mounted which establish the electrical connection over the longitudinal range required by the application.

[0103] As alternatives to the fixation described referring to Fig. 17, other types of fixation means may be used. In an alternative embodiment the BTE component housing can partially be opened by removing a cover. By doing so, the cavity which eventually holds the connection link with the electrical contacts is accessible. Within the cavity, the two contact pads are mounted. Preferably, the cavity is separated from the remaining inner portions of the BTE component housing by walls, so that the electronics is well protected during manipulation and length adjustment in the cavity. The contacts are fed through the walls of that cavity and are connected to the electronics with the remaining inner portion of the BTE component housing.

[0104] An example of such an alternative fixation is shown in **Figures 22-24**. In this alternative embodiment, the connection element 191 is equipped with a radially extending interlocking structure 192 near the electrical contacts. An example of such a (in the drawing: male) interlocking structure is shown in **Figure 22**, which depicts a contact support portion 132 of a further connection element. As shown in **Figure 23**, the cavity 197 of the BTE component housing holding the connection link has a given number of matching (in the drawing: female) interlocking structures 193, longitudinally spaced apart such as to offer the possibility to choose from a number of different lengths between the BTE component and the receiver component. The hearing professional will then place the connection link into the cavity at the desired position and will then close the cavity by moving a cavity locking element with respect to the rest of the BTE component housing. In the shown embodiment, the matching interlocking structures 193 of the BTE component housing - for example pivotable - with respect to a fixed part 195 of the housing and which is lockable by closing the cover (not shown in Fig. 23).

[0105] **Figure 24** shows a conceptual view of a BTE component, where such an alternative fixation is realised by providing the (female) interlocking structure as described above directly in the cover 202. The cavity 203 in this embodiment extends over a long proportion of a rear of the BTE component and is separated from the rest by for example moisture proof cavity walls. The embodiment of Fig. 24 also shows electric contacts 204 formed somewhat differently from the previously described embodiments. The electric contacts 204 have a tentacle-like shape and are, like the embodiment of Fig. 20, pre-stressed to press against corresponding electrical contacts 205 of the BTE component housing. The flexible part of the connection element 206 is denoted by 207 in the figure.

[0106] Other interlocking means are possible, one of them is a bolt which is inserted into the BTE component to fix the connection link position. The bolt locks the interlocking means on the connection link.

[0107] A different embodiment foresees the length adjustment by means of a thread mechanism (see **Figure 25**). The contact support part 212 of the connection element 211 is cylindrical and has two sections in longitudinal direction where the cylindrical electric contacts 214 are mounted. In addition, a sleeve 215 with a thread is put over the connection link at an adequate and fixed position along the connection link. The BTE component housing (not shown) has again a cavity with spring contacts that make contact with the cylindrical contact on the inserted connection link. The two electrical spring contacts of different polarity are, in contrast to the embodiment of Fig. 25, arranged at a distance in axial direction to each other. Thus, the connection link can freely be positioned in angular direction and can be longitudinally positioned within a range given by the size of the cylinder.

dricial contacts, defined such to cover the desired variation of the adjustment-length. The BTE component further comprises a counterpart of the threaded sleeve. The sleeve and the BTE component counterpart may be made of different materials. The thread lead may be defined such that one full turn corresponds to for example 2 mm so that that length adjustment is done quickly. However, it is a disadvantage of such a solution, that the device has to be removed from the user's ear when a length adjustment has to be done. In contrast, the advantage is that the threads provide the longitudinal fixing and mechanical stability.

[0108] The connection link may have position markers on its outer surface that are visible and help the hearing professional to preset the length of the connection link or to control the physical fitting process.

[0109] Referring to **Figures 26 and 27**, position variable contacts are described which are not slider contacts. In **Figure 26**, the electrical contacts 224 of the connection element 221 (the first contacts) and the contacts 225 associated with the BTE component housing 226 (the second contacts) are both threaded. The two first contacts 224 for different polarity and the two second contacts each are arranged at a longitudinal distance from each other. In the spaces between the contacts of different polarity both, the threaded portions of the connection element and of the BTE component housing are electrically insulating. The first contacts and/or the second contacts are extended in longitudinal direction (in the shown configuration the first contacts only), so that an electrical contact is formed over a longitudinal range of different relative positions of the connection element 221 with respect to the BTE component housing. The solution of these figures could also be used for the in-the-ear-canal component to adjust the insertion depth.

[0110] The connection element 231 of **Figure 27** comprises a radially extending interlocking structure as previously described. In contrast to the embodiments described so far, however, the interlocking structure also carries electrical contacts 234 co-operating with corresponding contacts 235 of the matching interlocking structure of the BTE component housing 233.

[0111] Combinations or variations of the set-ups of the above embodiments may be envisaged, for example with a threaded contact for one polarity and a slider contact for another polarity other geometries, etc. In embodiments of the kind of Figs. 22-24 and 27, where indentations and protrusions together form an interlocking structure, the BTE component may comprise the protrusions and the connection element the corresponding plurality of indentations.

[0112] In the following, the handling of a hearing device according to the second aspect of - the invention and comprising a BTE component and an external receiver assembly consisting of a receiver preferentially embedded in a housing and mechanically and electrically attached to a connection link which preferably comprises a plastic tubing with inlaid conducting wires is described

in three exemplary situations. The fourth use case (Component Identification) has no influence on the solutions presented herein but is mentioned for completeness.

5 First Case: First fit

[0113]

- Precondition:

● The BTE device delivered to the hearing professional preassembled, i.e. the connection link of the external receiver assembly is fully inserted in the BTE component

● Optionally the receiver housing is further attached to an ear canal fixation mean such as a custom made (open) otoplastic

- Main Scenario

●1. The hearing professional puts the BTE component behind the user's ear

● 2. The hearing professional places the receiver component (housing) into the ear canal

● 3. The hearing professional adjusts the connection length by pulling out the connection link at the BTE component, until a comfort fit is achieved

● 4. The hearing professional can reinsert the connection link into the BTE component, if required

● 5. The hearing professional applies a locking means to securely fix the length of the connection link

- Post-condition

● The BTE component with an external receiver is end-assembled according to the individual needs of the user

Second Case: Change of Receiver Type

[0114]

- Precondition

● The BTE component with an external receiver of a certain type is assembled according to the use case "First Fit".

- Main Scenario

- 1. The hearing professional unlocks the locking means
- 2. The hearing professional pulls out the external receiver assembly
- 3. The hearing professional inserts a new external receiver assembly (with a receiver of a different type)
- 4. The hearing professional continues with the use case "First Fit"
- Post-condition
 - The BTE component with a replaced external receiver is end-assembled according to the individual needs of the user

Third Case: Service/Repair

[0115]

- Precondition
 - The BTE component with an external receiver is assembled according to the use case "First Fit"
 - The receiver or the connection link is damaged such that the external receiver assembly needs to be replaced
- Main Scenario
 - 1. The hearing professional unlocks the locking means
 - 2. The hearing professional pulls out the external receiver assembly
 - 3. The hearing professional inserts a new external receiver assembly (with a receiver of the same type)
 - 4. The hearing professional continues with the use case "First Fit"
- Post-condition
 - The BTE component with a replaced external receiver is end-assembled according to the individual needs of the user

Fourth Case: Component Identification

[0116]

- Precondition
 - The BTE component device delivered to the hearing professional preassembled, i.e. the connection link of the external receiver assembly is fully inserted in the BTE component
 - Or, the BTE component with an external receiver is assembled according to the use case "First Fit"
 - Or, the external receiver assembly has been replaced with the same or different type of receiver
 - Optionally, the external receiver component is equipped with an identification module as described in WO 9909799

- Main Scenario

- 1. If automatic identification is possible, the hearing device checks during booting the components according to WO 9909799
- 2. Or the hearing professional enters manually the receiver type or changes the default value
- 3. The programming software causes to change and store the settings/operations in the memory of the hearing instrument
- Post-condition
 - The BTE component with an external receiver is end-assembled and the configuration is stored in the memory of the hearing device

[0117] In the following, embodiments of the **fourth aspect** of the invention are described.

[0118] **Figures 38 and 39** are shown in order to illustrate an advantage of the fourth aspect of the invention over the universal-fit holder solutions according to the prior art. In such universal-fit holders, the positioning of the receiver within the ear canal is not predictable and often not satisfactorily reproducible. The effective vent size is a priori not known since it is defined by the ear canal geometry. The resulting variations of the acoustic coupling are shown based on a model situation in Fig. 38 and 39.

[0119] **Figure 38** shows the Real-Ear-to-Coupler-Difference (RECD) of a model tube with a fixed vent diameter, which model tube is inserted in a model ear canal, as illustrated in the left panel. The RECD is the difference between the sound pressure level in a 2 cm³ coupler (being an idealised ear canal) used for standard measurements the closed ear canal and the actual sound pressure level in the real ear. The curves in the right panel

show the frequency dependence of the RECD for different vent positions l_{vent} . As can be estimated from the figure, an uncertainty of insertion depth of around 1 mm would correspond to changes of RECD in the order of 3 dB @ 2 kHz.

[0120] Figure 39 shows the corresponding situation when the vent diameter d_{vent} is varied at a constant vent position. An uncertainty of opening area translated to an uncertainty of the effective vent size of about 1 mm due to missing information about the ear canal geometry would correspond to changes of RECD in order of 5 dB@2 kHz.

[0121] The hearing instrument of Figure 40 comprises a BTE component 401 and an in-the-ear-canal component 402. Between the BTE component and the in-the-ear-canal component a connection element 403 is arranged. The connection element may optionally be built according to the second aspect of the invention. It comprises an electrical connection between sound processing means (not shown) in the BTE component and a receiver 404 arranged in the in-the-ear-canal component. It may - in accordance with an embodiment of the first aspect of the invention - further comprise sound conduction means for conducting sound produced by a further receiver being arranged in the BTE component. The BTE component may further comprise hook means or the like (not shown) for hooking it behind a user's ear.

[0122] The hearing instrument further comprises a fixation means 410. The fixation means is shaped to fit in the user's ear canal and to rest fixed therein. The fixation means 410 and the in-the-ear-canal component 402 are operable to be mechanically connected to each other. This mechanical connection may be permanent or, preferably, may be reversible.

[0123] In preferred embodiments, the fixation means is shaped to fit in an outer portion of the ear canal, i.e. outwards of the isthmus. In most embodiments, the in-the-ear-canal component 402 is mechanically connected to the fixation means outside of the ear canal and inserted in the ear canal together with the fixation means.

[0124] The hearing instrument system realised by the hearing instrument according to Fig. 40 or the following figures illustrating embodiments of the third aspect of the invention may be as illustrated in Fig. 13, the description of which is, for reasons of conciseness, not repeated here. As an alternative, the hearing instrument system may comprise multiple receivers and for example be realised in accordance with Fig. 4 (or as in Fig. 4 but with woofer and tweeter exchanged).

[0125] Departing from Fig. 40, the hearing instrument system may be an in-the-canal or a completely-in-the-canal system where all constituents (except, of course, the fixation means) of the hearing instrument are arranged in the in-the-ear-canal component.

[0126] An example of the fixation means 400 is shown in more detail in Figure 41. Fig. 41 depicts a front view (left upper panel), a side view including an in-the-ear-canal component (right upper panel), and a top view (low-

er panel) of a fixation means in each case in section. The fixation means comprises an outer shell 421 which is shaped to fit in the user's ear canal. Affixed to the outer shell by means of a support structure 423 is an inner shell 422 which is formed to receive and hold the in-the-ear-canal component 402. For example, the inner shell is resilient (in fact, it may be made of the same material as the outer shell) and has an inner diameter that is slightly smaller than an outer diameter of the in-the-ear-canal component 402. The fixation means further comprising a locking mechanism locking the in-the-ear-canal component once it has been fully introduced into the inner shell. The locking mechanism in the shown example comprises a cantilever 424 with a locking protrusion 425. When the in-the-ear-canal component 402 is introduced in the inner shell, the cantilever is swivelled outward in a radial direction, until the locking protrusion 425 snaps in a corresponding locking indentation 426 of the in-the-ear-canal component.

[0127] The shell is preferably made of polyamide. In order to achieve optimized fit of the shell within the user's outer ear and ear canal, the shell preferably has an outer surface individually shaped according to the measured shape of the user's outer ear and ear canal, i.e. the shell preferably has an individually customized outer shape. The shape of the user's outer ear and ear canal may be determined by direct three-dimensional scanning of the ear canal and the concha or by producing an impression of the ear canal and the concha which subsequently undergoes scanning. The scanning process may be carried out optically, preferably by laser scanning.

[0128] The digital data obtained by the scanning process is then used to create the hard shell by an additive or incremental layer-by-layer build up process. Such processes are also known as "rapid prototyping". A preferred additive build-up process is a layer-by-layer laser sintering process of powder material, preferably polyamide powder. Such processes are also known as "selective laser sintering" (SLS). The basic principle therein is the repeated deposition of a thin layer of material on a surface, with the desired sectional shape then being stabilized, i.e. hardened, by laser action. Other preferred additive layer-by-layer build-up processes are laser stereolithography or photo-polymerization. An overview regarding additive layer-by-layer build-up processes for producing customized shells for hearing aids can be found, for example, in US 2003/013358 or US 6533062.

[0129] Between the outer shell 421 and the inner shell 422 a passage 429 remains open. In the shown embodiment, the cross section of the passage is larger than the cross section of the inner shell with the in-the-ear-canal component.

[0130] The length in a longitudinal direction, i.e., a direction corresponding to the ear canal axis, of the outer shell and of the inner shell is approximately equal to the longitudinal length of the in-the-ear-canal component.

[0131] The in-the-ear-canal component 402 for example comprises a housing with a universal shape (i.e. the

shape is independent of the individual's ear and the same for all users) and comprises a shape which allows mounting of the in-the-ear-canal component to different kinds of fixation means.

[0132] Even though the fixation mean is shaped to the individual ear geometry, it is possible to use the actual and real vent dimensions (dimension of the passage) for optimizing the acoustic coupling during the fitting process. This is because the manufacturing of the fixation mean is based on digitized data and both vent size and insertion depth are controlled parameters.

[0133] The outer shell may be formed by an outer shell wall that is continuous or that comprises wall openings 431 as is illustrated in **Figure 42**. The outer shell may as an alternative comprise an otherwise open structure, such as a mesh structure. A structure with wall openings or an otherwise open structure has the aim to reduce the amount of material to a minimum while still imaging the individual ear canal geometry, to favour the resilient behaviour and at the same time to support minimal interference with the skin physiology.

[0134] Alternative embodiments of the fixation means are shown in front view in Figure 43. The inner shells 442, 452 of the variants A and B are arranged asymmetrically near a wall of the ear canal. In variant A, the wall of the inner shell in a section coincides with the wall 441 of the outer shell, whereas in variant B a support structure 453 is arranged between the inner shell 452 and the outer shell 451 and provides an additional mechanical de-coupling between the canal wall and the in-the-ear-canal component. This may be advantageous for situations where the in-the-ear-canal component noticeably vibrates when low frequency sounds are produced by the receiver. The mechanical de-coupling prevents the vibrations from being transferred to the canal wall where they may cause a tickling sensation. In variant C, the inner shell 462 is located centrally within the outer shell 461 and is held by a suspension structure 463 that comprises holding elements that extend essentially radially from the inner shell to the outer shell but that are shaped so as to not exert too strong a spring force against deformations of the outer shell (i.e. they may for example be sheet like and bended as illustrated in the figure).

[0135] The outer shell and the mounting structure (in all so far described embodiments, the mounting structure comprises an inner shell), though such a design is preferred, both need not be circumferential, i.e. need not, in at least one section, form a closed shape surrounding the ear canal on an interior or the in-the-ear-canal component on an exterior side, respectively. An example of an embodiment where the outer shell 471 is not circumferential is shown in **Figure 44**. The outer shell in an upper portion is completely open. The elasticity of the outer shell material and the spring force of the holding elements of the support structure 473 nevertheless causes the outer shell to rest against the canal wall once the fixation means is inserted. In the embodiment of **Figure 45**, the outer shell 481 is circumferential, but the mounting

structure comprises an inner shell 482 that is made of two inner shell proportions for framing the in-the-ear-canal component from two sides (in the figure from an upper and a lower side). In both, figure 44 and figure 45, the inner shell 472, 482 is held centrally in the ear canal by the support structure 473, 483.

[0136] In **Figure 46**, a locking mechanism for locking the in-the-ear-canal component 502 in the inner shell 492 is illustrated in more detail. The mechanism is a snap on / twist off mechanism. The inner shell comprises a cantilever comprising a locking protrusion of the kind illustrated in Fig. 41. In contrast to the embodiment of Fig. 41, where the cantilever has to be lifted by a small tool in order to unlock connection between the in-the-ear-canal component and the inner shell, in-the-ear-canal component 502 is shaped so that the cantilever may be lifted by a relative 90°-twist-movement. This is for example achieved by a locking indentation (or groove) that does not follow the full circumference. By rotating the in-the-ear-canal component, then, one may lift the locking protrusion out of the locking indentation. In Fig. 46, the left panel shows the cantilever 494 in the locking position, whereas in the right panel it is shown in the lifted position where the in-the-ear-canal component 502 is twisted by for example 90° and may be removed by a pull movement.

[0137] The above-described embodiments are by no means the only way to implement the aspects of the invention but may be altered in many ways.

Claims

1. A hearing instrument comprising at least one microphone (1), signal processing means (3, 3.1, 3.2), a first receiver (5.1) being, in an operating state, placed outside the ear canal and a second receiver (5.2), the first and second receivers being operatively connected with the microphone via the signal processing means, the first and the second receivers having a different frequency response.
2. A hearing instrument according to claim 1, wherein the hearing instrument comprises a behind-the-ear component fitting behind a user's ear, and wherein said behind-the-ear component comprises the signal processing means (3, 3.1, 3.2) and preferably also comprises a battery compartment.
3. A hearing instrument according to claim 2 wherein the first receiver (5.1) is placed in the behind-the-ear component.
4. A hearing instrument according to claim 2 wherein is placed in an in-the-ear component adapted to fit in the user's concha.
5. A hearing instrument according to claim 3 or 4 com-

- prising a sound conduction tube (31, 33, 36, 40, 45, 51, 52, 71) leading from the first receiver to the ear canal.
6. A hearing instrument according to any one of the previous claims, wherein the second receiver (5.2) is placed in the ear canal. 5
 7. A hearing instrument according to claims 5 and 6, wherein an electric connection between the signal processing means and the second receiver is mechanically coupled to the sound conduction tube (33, 40, 45, 71). 10
 8. A hearing instrument according to any one of the previous claims, wherein the second receiver (5.2), in an operating state, is placed outside the ear canal. 15
 9. A hearing instrument according to any one of the previous claims, wherein the sound processing means (3, 3.1, 3.2) are operable to feed the first receiver (5.1) with a first signal of a first central frequency and the second receiver (5.2) with a second signal of a second central frequency. 20
 10. A hearing instrument according to any one of the previous claims, wherein the signal processing means (3) comprise a signal processing unit having an input, a first output and a second output, the input being operatively connected an output of the at least one microphone, the first output being operatively connected to the first receiver (5.1) and the second output being operatively connected to the second receiver (5.2), wherein the signal processing unit is operable to produce a first output signal of a first central frequency and a second output signal with a second central frequency, wherein the first output signal is directed to the first output, wherein the second output signal is directed to the second output. 25
 11. A hearing instrument according to any one of claims 1-9, wherein the signal processing means comprise two signal processing units (3.1, 3.2), an input of both of which is operatively connected to an output of the microphone (1), and wherein the gain characteristics of the two signal processing units is such that one of the signal processing units is operable to predominantly amplify first proportions of an input signal and the other one is operable to predominantly amplify second proportions of an input signal. 30
 12. A hearing instrument according to any one of claims 1-9 wherein the signal processing means comprise a signal processing unit (3) having an input and an output, the input being operatively connected to an output of the microphone, and a frequency separating filter (7) an input of which is operatively connected to an output of the signal processing unit. 35
 13. A hearing instrument according to any one of claims 1-9 wherein the signal processing means comprise a signal processing unit having (3) an input and an output, the input being operatively connected to an output of the microphone, (1) the output being operatively connected to both, the first and the second receiver, so that both receivers, in an operating state, are fed by identical input signals. 40
 14. A hearing instrument according to any one of the previous claims, comprising a behind-the-ear component which fits behind a user's ear and contains at least the signal processing means (3), and an external component for being placed in the user's ear or in the user's ear canal and which comprises at least one of said receivers, and a connection link (105) between the behind-the-ear component and the external component, the connection link comprising at least two electrical contact lines, the connection link being reversibly connectable to the behind-the-ear component and/or the external component, the connection link having a length that is reversibly adjustable, and the hearing instrument comprising fixation means for reversibly fixing the adjusted length of the connection link. 45
 15. A hearing instrument according to any one of the previous claims comprising an in-the-ear-canal component (402) to be placed a user's ear canal and further comprising a fixation means (400, 410) for fixing the in-the-ear-canal component in a user's ear, the fixation means comprising an outer shell (411, 421, 441, 451, 461, 471, 481) shaped to fit in the user's ear canal and an in-the-ear-canal component mounting structure mechanically coupled to the outer shell and being shaped to hold the in-the-ear-canal component, wherein the in-the-ear-canal component is reversibly mountable to the fixation means, and wherein the fixation means is shaped so as to maintain a passage from an outside to an interior of the ear canal when the in-the-ear-canal component is inserted. 50

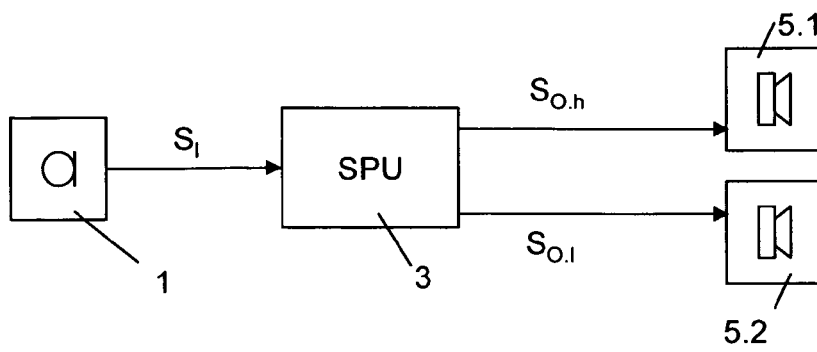


Fig. 1

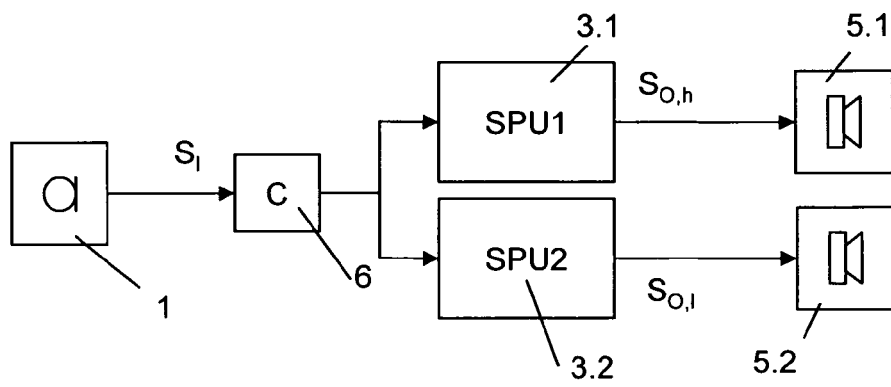


Fig. 2

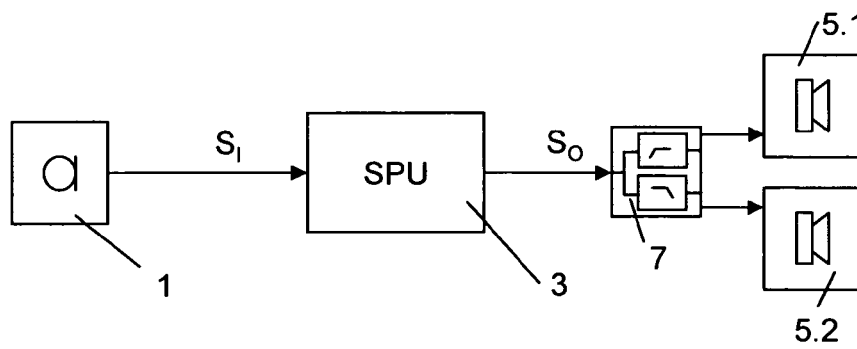


Fig. 3

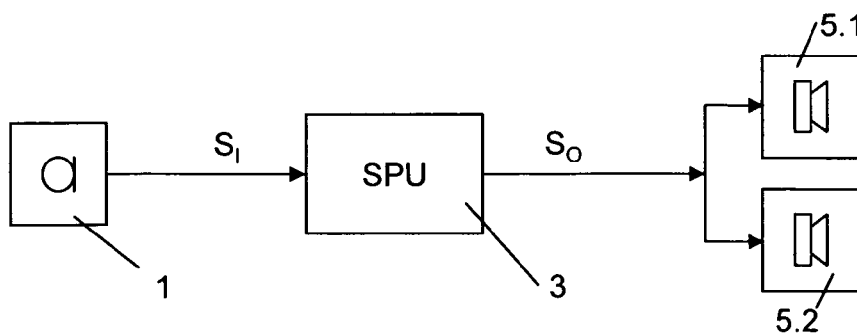


Fig. 4

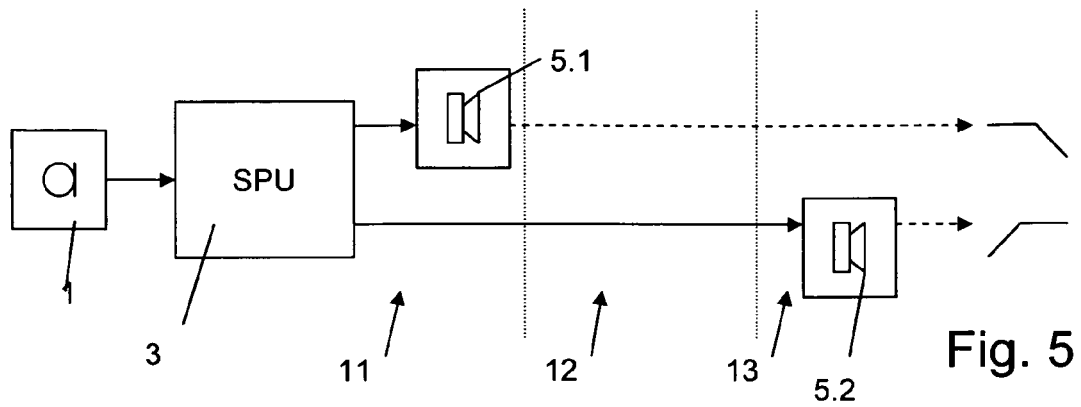


Fig. 5

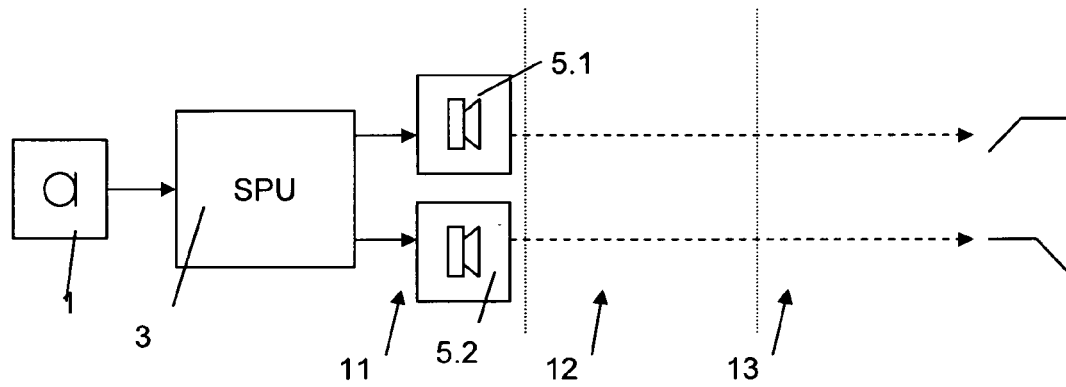


Fig. 6

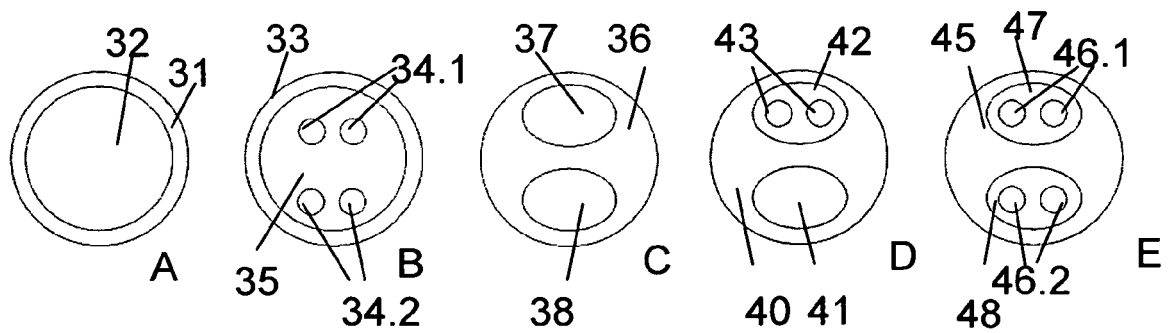


Fig. 7

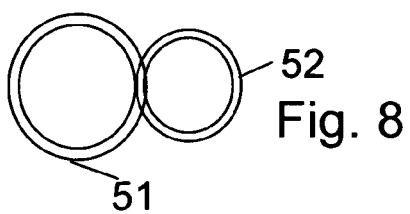


Fig. 8

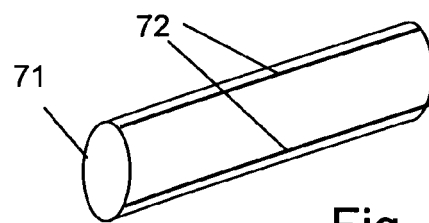


Fig. 9

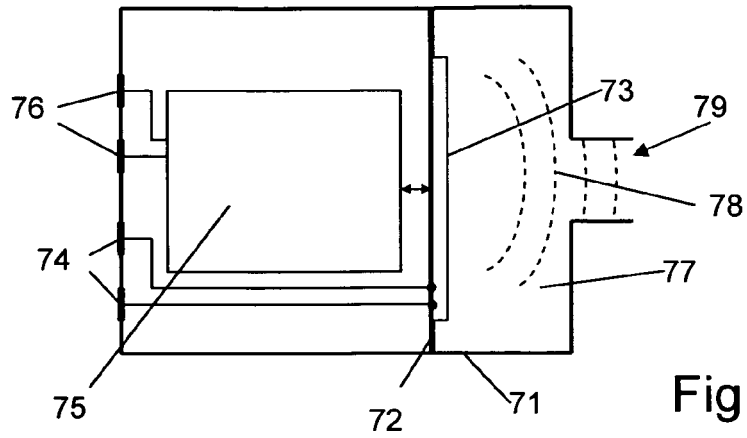


Fig. 10

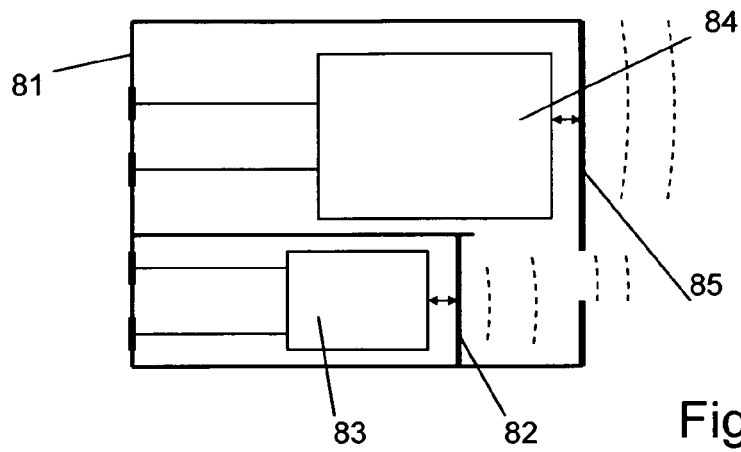


Fig. 11

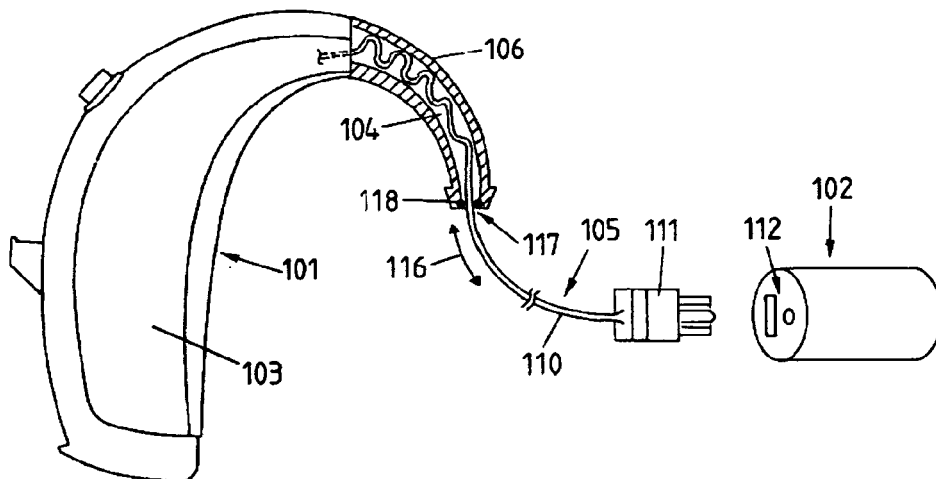


Fig. 12

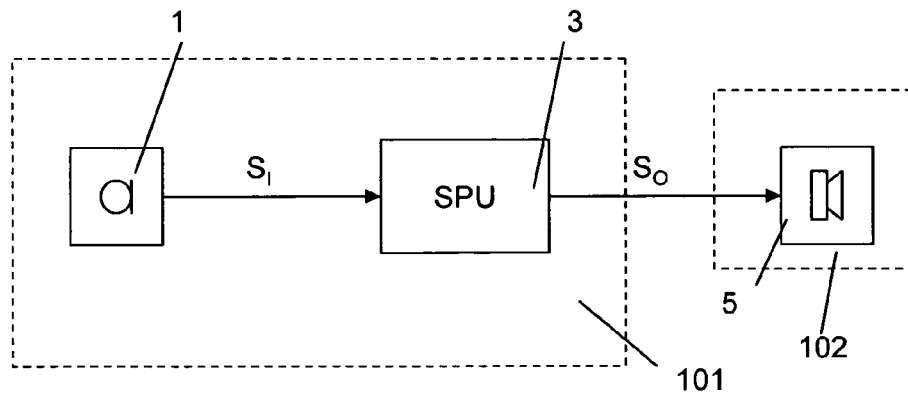


Fig. 13

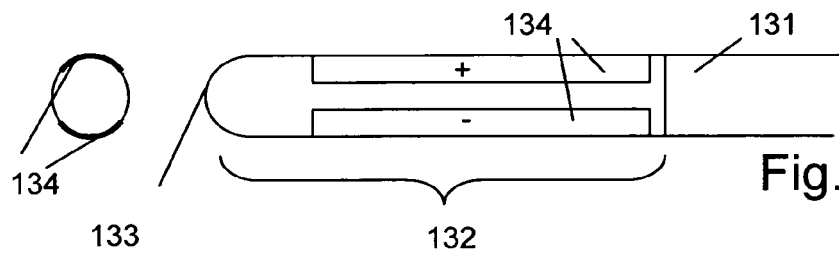


Fig. 14

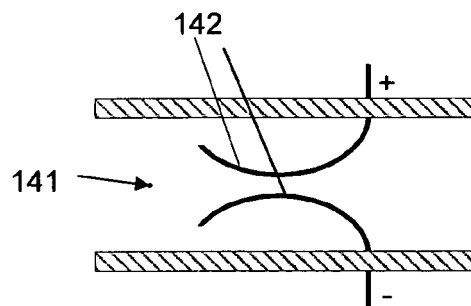


Fig. 15

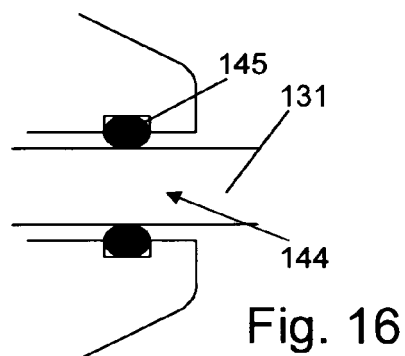


Fig. 16

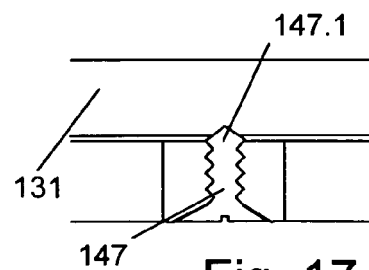


Fig. 17

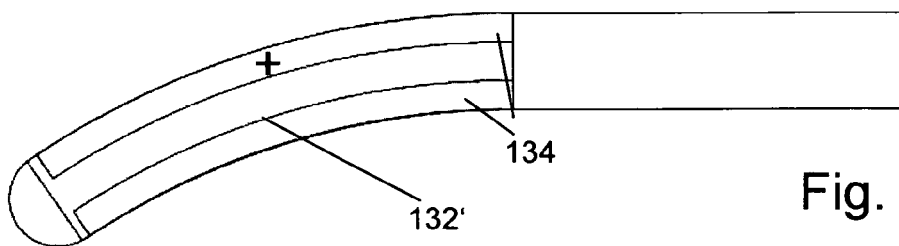


Fig. 18

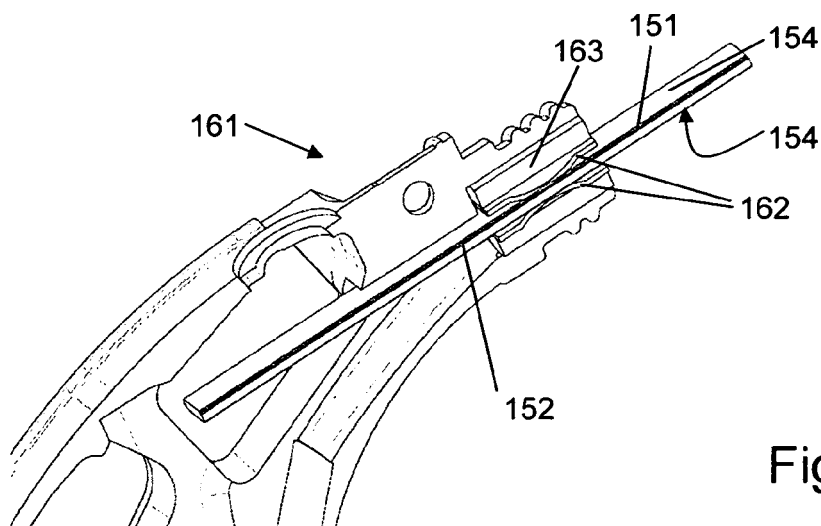


Fig. 19

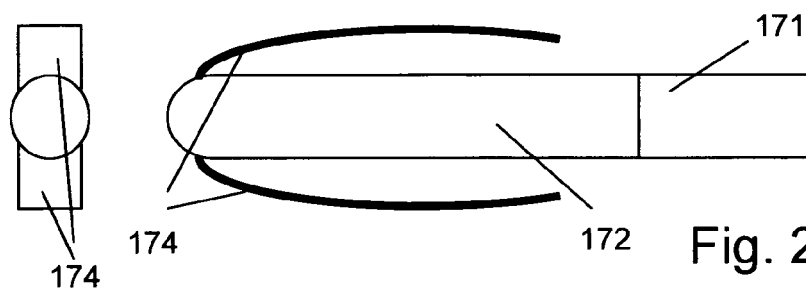


Fig. 20

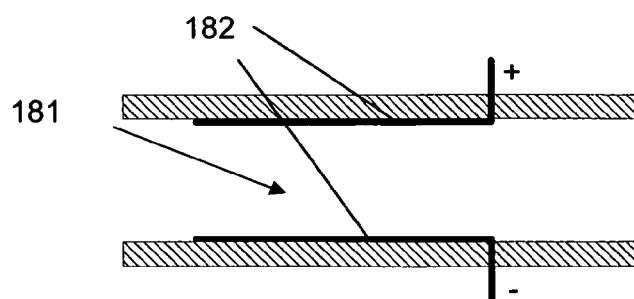


Fig. 21

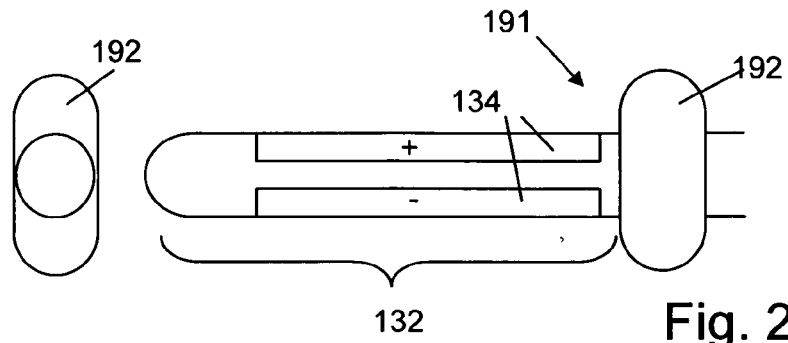


Fig. 22

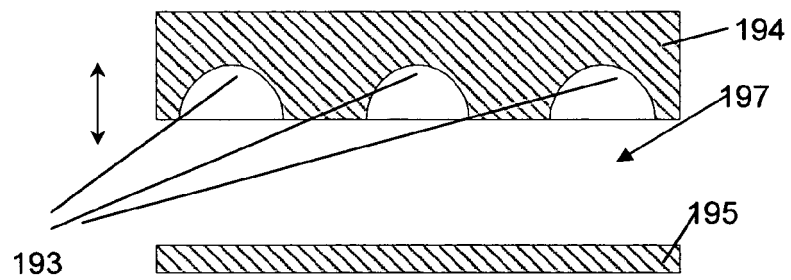


Fig. 23

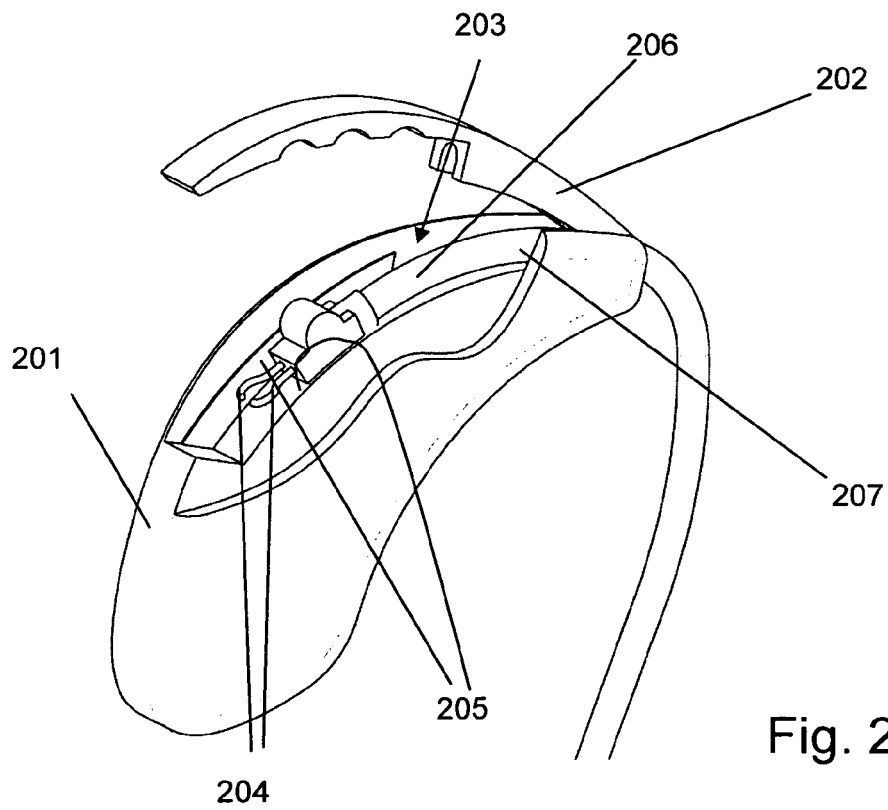


Fig. 24

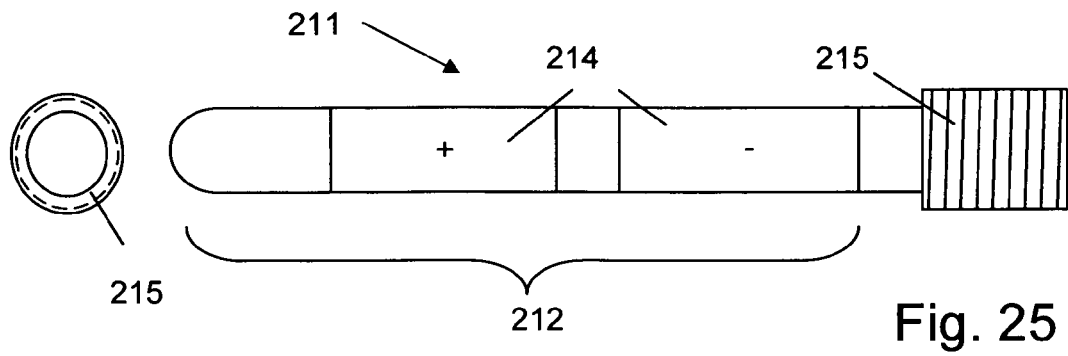


Fig. 25

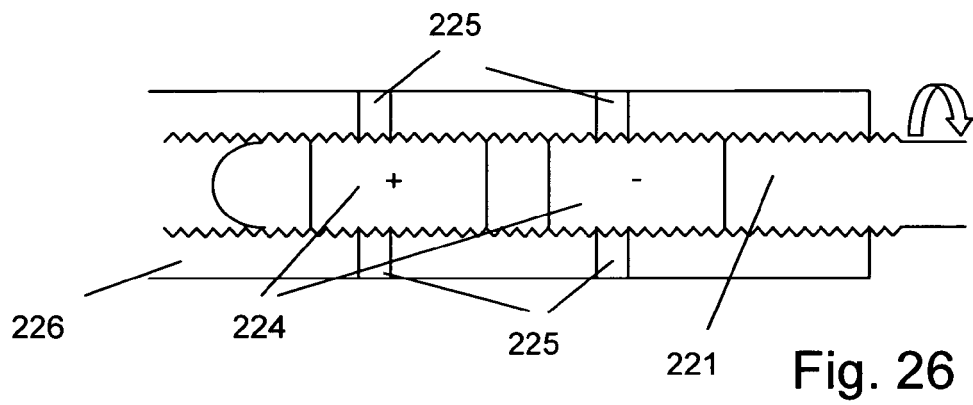


Fig. 26

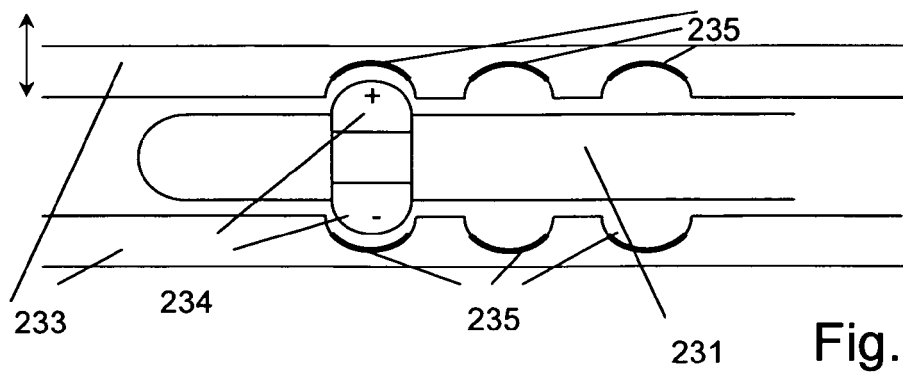


Fig. 27

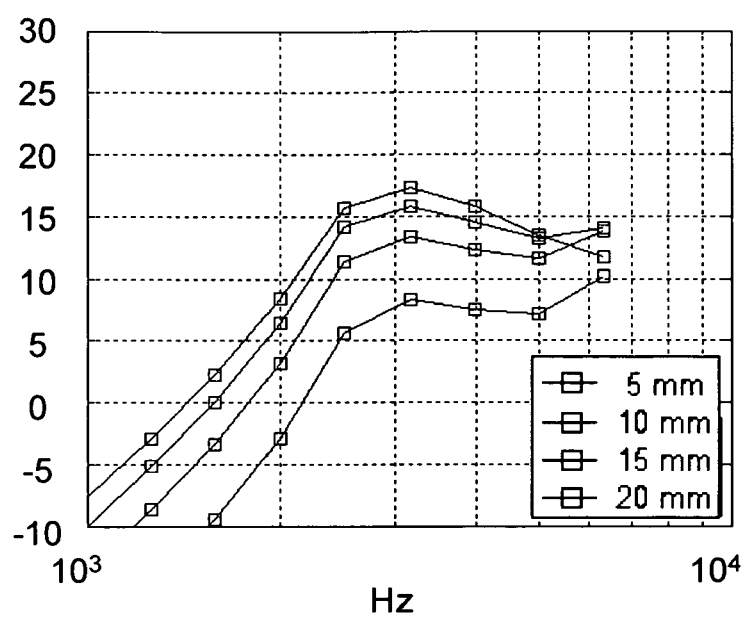
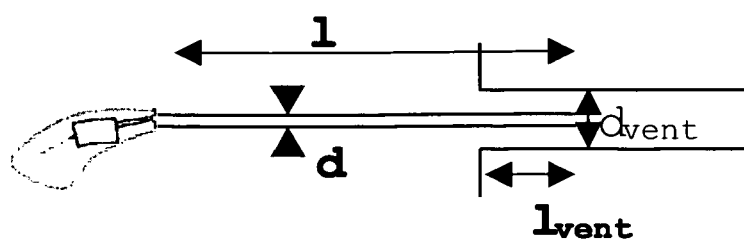


Fig. 38

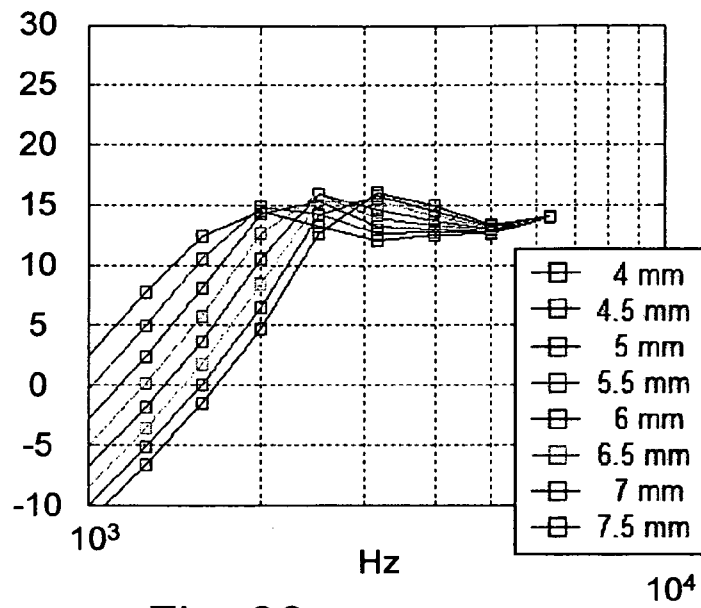
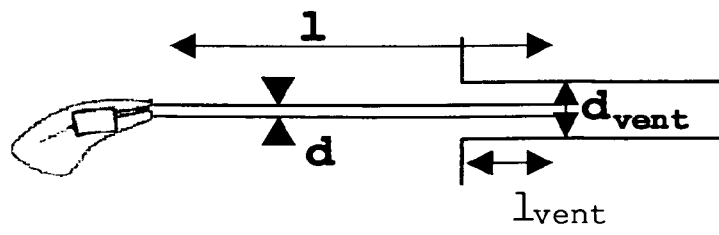


Fig. 39

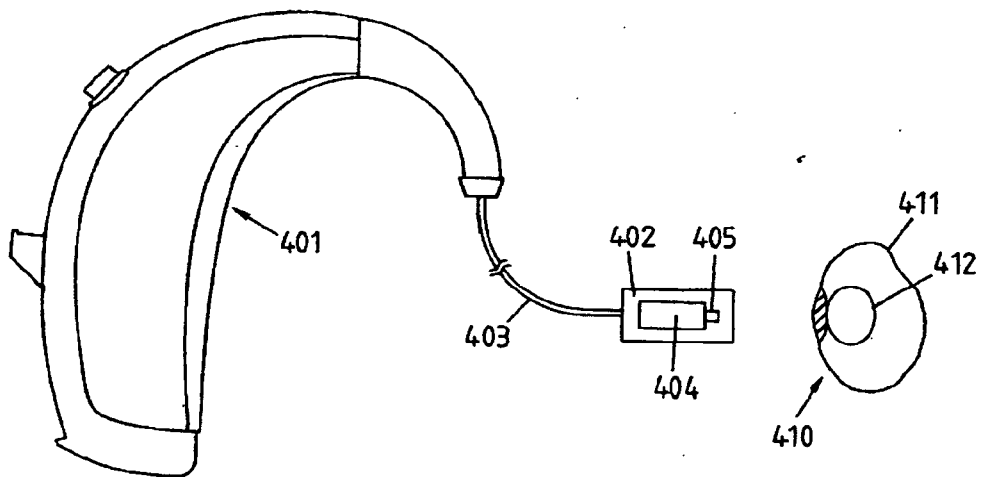


Fig. 40

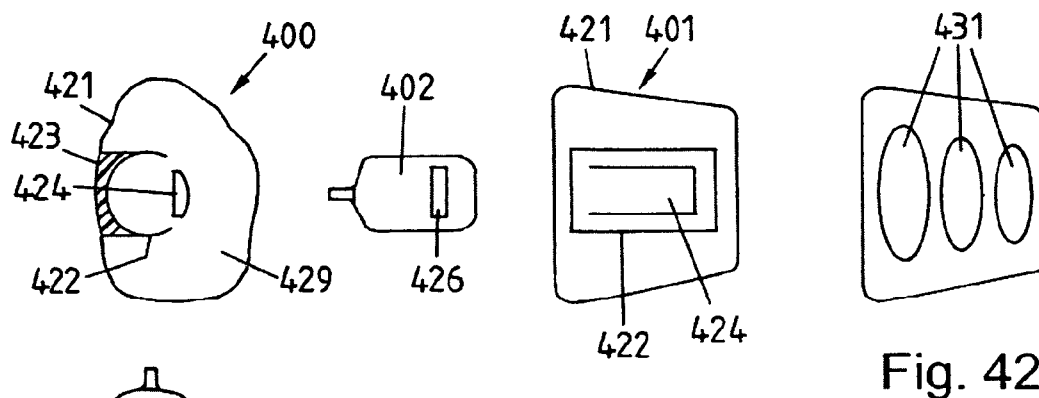


Fig. 42

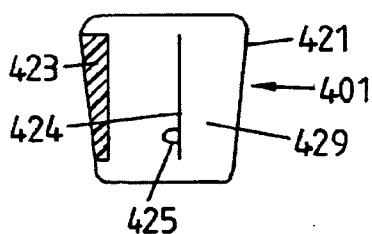
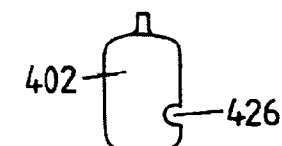


Fig. 41

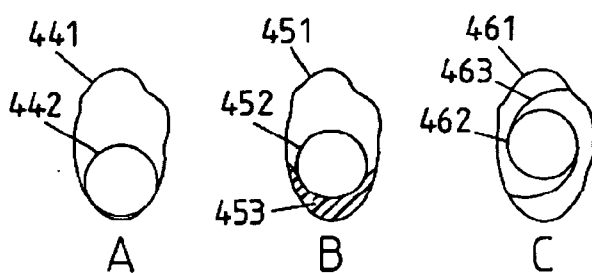


Fig. 43

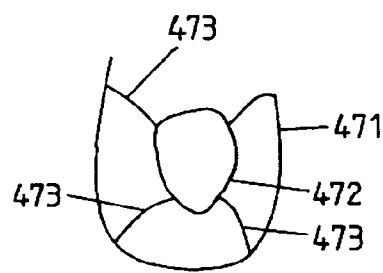


Fig. 44

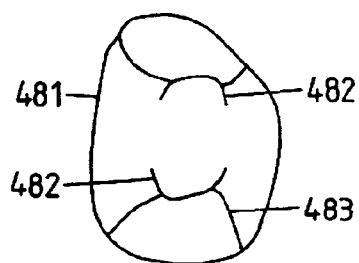


Fig. 45

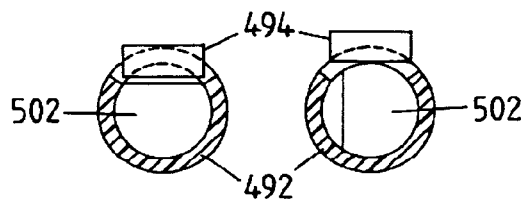


Fig. 46

REFERENCES CITED IN THE DESCRIPTION

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