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(54) Hearing device

(57) A hearing device according to the present invention comprises a venting channel (2) extending basically in a longitudinal direction (3) in a main body (1) of the hearing device. The venting channel (2) has at least one portion (4) being enlarged in cross-sectional area thereof. A valve member (5) is arranged at the enlarged portion (4) of the main body (1) and is movably supported relative to the venting channel (2) and is operationally connected to a servo device (6) for moving the valve member (6). A control means (12) serves for driving the servo device (6) to move the valve member (5) in a predetermined manner. Specifically, the enlarged portion (4) of the venting channel (2) and of the valve member (5) are provided with a predetermined shape so as to obtain a slit, the size of which can be varied when said valve member (5) is moved by said servo device (6).

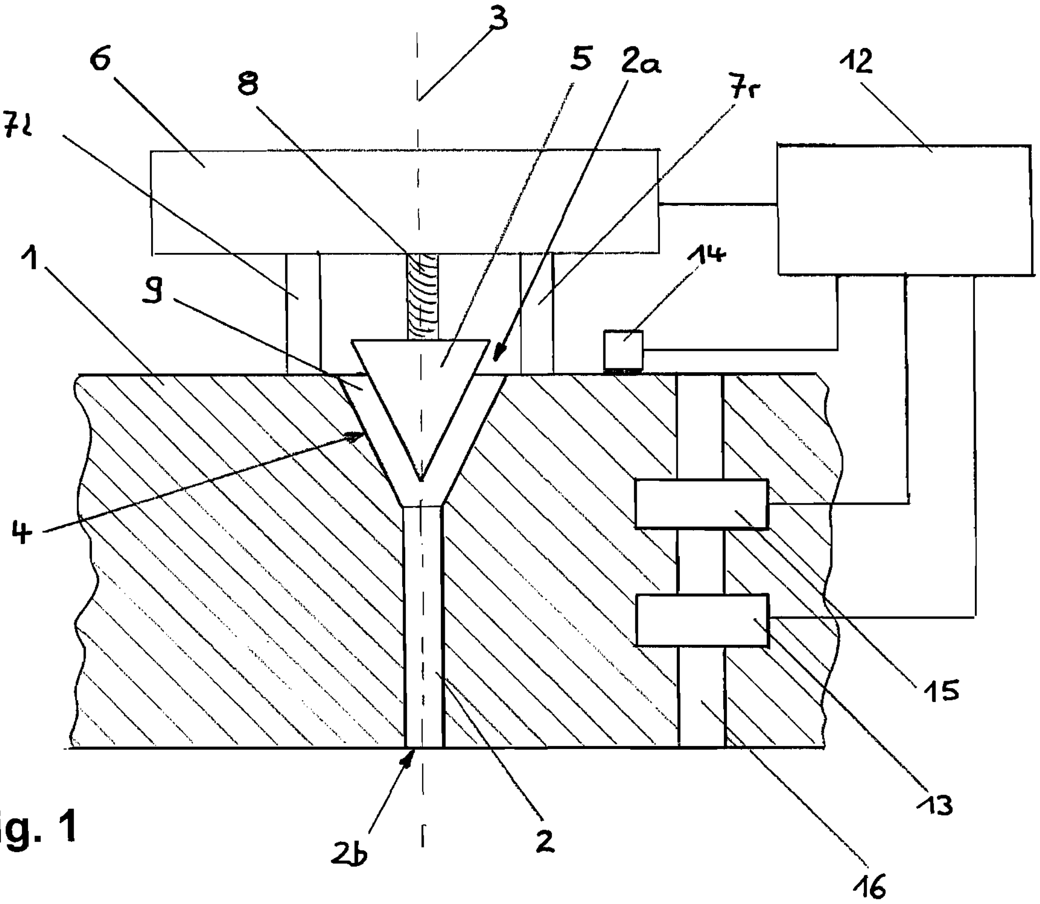

Fig. 1

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Description

[0001] The present invention refers to a hearing device, and specifically to a hearing device having a venting channel.

[0002] A venting channel or ventilation canal (vent) is known from prior art document WO 2007/054589. This document directed to a hearing device discloses an acoustical channel transmitting acoustical signals from the surroundings of a user of the hearing device into the user's ear. The acoustical channel provided for leading sound pressure from the surrounding of the user towards his ear drum is provided with a member which has a controllably variable shape and/or a controllably variable elasticity and/or a controllably variable oscillating behaviour in an open space of the acoustical channel which also has the function of a ventilation channel. A sensing means detects the sound pressure surrounding the user and a controller controllably varies at least one of the shape, elasticity and oscillating behaviour of the member for providing a predetermined attenuation of the sound transmitted by the acoustical channel. Depending upon the driving and operation of the member, the sound pressure attenuation is directly controlled by at least one of the shapes. The operation of the member affects the transmission of the acoustical signals from the surrounding of the user to the user's ear drum. The known hearing device includes a drive means for controllably varying one of the shape, elasticity and behaviour of the member, the drive means being based on any kind of actuator or motor and being instructed by the controller.

[0003] Prior art document DE 100 13 695 A1 discloses a speech-controlled hearing aid, wherein a pair of microphones is provided to detect the environmental sound conditions around the user of the hearing aid. One of the microphones is arranged in the auditory canal and the other is arranged outside in front of the ear. The hearing aid further includes a venting channel which can to a greater or smaller degree be closed or opened to provide a suitable ventilation and to avoid any occlusion of the venting channel or any feedback when the hearing aid is operated. The variation of the venting channel is provided by a valve which is electrically driven and controlled according to the acoustical conditions detected.

[0004] Prior art document US 6 549 635 B1 discloses a hearing aid with a ventilation channel which is adjustable in its cross-sectional area. The hearing aid can be directly insertable in the ear of a user or can be worn with an otoplastic which is be inserted in the ear. Adjusting elements are provided in the ventilation channel for adjusting the open cross-sectional area thereof, driven by a miniature drive arrangement and depending upon the environmental sound conditions detected by a respective detecting means.

[0005] Document US 2007/0177753 A1 discloses an earphone with leakage control, wherein the leakage can be controlled automatically or can be set by the user depending upon the sound source and the emitted sound thereof. The leakage control is specifically performed by adjusting a closure means to controllably open or close to a predetermined extent a channel providing connection of the user's ear drum to the outside.

[0006] Finally, prior art document US 5 645 074 discloses a hearing aid fitting system which can provide a three-dimensional acoustic environment for the user. An intra-canal prosthesis is positioned in the ear canal and comprises a microphone probe to measure the sound conditions in the ear canal at a common reference point, and a control of the hearing aid is provided in conjunction with the detected sound conditions around the user.

[0007] In the cases mentioned above, the sound conditions around the user and in particular the sound pressure are detected and depending upon the detection result a corresponding adaptation of the transmissibility of an acoustical canal or of a venting channel (vent) can be set to provide a controlled acoustical impression for the user. In the cases above, it may be difficult to precisely control the opening of the venting channel and the adaptation of the venting channel's acoustical properties as the elements for opening or closing the venting channel or for to a certain extent limiting the acoustical properties of the venting channel, members are provided in the venting channel and are operated by an actuator.

[0008] In more detail, regarding the arrangement shown in Fig. 5, this diagrammatical representation shows a venting channel V arranged in a hearing aid (which basically corresponds to the technical teaching disclosed in document WO 2007/05489). The venting channel V has an input opening Vi as well as an output opening Vo. The acoustical waves originate from acoustical signals Si input to the venting channel and a corresponding sound pressure in the environment of the user using the hearing aid having the structure according to Fig. 5.

[0009] A control means C is provided for controlling the properties, such as at least one of shape, elasticity or behaviour of a member for (to a more or less extent) closing or opening of the venting channel V so that the effective or relevant diameter of the venting channel V and, thus, the acoustical properties thereof can be varied. The control means C is adapted to receive an acoustical information about the sound pressure around the user (signals Si), and the member M for opening or closing the venting channel V is driven by the control means C depending upon the acoustical information actually sensed. The control means C also controls an output sound So to be output to the user of the hearing device.

[0010] The member M in the venting channel V acts as an attenuation means, and a sound pressure transmitted through the venting channel V is controlled depending upon the acoustical conditions, such as the acoustical sound signal Si entering the venting channel V and being sensed by the control means C. The sound pressure attenuation in the venting channel V is varied by operating the member M, such as controlling for example the shape of the member M. The shape variation of the member M is basically an elastic variation in the size thereof and causes a more or less opening or closure of the venting channel V, thereby providing the attenuation of the sound pressure transmitted by the venting channel V from the outside of the ear of the user to the user's ear drum and the acoustic properties of the venting channel V.

[0011] Moreover, in a general manner, Figs. 6 and 7 show characteristic curves representing the influence of the opening of the venting channel on the occlusion effect and the acoustical properties of the venting channel. In detail, Fig. 7 represents the theoretical measured sound pressure level which is measured outside the hearing device or hearing aid, and which results from the inside of the hearing aid passing through the venting channel. Different curves depend on the different opening diameters of the venting channel and correspond to effective diameters from zero (closed) to about 15 mm. Fig. 6 shows the theoretical perceived occlusion as a function of the ventilation diameter. Different curves result from different diameters of the venting channel. As the diameter is increased, less amplification of low frequencies is experienced, as compared to a closed hearing aid represented by a flat response at low frequency.

[0012] As can be seen, the (effective) diameter, that is, the opening of the venting channel influences both the low pass behaviour of the venting channel as well as the possibility of obtaining a feedback from the sound inside the user's ear to the outside (Fig. 7).

[0013] Hence, a precise control of the diameter or, more specifically, the active diameter of the venting channel is necessary for proper adjustment of the amplification of the hearing aid as well as to avoid feedback and to reduce the occlusion effect which makes the user feel uncomfortable when wearing such a hearing aid. However, when the member for closing or opening the venting channel is of a flexible nature, for example a flexible foil, and can be varied in shape, elasticity or acoustical behaviour in the open space of the channel or in more than one of these parameters at the same time (as it can be done according to prior art document WO 2007/05489), a precise operation of the member and a basically symmetrical arrangement of the member in the venting channel cannot be ensured. Therefor, a precise control of the hearing aid depending upon the environmental sound conditions as detected cannot be performed.

[0014] It is therefore an object of the present invention, to provide a hearing aid wherein the acoustical properties of a venting channel can precisely be controlled or adapted. According to the present invention, this object is accomplished by a hearing aid as put forward in the appended claims.

[0015] The hearing device according to the present invention comprises a venting channel basically extending in a longitudinal direction in a main body of the hearing device, the venting channel having at least a portion being enlarged in its cross-sectional area, a valve member arranged at the enlarged portion of the main body and being movably supported relative to the venting channel and being operationally connected to an actuator for moving the valve member, and a control means for driving the actuator to move the valve member in a predetermined manner, wherein the enlarged portion of the venting channel and the valve member are provided with a predetermined shape so as to obtain a slit, the size of which can be varied when the valve member is moved by the actuator.

[0016] The arrangement according to the present invention ensures a precise adaptation of the slit and the varying size thereof to provide an influence on the venting channel in view of its acoustical properties. The valve element can exactly be adjusted, and can specifically be moved by the actuator when the actuator receives corresponding driving signals from the control means. That is, based on a control concept implemented in the control means, the actuator is operated to adjust or adapt the transmissibility of acoustical waves through the venting channel by precisely moving the valve element arranged in the enlarged portion of the venting channel, thereby increasing or decreasing the size of the slit which constitutes the actual or active opening of the venting channel. More specifically, the valve element and the enlarged portion of the venting channel are provided such that both elements have a predetermined shape so as to obtain the slit-shaped opening of the venting channel. When the valve member is moved by the actuator under control of the control means, the size of the slit is adapted for obtaining predetermined desired acoustical properties of the venting channel.

[0017] The predetermined shape of the enlarged portion of the venting channel and the predetermined shape of the valve member may basically be conical, and the valve member may be movably accommodated in the enlarged portion in the venting channel. Moreover, the slit is defined by the valve member accommodated in the enlarged portion of the venting channel basically resulting in a ring-shaped slit.

[0018] Preferably, the enlarged portion of the venting channel is arranged at one of a first and a second end portion of the venting channel, or may be arranged between the first and second end portions.

[0019] The servo device may include a linear motor, and the servo device can be coupled to the valve member preferably by a threaded screw. The servo device may be a rotational electric motor rotating the threaded screw for moving the valve member along a longitudinal axis of the venting channel.

[0020] According to a further development, the servo device can be a piezo electric motor using piezoelectric elements as active elements for providing the movement of the valve member. Moreover, the servo device may include a piezoelectric actuator according to a smooth impact drive mechanism using piezoelectric elements as active elements for providing the movement of the valve member.

[0021] Preferably, the hearing device may further comprise a first sound pressure sensing means for detecting the sound pressure impacting on the hearing device from the outside and transmitting a detection signal to the control means for controlling movement of the valve member depending upon the detected sound pressure. There may also be provided a second sound pressure sensing means for detecting the sound pressure in a user's ear canal and generating a detection signal and transmitting the detection signal to the control means for controlling movement of the valve member depending upon the detected sound pressure.

[0022] Further preferably, the predetermined shape of the enlarged portion of the venting channel and the predetermined shape of the valve member may basically be of an elliptical shape or a spherical shape, and the valve member may be movably accommodated in the enlarged portion of the venting channel.

[0023] The movement of the valve member accommodated in the enlarged portion of the venting channel can be controlled by the control means to adjust the dimension of the slit between the valve member and the enlarged portion of the venting channel.

[0024] Preferably, the predetermined shape of the enlarged portion of the venting channel and the predetermined shape of the valve member may be of a non-rotation-symmetric shape and the slit between the valve member and the enlarged portion of the venting channel may have a geometrical shape departing from the ring shape.

[0025] The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detail description in conjunction with the appended drawings referring to embodiments of the present invention.

[0026] The drawings according to the present invention show in

Fig. 1 an overall view of the hearing aid according to a first embodiment of the present invention,

Fig. 2 a view of details of the valve element accommodated in the main body according to the arrangement of Fig. 1,

Fig. 3 the arrangement of a valve member in the venting channel of the hearing device according to a second embodiment of the present invention,

Fig. 4 a diagram representing measurement curves of the attenuation relative to different opening degrees of the venting channel over the frequency of sound waves with the valve element placed at different positions,

Fig. 5 a schematic view of a venting channel having a closing member for opening or closing the venting channel according to the prior art,

Fig. 6 a diagram of theoretical perceived occlusion as a function of the effective venting channel diameter over the frequency of sound waves, and

Fig. 7 a theoretical measured sound pressure level on the outside of the hearing aid over the frequency of sound waves.

First Embodiment

[0027] The present invention is now described in conjunction with the presentation of Figs. 1 and 2 showing the arrangement of a hearing device according to the first embodiment of the present invention. The hearing device is adapted for insertion in the human ear, that is, into the user's ear canal (type: CIC, ITC, ITE).

[0028] Regarding the overall arrangement shown in Fig. 1 and the further details shown in Fig. 2, reference number 1 denotes a main body of the hearing aid. As can be seen from Figs. 1 and 2, in the main body represented in a cross sectional view, a venting channel 2 is provided. The venting channel 2 extends along a longitudinal direction of the main body 1, this longitudinal direction being represented by a dashed line in conjunction with reference number 3 in Figs. 1 and 2. One section of the venting channel 2 in the main body 1 constitutes an enlarged portion 4, that is, in this enlarged portion 4 the width of the venting channel 2 is higher than in further portions of the venting channel 2 in the main body 1. The enlarged portion 4 is located at one end of the venting channel 2 (close to the upper end of the venting channel 2 according to the representation in Figs. 1 and 2) which is a first end portion 2a of the venting channel 2 and has a predetermined shape. Specifically, the enlarged portion 4 of the venting channel 2 has basically a conical form (shape), which opens towards the upper end (first end portion 2a) of the venting channel 2 and the diameter is reduced towards the lower end of the venting channel 2 (which represents a second end portion 2b of the venting channel 2), as can be seen in Figs. 1 and 2.

[0029] The hearing device according to the present invention further comprises a valve member 5, which is partly inserted in the enlarged portion 4 of the venting channel 2. The valve element 5 basically has the same (corresponding) shape as that of the enlarged portion 4 of the venting channel 2, which is basically a conical shape. That is, the valve element 5 has smaller dimensions perpendicular to the longitudinal axis 3 of the venting channel 2 in the lower portion of the valve element 5, and has higher dimensions (bigger size) in the upper portion of the valve member 5 adjacent to the second end portion 2b (upper opening) of the venting channel 2 which is the greater opening of the enlarged portion 4 of the venting channel 2.

[0030] The valve member 5 is movably supported by a servo device 6 which is adapted for moving in a predetermined manner the valve member 5 along the longitudinal axis 3.

[0031] The servo device 6 is supported by a left and a right support element 71 and 7r and fixed to the main body 1 of the hearing device. The servo device 6 may provide the longitudinal movement of the valve member 5 along the longitudinal axis 3 by means of a threaded screw 8 which is rotated by the servo device 6. When the servo device 6 rotates in a predetermined and controlled manner the threaded screw 8, the valve member 5 is moved back and forth along the longitudinal axis 3 of the venting channel 2, and the degree of inserting (accommodating or housing) the valve member 5 into the enlarged portion 4 of the venting channel 2 can be varied.

[0032] As can be seen from Figs. 1 and 2, when the valve member 5 is to a certain extent inserted into the enlarged portion 4 of the venting channel 2, as for example shown in Fig. 2, a variable basically ring-shaped slit 9 is created between the valve member 5 and the main body 1 in the enlarged portion 4 of the venting channel 2.

[0033] That is, by the operation of the servo device 6 and the provision of the longitudinal movement of the valve member 5 to variably insert the valve member 5 into the enlarged portion 4 of the venting channel 2 the ring-shaped slit 9 can be adapted to a different size, resulting in a different effective diameter d_{eff}. In this case, the effective diameter d_{eff} corresponds to an open area (the slit or gap between the valve member 5 and the enlarged portion 4 of the venting channel 2) which can be calculated according to the following equation 1, wherein a is the maximum diameter of the valve member 5, h is the length of the enlarged portion 4 along the longitudinal axis 3, and Δh is the difference between a theoretical tip end 10 of the valve member 5 and a theoretical tip end 11 of the enlarged portion 4, which is preferably provided in a conical form or shape (Fig. 2).

$$d_{eff} = 2\sqrt{a^2 - \left(\frac{ah - a\Delta h}{h}\right)^2} \qquad \text{equation 1}$$

[0034] When the servo device 6 is controllably operated and moves the valve member 5 in a predetermined manner along the longitudinal axis 3 of the venting channel 2, this changes the acoustic mass of the ventilation channel and, thus, the acoustical properties of the transmission of acoustic waves through the venting channel 2. The acoustic mass Ma of an air filled tube, which constitutes a specific parameter for acoustics, is given by

$$Ma = (\rho\ air * L)/A \qquad \text{units: } kg/m^4, \qquad \text{equation 2}$$

wherein ρ air is the density of the air [kg/m^3], A is the cross sectional area [m^2] and L is the length [m] of the (theoretical) tube.

[0035] When such a tube is considered approximating an acoustic meatus of the human ear, sound is transmitted through the jaw bone (own speech/chewing noises) and this sound sets the soft tissue in the ear canal into vibrations creating an increased in low frequency transmitted sound. In a CIC/ITC/ITE hearing aid, the ear canal is blocked, causing a build up of low frequency sound pressure, resulting in the well-known occlusion effect. This phenomenon can, to a large extent, be suppressed by including the venting channel in the hearing aid, as is shown in Figs 1 and 2. The inertia of the acoustic mass Ma can more easily be overcome at low frequencies. From the above equation 2, it can be seen that as the inertia to overcome is proportional to the acoustic mass Ma of the air, an increase in diameter of the venting channel will result in a reduction of the acoustic mass Ma. Hence, higher frequencies of sound will be able to overcome the inertia. This phenomenon is shown in Fig. 6 as discussed above.

[0036] In other words, a large venting channel (having a greater diameter or cross-sectional area) will allow a broader spectrum of sound to escape through it. This presents a paradox as a receiver in the hearing device inside the ear canal will now more efficiently transmit the amplified higher frequencies of the ear, thereby creating the undesired feedback effect (see Fig. 7). In general, the venting channels of hearing devices of today have to compromise gain with occlusion the best way possible. This means that the cross-sectional area or effective diameter of the venting channel has the following impacts:

[0037] A large effective diameter will result in less occlusion, but reduce the amount of possible gain before feedback is introduced.

[0038] A small effective diameter will increase the amount of gain possible in the hearing device, but occlusion becomes more and more pronounced.

[0039] It is advantageous to have a venting channel that would simultaneously permit low frequencies sounds to leave the ear canal at certain times, but also to prevent higher frequencies (2 to 6 kHz) sound from exiting the ear canal and causing feedback which is very uncomfortable for the user of the hearing device.

[0040] A precise dynamic control of the effective diameter of the venting channel 2 is therefore provided according to the present invention by thoroughly adapting the degree of insertion of the valve member 5 into the enlarged portion 4 of the venting channel 2 to obtain the variable ring-shaped slit (gap) representing the effective diameter of the venting channel 2 and characterizing the acoustic properties of the venting channel 2 and of the entire hearing device.

[0041] To this end, the hearing device comprises a control means 12 in the form of an electronic controller usually based on a microprocessor or any microcomputer, this control means 12 picking up information about the environmental sound conditions and the sound conditions in the user's ear canal and providing, upon further data evaluation of the detection results a predetermined control of the movement and as a result thereof, of the actual position of the valve member 5 in the enlarged portion 4 of the venting channel 2 to precisely define the diameter of the venting channel 2 effective for the acoustic properties (mainly the attenuation) thereof.

[0042] For obtaining the data about the environmental acoustical conditions, the control means 12 is connected to a first microphone 13 or similar sound pressure sensing means, for picking up the acoustic signals surrounding the user in the form of the actual sound pressure from outside, as well as a second microphone 14, or similar sound pressure sensing means, arranged at an upper surface of the main body 1, and at the first end portion 2a of the venting channel 2, facing the user's ear drum and being located adjacent to the opening of the enlarged portion 4 of the venting channel 2. The second microphone 14 senses the acoustical conditions and specifically the actual sound pressure in the user's ear canal, so that a difference between the sound pressure outside in the surroundings the user, and the sound pressure within the user's ear canal can be determined.

[0043] The hearing device further comprises a speaker 15 (in hearing aid connection usually termed receiver) which is operated by the control means 12 to provide the desired and necessary amplification. The microphone 13 and the receiver 15 are located in an electro-acoustic signal path 16 which is substantially parallel to the venting channel 2. That is, the venting channel 2 represents a bypass to the electro-acoustic signal path 16 of the hearing device.

[0044] According to the control concept of the present invention, the control means 12 receives an information about the acoustic conditions, and in particular a sound pressure information from the outside (surrounding the user) by microphone 13 and from the ear canal of the user by microphone 14 and controls both the receiver15 for amplifying sounds, as well as the servo device 6 for adjusting the effective diameter of the venting channel 2.

[0045] The control means 12 receives the acoustic conditions (surrounding sound) in the form of sensing signals and provides a data evaluation which results in drive signals which are fed to the servo device 6. The valve member 5 partly inserted in the enlarged portion 4 of the venting channel 2 is moved according to the longitudinal axis 3 of the venting channel 2 so as to adapt the ring-shaped slit 9 between the valve member 5 and the enlarged portion 4 of the venting channel 2. The precise control is possible since the valve member 5 and the enlarged portion 4 of the venting channel 2 are both provided with a corresponding shape which is preferably the conical shape and which allows an exact definition of the active diameter of the venting channel 2 by precisely defining the dimensions of the ring-shaped slit 9 via movement (translation) of the valve member 5. That is, the size of the ring-shaped slit 9 (gap, clearance) is controllably modified to vary the cross-sectional area depending upon the acoustical conditions sensed and evaluated by the control means 12.

[0046] The present invention can therefore provide a precise and dynamical adjustment of the hearing device to the specific environmental conditions in view of sound, and in particular by providing a precise adjustment of the acoustical properties of the venting channel 2 which is necessary for obtaining a high comfort of the hearing device attached to the user's ear(s).

[0047] The hearing device according to the present invention and having the above control concept and control means for controlling the ring-shaped slit 9 of the venting channel 2 can cope with higher differences in sound pressure depending upon the environmental conditions with high speed and short response time due to the precise guiding and positioning of the valve member 5 in the enlarged portion 4 of the venting channel 2 by means of the servo device 6. This results in a dynamic and precise control of the attenuation of incoming sound from the outside and of a certain sound pressure coming from within the user's ear canal to avoid the undesired feedback conditions.

[0048] According to the presentation in Figs 1 and 2 the enlarged portion 4 of the venting channel 2 is arranged in the upper portion of the main body 1 of the hearing device which is the first end portion 2a of the venting channel 2. While the enlarged portion 4 of the venting channel 2 in conjunction with the valve member 5 and the corresponding servo device 6 is arranged at the first (upper) end portion 2a of the venting channel 2, the present invention is not limited to this particular exemplary arrangement. According to a further modification of the first embodiment, the advantages as described above obtained by the present invention are also ensured when the enlarged portion 4 of the venting channel 2 is arranged at the second (lower) end portion 2b of the venting channel 2, together with the servo device 6 mounted to the lower portion or the lower surface of the main body 1.

[0049] The arrangement of the microphone 13, the receiver 15 and the microphone 14 remain the same irrespective of whether the means for adapting the ring-shaped slit are provided at the first (upper) end portion 2a or at the second (lower) end portion 2b of the venting channel 2.

[0050] In both cases, the servo device 6 is preferably provided in the same form, and is supported by right and left supporting elements 7r and 7l and is operatively connected with the valve member 5 to be moved by a connecting means preferably in the form of the threaded screw 8. The servo device 6 in conjunction with the valve member 5 to be moved in the enlarged portion 4 of the venting channel 2 is controlled in the same manner in both the above-discussed cases of the arrangement of the enlarged portion 4 of the venting channel 2. Any servo device 6 may be used at this place, in particular also a Smooth Impact Drive where there is no thread.

[0051] The servo device 6 is controllably driven by the control means 12, which sends instruction signals to the servo device 6. The servo device 6 may include any suitable actuator in the form of an electric motor, such as a piezoelectric motor using piezoelectric elements as active elements for providing the movement of the valve member 5. Such a piezoelectric motor may cause a rotation of the threaded screw 8 connecting the valve member 5 to the servo device 6, and the rotation of the threaded screw 8 converts the rotational movement into a translation along the longitudinal axis 3 of the venting channel 2. Also a linear drive such as in Piezoelectric SQUIGGLE Motors provided by New Scale Technologies may be applied.

[0052] Specifically, the actuator of the servo device 6 may use a piezoelectric motor such as an ultrasonic motor which can be used as micro-actuators, and such ultrasonic motor provides a relatively high torque, a low speed and a simple construction. Such a motor is usually a cylindrical-shaped motor, using for example a lead zirconate titanate (PZT) thin film. The motor having such a construction has dimensions of few millimetres in diameter and length and is suitable for operation in the servo device 6 for controllably moving the valve member 5 under control of the control means 12.

[0053] For obtaining the desired translation movement along the longitudinal axis 3 of the venting channel 2 there may be provided by a sliding arrangement in the form of a SIDM actuator (SIDM: Smooth Impact Drive Mechanism). The Smooth Impact Drive Mechanism consists of a solid base, a stack piezo device, a driving rod (which is usually provided simply in the form of a piece of metal) and a moving body. The moving body grips onto the driving rod with a certain force and can accordingly slide up and down the rod if a sufficient force is provided making it overcome the frictional forces holding it at a certain position. Such a drive mechanism provides a high precision and a simple arrangement for obtaining the movement along the longitudinal axis 3.

[0054] The actuator of the servo device 6 may also be based on a drive arrangement based on a pneumatic drive, a hydraulic drive or an electro static drive or on a conventional electric motor having magnetic cores and electric coils as active parts.

[0055] Regarding the predetermined shape of the valve member 5 accommodated in the enlarged portion 4 of the venting channel 2, as discussed above, this predetermined shape is preferably a conical shape so that the movement of the valve member 5 relative to the enlarged portion 4 can precisely be controlled from the fully close position (valve member 5 at lowest position in Figs. 1 and 2 and fully abutting on the enlarged portion 4) to the fully open position (maximum effective diameter of the ring-shaped slit between the valve member 5 and the enlarged portion 4). The conical shape of both the valve member 5 and the enlarged portion 4 of the venting channel 2, that is, when both elements have a corresponding shape, forms the basis for the precise control of any intermediate ring-shaped slit dimension between zero and the maximum value thereof. In this connection, the control means 12 is adapted to provide a control of the movement of the valve member 5 depending upon this conical shape. Preferably, the conical shape of both the valve member 5 and the enlarged portion 4 is basically rotation-symmetric relative to the longitudinal axis 3 of the venting channel 2. The present invention is, however, not limited to the conical form of both elements as described above.

[0056] Alternatively, the shape of the valve member 5 and of the enlarged portion 4 of the venting channel 2 may be provided in the form of for example an elliptical shape. Since in conjunction with this alternative the shape of the valve member 5 and that of the enlarged portion 4 directly correspond to each other, and since the elliptical shape also has rotation symmetry, the ring-shaped slit 9 is likewise defined with varying dimensions depending upon the degree of inserting the movable valve member 5 into the enlarged portion 4 of the venting channel 2. In a similar manner as in the case of a conical shape of the valve member 5 and the enlarged portion 4, the effective diameter of the ring-shaped slit (opening degree of the venting channel 2) can precisely and effectively be controlled.

[0057] According to a further alternative, the physical form of the valve member 5 may be basically a spherical shape (ball-shape), which is also rotation-symmetric and provides the ring-shaped slit 9 between the valve member 5 and the enlarged portion 4 of the venting channel 2. The predetermined shape may also be an oval shape, being oval in the plane parallel to the longitudinal axis 3 and/or in a plane perpendicular to the longitudinal axis 3.

[0058] In the cases of the alternative physical forms discussed above, the control characteristic (characteristic curve of control) to be performed by the control means 12 is preferably based on different concepts since a particular movement of the valve member 5 along the longitudinal axis 3 will cause different variation of the ring-shaped slit 9 due to the different characteristic curves.

[0059] In all the modifications of the physical form of the valve member 5 and the enlarged portion 4, the dimensions of the ring-shaped slit 9 and, thus, of the effective cross-sectional area of the opening of the venting channel 2 can be controlled on the basis of the prevailing acoustical conditions as sensed. Irrespective of the predetermined shape of the enlarged portion 4 and the valve member 5 the control is performed as a dynamic control based on the continuously sensed acoustical conditions, including the acoustical conditions outside the hearing device and inside the user's ear canal.

[0060] In all these cases and irrespective of the physical shape of the valve member 5 and the enlarged portion 4, the dimensions of the ring-shaped slit 9 (acoustical effective diameter thereof) are controlled as a general control parameter of the entire control of the hearing device to optimize the acoustical properties thereof and the maximum comfort for the user of the hearing device.

[0061] It is again referred to the arrangement shown in Fig. 1. The servo device 6 including the actuator to move the valve member 5 by means of a connection rod, provided in the present case in the form of the threaded screw 8, causes a rotation of the threaded screw 8 to obtain the desired translation of the valve member 5 along the longitudinal axis 3. The rotation of the threaded screw 8 may be transmitted to the valve member 5 so that the valve member 5 may rotate in a similar manner. Alternatively the threaded screw 8 may be pivotally supported in the valve member 5, or the valve member 5 may also be supported in a predetermined manner allowing the translation but inhibiting a rotational movement thereof.

[0062] In this connection, as a further alternative or modification, the predetermined shape of the valve member 5 and the enlarged portion 4 of the venting channel 2 may basically be a rotation symmetric shape, but may have a guiding element (not shown) adapted for inhibiting the rotation of the valve member 5 when moved in the enlarged portion 4 of the venting channel 2. The guiding element arranged on the valve member 5 may protrude in the axial direction (in the direction perpendicular to the longitudinal axis 3) from the valve member 5 to the inner wall of the enlarged portion 4 of the venting channel 2, and at a corresponding position the inner wall of the enlarged portion 4 of the venting channel 2 may have a recessed portion, such as a groove, so that the guiding element protruding from the valve member 5 may be in operational connection to the groove of the enlarged portion 4 and may fit with this groove. When moving the valve member 5 along the longitudinal axis 3, a rotational movement of the valve member 5 itself is inhibited. The protruding guiding element of the valve member 5 (not shown in the Figures) may be formed so as to have the desired operational connection to the inner wall of the enlarged portion 4 independent of the actual position of the valve member 5 when moved along the longitudinal axis 3.

[0063] The precise control of the acoustically effective diameter of the venting channel 2, i.e. the precise control of the dimensions of the ring-shaped slit 9 is the same irrespective of whether the valve member 5 is rotated or not.

[0064] The present invention is not limited to a rotation symmetry of the valve member 5 and of the enlarged portion 4 of the venting channel 2. In case of a non-rotation-symmetric shape of the valve member 5 and the enlarged portion 4 the slit does not have the form of a ring but has another regular geometrical shape. The resulting slit can also be controlled exactly in the same manner as the ring-shaped slit 9 described above.

[0065] According to the first embodiment of the present invention, Fig. 1 shows an arrangement of the two supporting elements 7r and 7l for fixedly mounting the servo device 6 to the main body 1 of the hearing device. The present invention is not limited to the arrangement of two supporting elements 7r and 7l, but any suitable number of supporting elements may be provided to ensure safe and stationary mounting of the servo device 6. The number of supporting elements for mounting the servo device 6 may depend upon the arrangement of the entire hearing device, that is, the arrangement of the venting channel 2 and of the electro acoustic signal path 16, the sensor means in the form of the microphone 14 as well as the control means (controller) 12. In specific cases, three supporting elements or more supporting elements may be suitable for fixedly mounting the servo device 6 to the main body 1.

Second Embodiment

[0066] On the basis of Fig. 3, a second embodiment of the present invention is described.

[0067] As is shown in Figs 1 and 2, reflecting the first embodiment of the present invention, the enlarged portion 4 of the venting channel 2 for accommodating the valve member 5 is provided at the first end (upper end) portion 2a of the venting channel 2. Alternatively, the enlarged portion 4 can also be arranged at the second end (lower end) portion 2b of the venting channel 2.

[0068] The second embodiment concerns the arrangement of the enlarged portion 4 at an intermediate position or range between the first and the second end portions 2a and 2b of the venting channel 2.

[0069] In Fig. 1 the servo device 6 is mounted to the main body 1 of the hearing device outside the venting channel 2 at the first end portion 2a thereof. Alternatively, the servo device 6 can be arranged close to the second end portion 2b and outside the venting channel 2.

[0070] According to Fig. 4, the valve member 5 as well as the necessary drive arrangement is positioned in the venting channel 2.

[0071] In more detail, the venting channel 2 comprises an enlarged portion 4 for basically accommodating the valve member 5 under the condition, that both the valve member 5 and the enlarged portion 4 of the venting channel 2 have a corresponding outer shape as described in detail above in conjunction with the first embodiment and its modifications or alternatives.

[0072] According to the second embodiment, the enlarged portion 4 of the venting channel 2 comprises an extension region 17 wherein the servo device 6 is located. In other words, the enlarged portion 4 of the venting channel 2 includes one portion for accommodating the valve element 5 as well as the extension region 17 for accommodating the servo device 6.

[0073] The control of the movement of the valve member 5 relative to the enlarged portion 4 of the venting channel 2, is carried out in a manner similar to the first embodiment, and the same advantages as discussed in conjunction with the first embodiment are obtained.

[0074] In the first embodiment the servo device 6, as shown in Fig. 1, is mounted to the main body 1 of the hearing device by means of left and right supporting elements 7r and 7l.

[0075] According to the second embodiment, the servo device 6 which can be provided in the form of a linear motor, a regular electric motor based on electromagnetic means, and a piezo electric motor using piezo elements as active elements, is fixedly mounted to the main body 1 by a plurality of fixing elements 18. In more detail, the servo device 6 is mounted to the inner wall of the venting channel 2, and in particular to the inner wall of the extension region 17 of the enlarged portion 4 of the venting channel 2 by the plurality of fixing elements 18.

[0076] Fig. 3 shows a plurality of such fixing elements 18 on the sides of the housing of the servo device 6, and in the embodiment shown in Fig. 3 the servo device 6 is fixed by means of, for example, eight fixing elements 18.

[0077] The invention is, however, not limited to this number of fixing elements, but any number of fixing elements is suitable if the servo device 6 is reliably fixed to the inner wall of the extension region 17 of the enlarged portion 4 so that the servo device 6 is stationary relative to the venting channel 2.

[0078] The movement of the valve member 5 may be carried out by the threaded screw 8, which forms the link between the valve member 5 and the servo device 6, in order to obtain the translation of the valve member 5 along the longitudinal axis 3 which is shown as a dashed line extending along the venting channel 2.

[0079] According to the arrangement shown in Fig. 3, the servo device 6 located in the venting channel 2 provides a further device in this venting channel 2 so that the acoustic properties of the venting channel 2 are further influenced by the servo device 6 having this location. The control characteristic (characteristic curve of the control) to be performed by the control means 12 may be adapted to consider the arrangement of the servo device 6 in the venting channel 2. Moreover, the plurality of fixing elements 18 should not adversely affect the opening of the venting channel 3.

[0080] The further arrangement of the control means 12, the receiver 13, the microphone 14 and the receiver 15 in the electro-acoustic signal path 16 is the same as in the first embodiment. The connection of the servo device 6 to the control means 12 (for exchanging control signals) according to the second embodiment is the same as in the first embodiment, but for simplicity of presentation not explicitly shown in Fig. 3.

[0081] It is further to be noted that valve member 5 in conjunction with the enlarged portion 4 of the venting channel 2 may have a different, but in any case a corresponding, physical shape to obtain a controlled variation of a slit of the effective opening of the venting channel 2, be it a ring shaped slit or a slit of other geometrical shape.

[0082] The present invention is not limited to the arrangement of two supporting elements 7r and 7l, shown in fig. 1 but any suitable number of supporting elements may be provided to ensure safe and stationary mounting of the servo device 6. In specific cases, three supporting elements or more supporting elements may be suitable for fixedly mounting the servo device 6 to the main body 1.

[0083] Fig. 4 shows the results of the precise control of the acoustically effective diameter, i.e. the dimensions of the ring-shaped slit 9, in view of the acoustical properties of the venting channel 2 for a frequency range of 100 Hz to 10 000 Hz and the attenuation in dB relative to the open venting channel 2.

[0084] The achieved damping is higher for higher frequencies and smaller effective diameters of the opening of the venting channel 2, as can be seen from Fig. 4. Lower frequencies more easily pass without considerable attenuation, clearly indicating the low pass property of the venting channel 2. Fig. 4 shows different curves wherein each curve taken by experiment (measurement) is assigned to a particular effective diameter of the opening of the venting channel 2.

[0085] As it is shown in Fig. 4, the opening of the venting channel 2 in conjunction with the valve member 5 and the enlarged portion 4 of the venting channel 2 can precisely be controlled, so that the desired precise and dynamic control of the opening degree of the venting channel 2 with short response or reaction time is ensured.

[0086] While the present invention has been illustrated and described in detail in the drawings and the foregoing description, such illustrations and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments, and even reference numbers shown in the drawings and referred to in the description and the claims do not limit the scope of the present invention. It is considered that all technical means and equivalent elements or components are included in the present invention and are considered to form part of the scope of the present invention as defined by the appended claims.

Claims

1. A hearing device, including

    a venting channel (2) extending basically in a longitudinal direction (3) in a main body (1) of the hearing device, said venting channel having at least one portion (4) being enlarged in cross sectional area,
    a valve member (5) arranged at said enlarged portion (4) of the main body and being movably supported relative to the venting channel and being operationally connected to a servo device (6) for moving said valve member, and
    a control means (12) for driving said servo device to move said valve member in a predetermined manner, wherein said enlarged portion (4) of said venting channel (2) and said valve member (5) are provided with a predetermined shape so as to obtain a slit, the size of which can be varied when said valve member is moved by said servo device.

2. The hearing device according to claim 1, wherein said predetermined shape of said enlarged portion of said venting channel (2) and said predetermined shape of said valve member (5) are basically conical, and the valve member is movably accommodated in said enlarged portion (4) in said venting channel.

3. The hearing device according to claim 1, wherein said slit (9) defined by said valve member (5) accommodated in said enlarged portion (4) of said venting channel (2) is a ring-shaped slit.

4. The hearing device according to claim 1, wherein said enlarged portion (4) of said venting channel (2) is arranged at one of a first and a second end portion (2a, 2b) of said venting channel (2), or is arranged between said first and second end portions.

5. The hearing device according to claim 1, wherein said servo device (6) includes a linear motor.

6. The hearing device according to claim 1, wherein said servo device (6) is coupled to said valve member (5) by a threaded screw (8), and said servo device being a rotational electric motor rotating said threaded screw for moving said valve member along a longitudinal axis (3) of said venting channel (2).

7. The hearing device according to claim 1, wherein said servo device (6) is a piezo electric motor using piezoelectric elements as active elements for providing the movement of the valve member (5).

8. The hearing device according to claim 1, wherein said servo device (6) includes a piezoelectric actuator according to a smooth impact drive mechanism using piezoelectric elements as active elements for providing the movement of said valve member (5).

9. The hearing device according to claim 1, further comprising a first microphone (13) for detecting the sound pressure impacting on the hearing device from the outside and transmitting a detection signal to said control means (12) for controlling movement of said valve member (5) depending upon the detected sound pressure.

10. The hearing device according to claim 1, further comprising a second microphone (14) for detecting the sound pressure in a user's ear canal and generating a detection signal and transmitting said detection signal to said control means (12) for controlling movement of said valve member (5) depending upon the detected sound pressure.

11. The hearing device according to claim 1, wherein said predetermined shape of said enlarged portion (4) of said venting channel (2) and the predetermined shape of said valve member (5) are basically of an elliptical shape or a spherical shape, and the valve member being movably accommodated in said enlarged portion of said venting channel.

12. The hearing device according to claim 11, wherein the movement of the valve member (5) accommodated in said enlarged portion (4) of said venting channel (2) is controlled by said control means (12) to adjust the dimension of said slit (9) between the valve member and the enlarged portion of the venting channel (2).

13. The hearing device according to claim 1, wherein said predetermined shape of said enlarged portion (4) of said venting channel (2) and the predetermined shape of said valve member (5) are of a non-rotation-symmetric shape and the slit (9) between the valve member and the enlarged portion of the venting channel (2) has a geometrical shape departing from the ring shape.

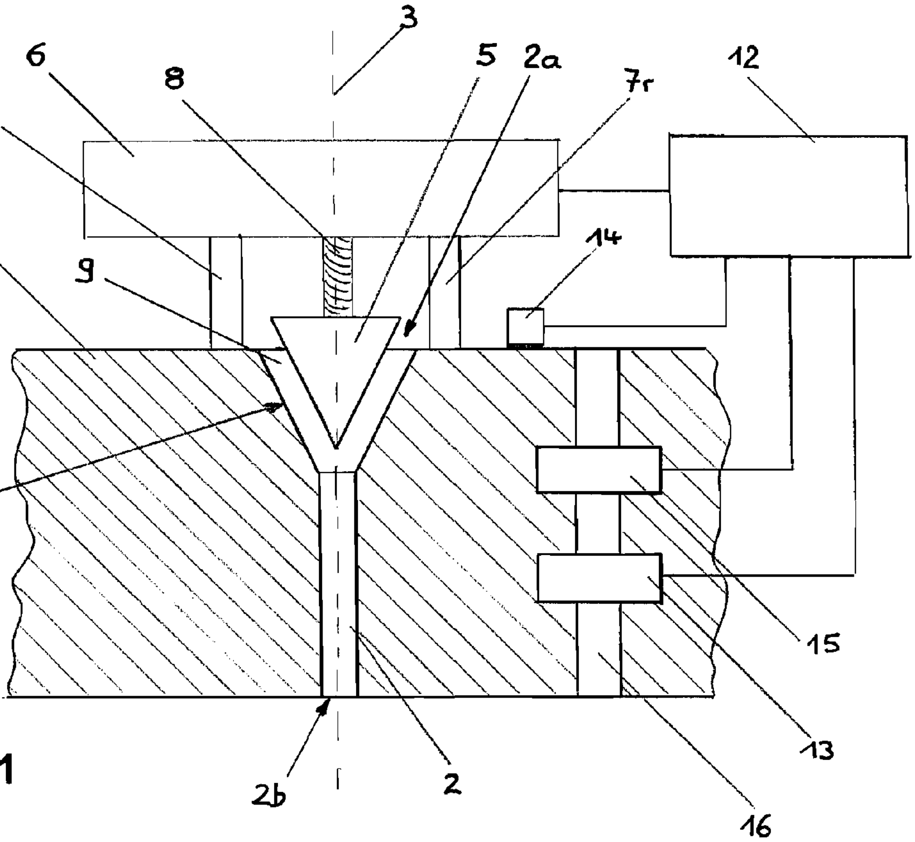


Fig. 1

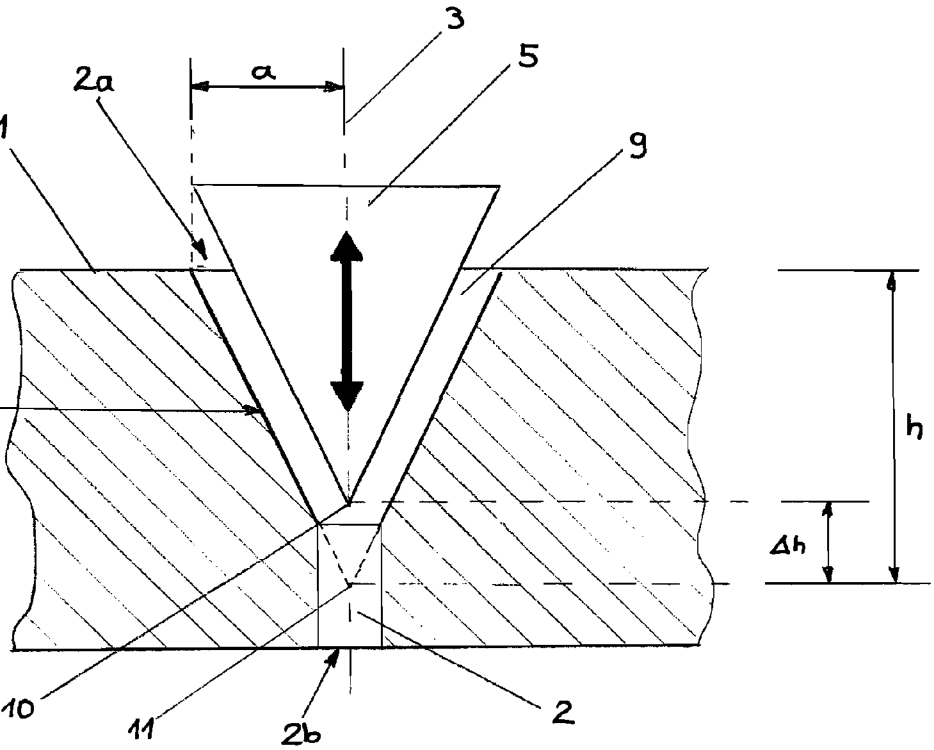


Fig. 2

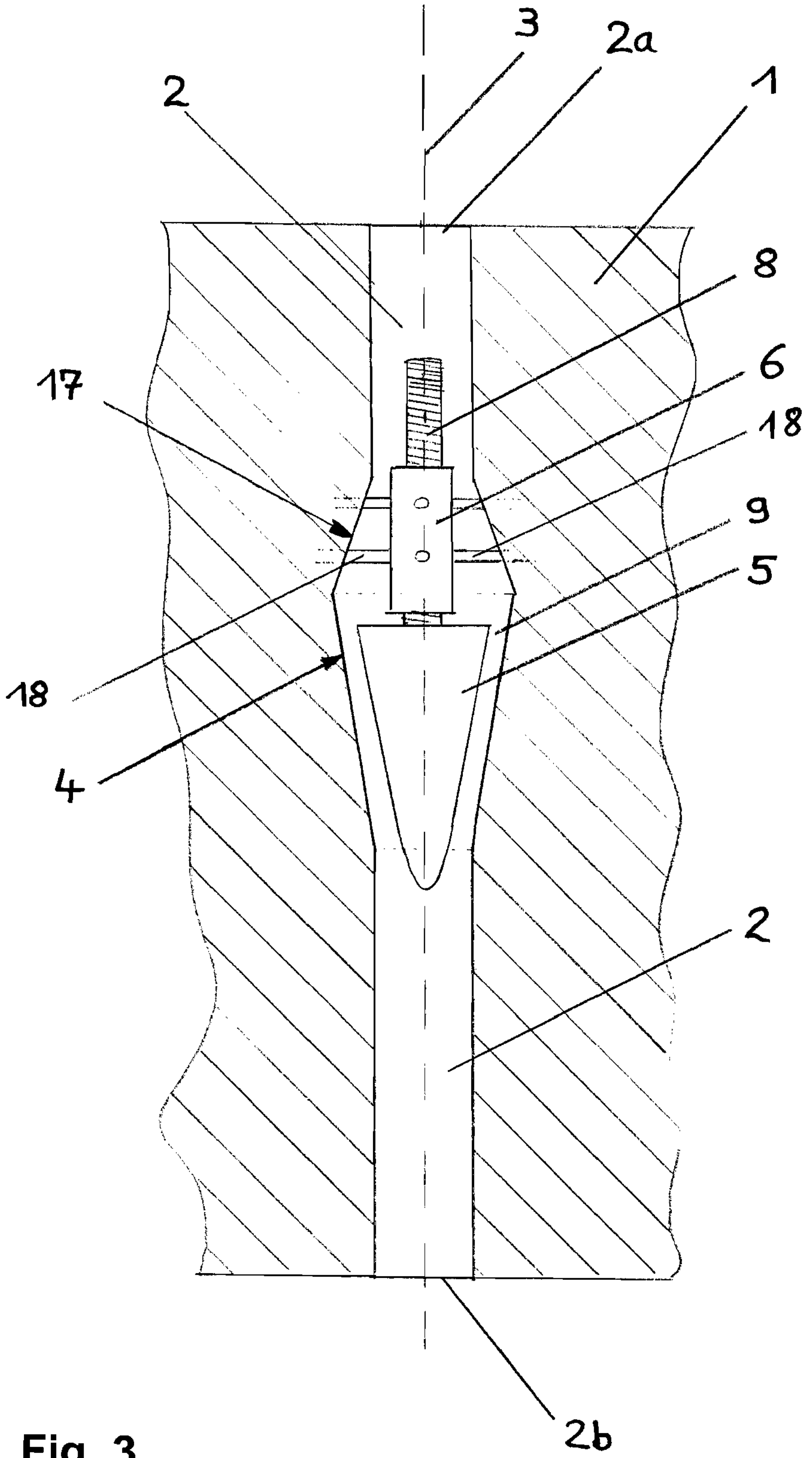
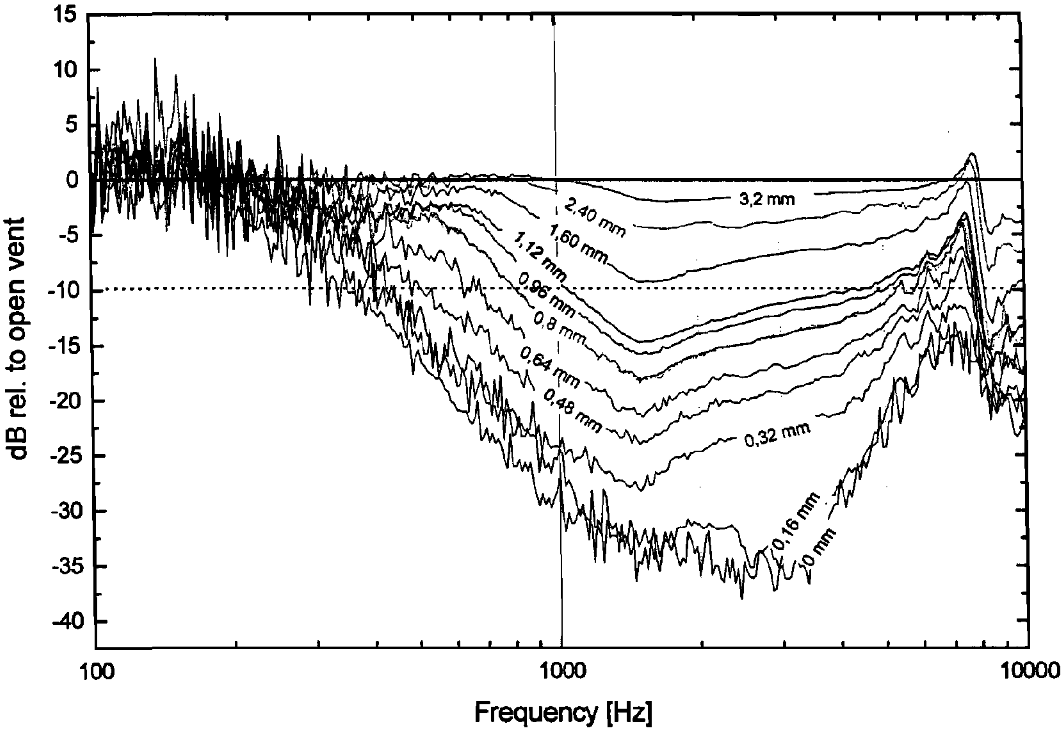


Fig. 3


15
10
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Frequency [Hz]
3,2 mm
2,40 mm
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1,12 mm
0,96 mm
0,8 mm
0,64 mm
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0,32 mm
0,16 mm
0 mm

Fig. 4

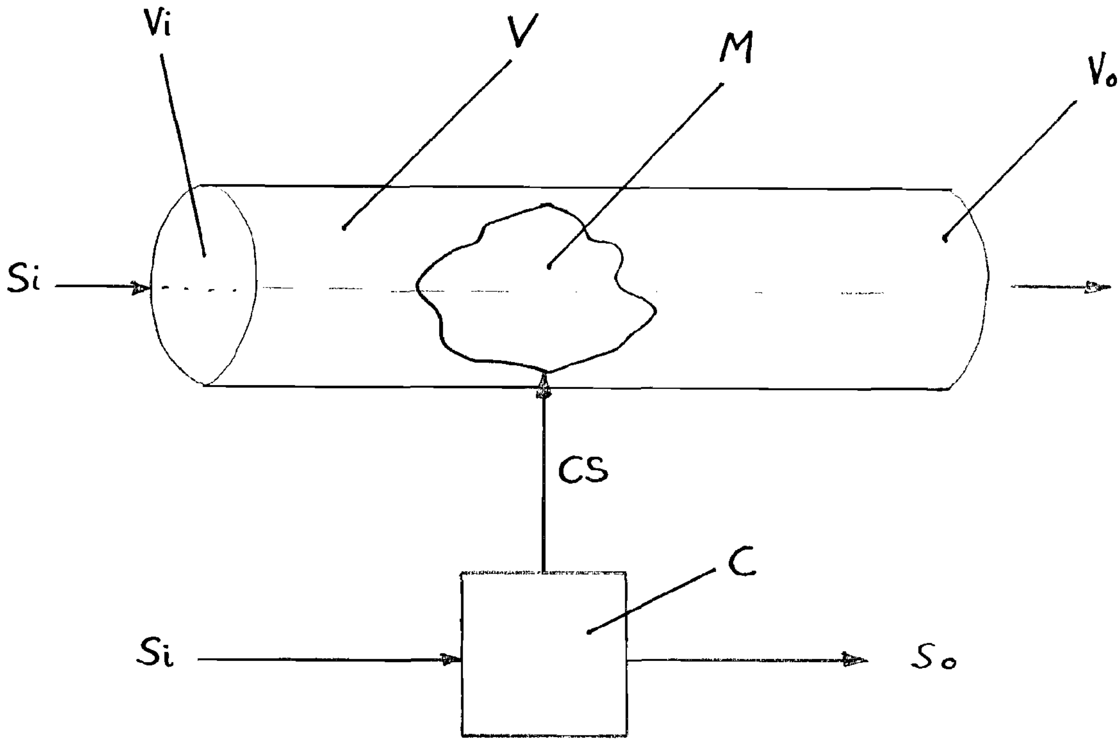
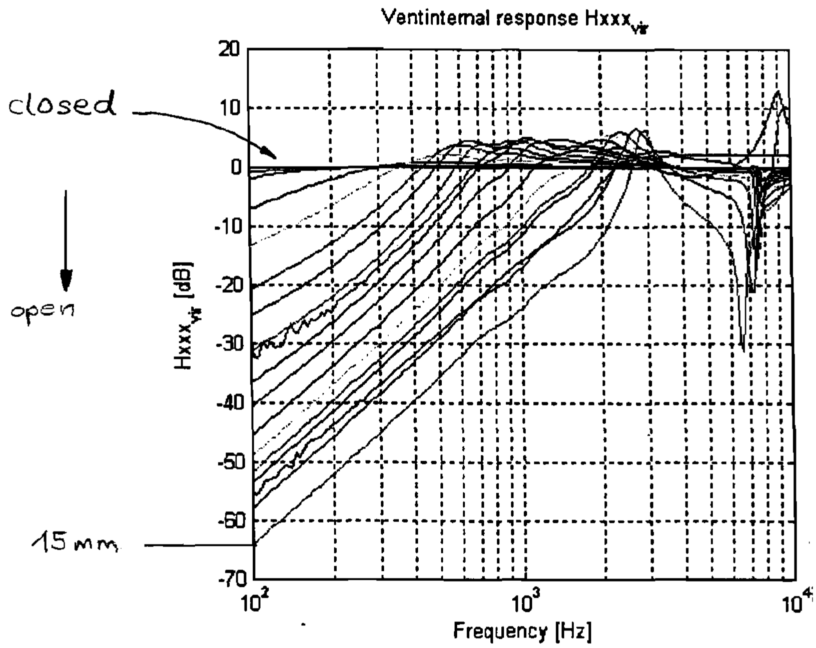


Fig. 5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open
15mm
Hxxx$_{vir}$ [dB]
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10
0
-10
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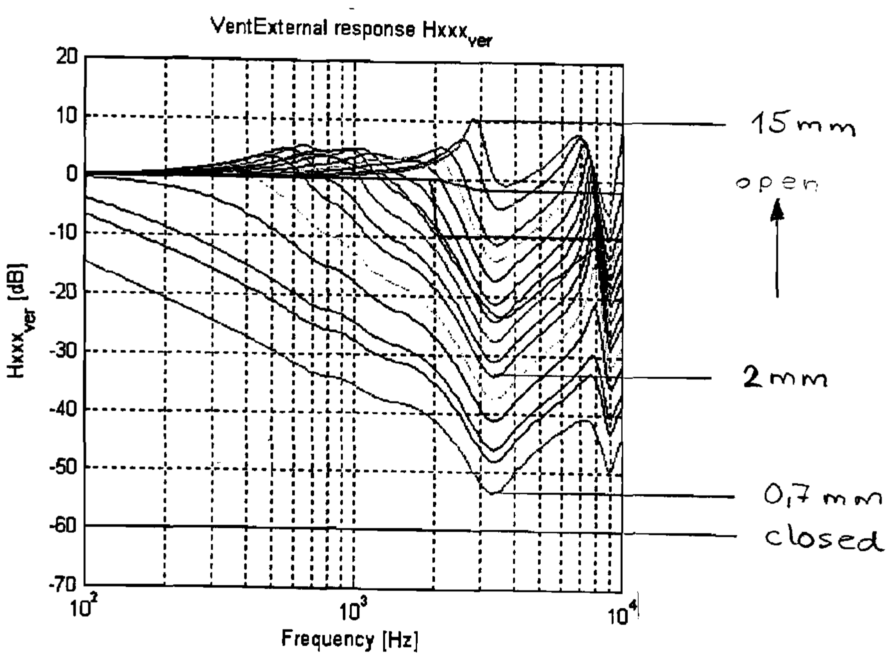
-60
-70
10^2
10^3
10^4
Frequency [Hz]

Fig. 6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Hxxx$_{ver}$ [dB]
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-40
-50
-60
-70
10^2
10^3
10^4
Frequency [Hz]

Fig. 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 12 2121

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 549 635 B1 (GEBERT ANTON [DE]) 15 April 2003 (2003-04-15) * column 1, line 55 - column 4, line 48; claim 1; figures 1,2 * -----	1,4,5, 7-9,12, 13	INV. H04R25/00
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 April 2008	Righetti, Marco

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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4

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 12 2121

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