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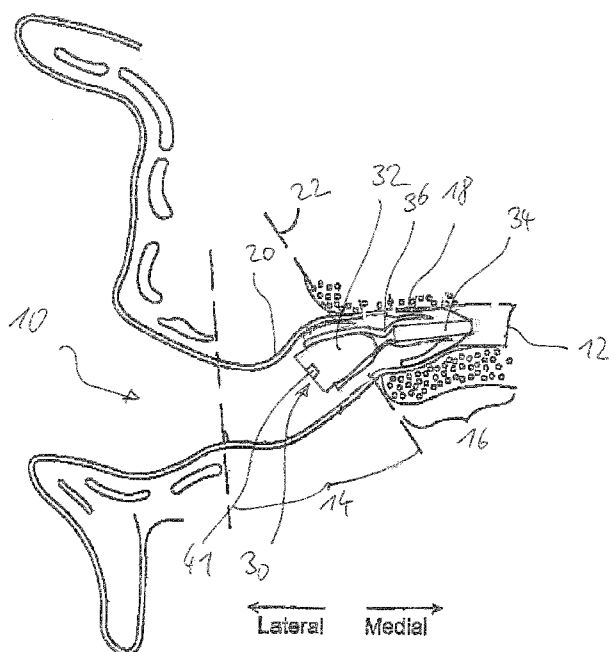


FIG. 1

(57) Abstract: The invention relates to a dynamic hearing protection device to be worn completely in a user's ear canal (10), comprising: a lateral part (32, 36) and a medial part (34, 36) flexibly connected in such a manner that the lateral part and the medial part can bend relative to each other so as to follow the shape of the ear canal, wherein the medial part is to be inserted at least in part into the bony part (16) of the ear canal and comprises an acoustic damping element (70) at its periphery which is adapted to touch the wall (18) of the bony part of the ear canal for attenuating sound impinging on the hearing protection device, wherein the lateral part includes a microphone arrangement (42) including a microphone port (41) for capturing audio signals from ambient sound, wherein the microphone port is to be located at least 1 mm inside the ear canal, wherein the hearing protection device includes a non-replaceable battery (48) and an audio signal processing unit (44) for processing the audio signals captured by the microphone assembly, wherein the medial part includes a loudspeaker (52) for stimulating the user's hearing according to the processed audio signals, and wherein the audio signal processing unit is adapted to provide at least for an attenuation mode in which the gain applied to the audio signals is less than the mechanical acoustic damping provided by the hearing protection device when worn in the ear canal.



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Dynamic hearing protection device and method

The invention relates to a dynamic hearing protection device to be worn in a user's ear canal.

Earplug-type dynamic hearing protection devices comprise some kind of shell to be inserted into the ear canal and providing for mechanical acoustic attenuation of sound impinging on the earplug, a microphone for capturing audio signals from ambient sound, an audio signal processing unit for processing the captured audio signals and a loudspeaker for stimulating the user's hearing according to the processed audio signals. Usually, the shell extends only into the cartilaginous part of the ear canal. Typically, the audio signals are processed in such a manner that at low ambient sound/noise levels the ambient sound is provided more or less unattenuated to the tympanic membrane by selecting the gain applied by the audio signal processing unit accordingly, i.e. the acoustic attenuation provided by the earplug is at least in part compensated by the electronic sound amplification of the device. The earplug may be made of a relatively soft material in order to conform to different sizes of ear canals, or it may be a customized earplug which is manufactured according to the measured shape of the individual's ear canal.

GB 2 373 951 A relates to a customized dynamic hearing protection device shaped as an earplug which is to be partly inserted into the user's ear canal and which is provided with an expanded foam material at its tip.

US 2002/0080979 A1 relates to a dynamic hearing protection earplug having a soft shell which is to be worn at least in part in the ear canal. In addition to the acoustic attenuation provided by the earplug, the audio signal processing unit may be adapted to actively attenuate sound signals according to an active noise suppression algorithm (i.e. by generating "anti-sound", i.e. audio signals which are phase-shifted with regard to the sound impinging on the ear so as to provide for destructive interference between such direct sound and the sound produced by the loudspeaker). For relatively low noise levels the gain is selected such that the earplug is "acoustically transparent", i.e. the attenuation provided by the earplug is electronically compensated.

US 2007/0263891 A1 relates to a dynamic hearing protection device which may be worn as a CIC (completely in the canal) device, wherein the hearing protection function is provided by generating phase-shifted anti-sound. At very high ambient sound levels the output from the device may be totally muted.

- 5 US 3,890,474 relates to a dynamic hearing protection device provided as an earplug which may be inserted completely into the cartilaginous part of the ear canal, wherein the sound level provided by the loudspeaker is limited at high ambient sound levels.

There is a certain type of hearing aids which are worn deeply within the ear canal and extend into the bony part of the ear canal, with the speaker being located very close to the tympanic
10 membrane. Such devices are provided with a flexible structure so that the lateral part and the medial part of the device can bend relative to each other so as to follow the bent shape of the ear canal when being inserted into the ear canal. Further, such hearing aids have a very low power consumption and thus are suitable for extended wear, for example up to several months, within the ear canal without being removed during this time. When the battery is
15 empty, the entire hearing aid is removed from the ear canal and is disposed and replaced by a new device. Examples of such extended wear hearing aids are described in US 6,473,513 B1, US 7,215,789 B2, US 7,298,857 B2 and US 7,580,537 B2.

A hearing aid typically provides for an amplification (i.e. an increased level) of the sound reaching the user's ear, whereas a hearing protection device typically provides for sound
20 attenuation (apart from a transparent mode in which the mechanical acoustic attenuation provided by the shell of the hearing protection device is compensated by the electronically generated sound). US 6,914,994 B1 and US 2006/0002574 A1 relate to extended wear hearing aid which comprise a transparent mode wherein the gain is selected to compensate for the acoustic attenuation provided by the shell of the hearing aid within the ear canal.

25 Typically, known dynamic hearing protection devices extend at least partially out of the ear canal and, as such, may interfere with head gear such as helmets, facial masks, respiratory masks, gas masks or the like, and suffer from a lack of comfort, rendering a prolonged use impossible. Further, with the microphones typically being located in the concha (for ITE (in

the ear) style devices) or even behind the ear (for BTE (behind the ear) style devices), the sound localization capabilities of the user are severely reduced. Typically, such devices are frequently removed from the ear canal and then inserted again for further use; as a result of such frequent removal of the device the devices may be lost or may not be present when
5 needed. Also, the battery has to be changed regularly, and also other maintenance actions are regularly needed, such as cleaning of the transducers or protective elements from ear wax and other contaminants. Moreover, known hearing protection devices involve considerable occlusion effect due to their size and position.

It is an object of the invention to provide for a dynamic hearing protection device having high
10 use comfort and maintaining normal hearing sensation at low noise levels as far as possible. It is also an object to provide for a corresponding hearing protection method.

According to the invention, these objects are achieved by a dynamic hearing protection device as defined in claim 1 and a hearing protection method as defined in claim 27.

The invention is beneficial in that - by providing a hearing device having an “extended wear”
15 design, namely a flexible structure allowing the device to extend into the bony part of the ear canal, with the speaker being located very close to the tympanic membrane, with a dynamic hearing protection function, namely by providing the medial part extending into the bony part of the ear canal with an acoustic damping element and by providing the signal processing unit with an attenuation mode in which the gain applied to the audio signals is less than the
20 acoustic attenuation provided by the attenuation element - a dynamic hearing protection device is provided which allows for being worn permanently within the ear canal, for example for several months, which preserves the sound localization capabilities of the user at least to some extent, which results only in a relatively small occlusion effect, which does not interfere with head gear, and which does not require wax protection on the speaker side (as it is placed
25 beyond the wax glands within the ear canal).

Compared to an “extended wear” hearing aid, a hearing protection device based on the same architecture – due to the relatively low sound output levels necessary for a dynamic hearing protection function as compared to a hearing aid function – may use a smaller speaker which

will result in a significantly enhanced fit rate and autonomy. Also, the battery consumption for a hearing protection mode will typically be lower than for a hearing aid mode, as no or very little acoustic gain is to be provided, which results either in a smaller battery, i.e. in an enhanced fit rate, or in larger autonomy (longer wearing period). Compared to conventional hearing protection devices, the devices according to the invention are particularly well-suited for environments having continuous noise exposure (also at night), since the device can be worn continuously.

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

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

Fig. 1 is a lateral view of a hearing protection device according to the invention when positioned within the ear canal;

Fig. 2 is a lateral view illustrating an embodiment of a hearing protection device according to the invention prior to being inserted into the ear canal; and

Fig. 3 is a block diagram of an example of a hearing protection device according to the invention.

As shown in Fig. 1, the ear canal 10 comprises, in its lateral part (i.e. away from the tympanic membrane 12) a cartilaginous region 14, which is relatively soft due to the underlying cartilaginous tissue and, in its medial (towards the tympanic membrane 12) part a bony region 16, which is relatively rigid due to the underlying bony tissue. The skin 18 in the bony region 16 is relatively thin and more sensitive to touch or pressure than the skin 20 in the cartilaginous region 14. There is a characteristic bend in the ear canal 10, which roughly occurs at the bony-cartilaginous junction 22 separating the regions 14 and 16.

The hearing protection device 30 shown in Figs. 1 and 2 comprises a lateral module 32, a medial module 34 and a flexible joint assembly 36, which connects the medial end 38 of the lateral module 32 and the lateral end 40 of the medial module 34. The lateral module 32

comprises a microphone arrangement 42 for capturing audio signals from ambient sound, an audio signal processing unit 44 for processing the captured audio signals, a power amplifier 46, a battery 48 for supplying power to the electrical components of the lateral module 32 and a housing 50. The medial module 34 comprises a loudspeaker 52 and a housing 54. A wiring 56 extends from the lateral module 32 to the medial module 34 for supplying the processed amplified audio signals from the lateral module 32 to the speaker 52 of the medial module 32.

The flexible joint assembly 36 comprises an elastic sleeve 58 having a lateral portion 64 surrounding at least the medial end 38 of the lateral module 32, a medial portion 66 surrounding the lateral end 40 of the medial module 34, and a pivotal portion 60 enclosing a lumen 62 extending between the medial end 38 of the lateral module 34 and the lateral end 40 of the medial module 34. The lumen 62 includes the electrical wiring 56. The cross-section of the pivotal portion 60 is smaller than in the lateral portion 64 and the medial portion 66.

The lateral module 32 and the medial module 34 are spaced apart by the lumen 62 so as to enable pivoting movement of the medial module 34 relative to the lateral module 32, so that being inserted into the ear canal 10, the hearing protection device 30 can follow the shape of the ear canal 10. In other words, during and after insertion of the hearing protection device 30 into the ear canal 10, the modules 32 and 34 may take an angled position relative to each other.

This can be seen in Fig. 1, where the hearing protection device 30 is shown in its final position in the ear canal 10, wherein the medial module 34 is located at a position in the bony part 16 of the ear canal close to the tympanic membrane 12, while the lateral module 32 is located in part in the cartilaginous region 14 and in part in the bony region 16. When the shape of ear canal 10 in the cartilaginous region 14 changes due to actions like speaking or chewing, the hearing protection device 30 may follow such changes at least to some extent due to the flexibility of the pivotal portion 60 of the joint assembly 36. The flexibility of the pivotal portion 60 with regard to pivoting motion of the modules 32 and 34 relative to each other can be tailored by selecting the material of the sleeve 58, the wall thickness of the sleeve 58, the axial length of the portion 60 and the shape of the sleeve 58 in the pivotal portion 60. In particular, the flexibility may be enhanced by selecting a softer material, by reducing the

wall thickness, by increasing the axial length and/or by introducing corrugations in the pivotal portion 60.

When the hearing protection device 30 has been inserted into the ear canal 10, the microphone port 41 of the microphone 42 is located at least 1 mm inside the ear canal 10.

- 5 Preferably, the sleeve 58 is made of a silicone polymer.

Preferably, the pivotal portion 60 is designed such that the bending forces transmitted via the pivotal portion 60 from the lateral module 32 to the medial module 34 upon deformation of the ear canal 10 are so little that the wearer does not sense pain in the ear canal. Preferably, the transmitted bending forces are below the capillary venous return pressure of the vasculature of the canal epithelium.

More detailed examples of a hearing aid of the type described so far can be found in US 2007/0036379 A1

In the example shown in Figs. 1 and 2, the medial module 34, or more precisely the medial end 66 of the joint assembly 36, is provided with an acoustic damping element 70 which surrounds the periphery of the medial module 34 and which is provided for touching the wall/skin 18 of the bony part 16 of the ear canal 10 for attenuating sound impinging on the hearing protection device 30 when inserted within the ear canal 10. In other words, the damping element 70 serves to acoustically seal the ear canal by providing for a mechanical attenuation of the sound waves reaching the ear canal 10. Preferably, the damping element 70 is designed to provide for an acoustic attenuation of at least 10 dB in the audible frequency range. Preferably, the damping element 70 is made of an elastomeric foam material or of a silicone material. For example, the elastomeric foam material may be a polyurethane, silicone, polyethylene, fluoropolymer or a copolymer thereof. According to the example shown in Figs. 1 and 2, the damping element 70 is formed by a resilient shell having a dome-like/bell-like shape and surrounding at least a portion of the central body of the medial module 34, with the apex portion 72 of the shell being located towards the medial end 54 of the medial module 34. The damping element 70 is adapted to exert elastic forces onto the wall/skin 18 of the bony

part 16 of the ear canal 10. The damping element 70 may include lamella-like and/or ring-like structures.

The damping element 70 may comprise a vent channel 74 for enabling pressure equalization of the ear canal volume between the medial module 34 and the tympanic membrane 12 with the atmosphere outside the ear. The damping element 70 preferably has an in-situ water vapor transmission rate of at least 2.3×10^{-2} g/day kPa (3×10^{-3} g/day mmHg) and an in-situ water vapor permeance of at least 385 g/day m²/kPa (50 g/day m²/mmHg). Preferably, the damping element 70 and the sleeve 58 are provided with an anti-microbial coating including an anti-microbial agent such as a silver-based agent or an antibiotic. Preferably, the damping element 70 is configured such that the spring pressure exerted by the damping element 70 on the walls of the ear canal 10 does not exceed 1.6 kPa (12 mmHg), and preferably is within the range of 0.3 to 0.8 kPa (2 to 6 mmHg).

Examples of suitable configurations of the damping element 70 are described in US 7,580,537 B2.

A schematic block diagram of an example of a hearing protection device according to the invention is shown in Fig. 3, wherein the audio signal processing unit 44 comprises a filter unit 76 and a classifier unit 78. The filter unit 76 serves to apply a certain gain to the audio signals captured by the microphone 42 prior to supplying the audio signals to the amplifier 46. Typically, the audio signals are divided into spectral classes, so that the gain can be applied in a frequency-selective manner in order to achieve a desired transfer function. The classifier unit 78 serves to analyze the audio signals captured by the microphone 42 in order to provide for an auditory scene analysis, and the gain to be applied to the audio signals by the filter unit 76 is selected according to the result of the analysis by the classifier unit 78. Typically, for such analysis the audio signals are divided into spectral classes. Primarily, the classifier unit 78 determines the level of the audio signals (in each spectral class, if the signal is divided into spectral classes), and the gain applied by the filter unit 76 to the audio signals is selected according to the determined audio signal level. Preferably, such level-dependent gain control is based on the lower frequencies (typically below 1kHz) in order to ensure that the hearing protection device worn at the right ear and the hearing protection device worn at the left ear

provide for about the same amplification (due to shadowing effects, the levels of the sound reaching the user's ears will be different between the two ears at higher frequencies).

According to the invention, the audio signal processing unit 44 provides at least for an attenuation mode in which the gain applied to the audio signals by the filter unit 76 is less
5 than the mechanical acoustic damping provided by the hearing protection device 10, in particular by the damping element 70, when worn in the ear canal; i.e. in the attenuation mode the total gain provided by the hearing protection device (i.e. acoustic attenuation plus electronic gain) is negative in order to provide for a hearing protection function. Typically, in the attenuation mode the gain applied to the audio signals is variable, i.e. the higher the level
10 of the captured audio signals is, the lower the gain applied to the audio signals will be.

Preferably, the audio signal processing unit 44 also provides for a transparent mode in which the gain applied to the audio signals equals the mechanical acoustic damping provided by the hearing protection device, i.e. by the damping element 70, when worn in the ear canal 10. The transparent mode is applied when the ambient sound pressure level, i.e. the level of the
15 captured audio signals, is low, i.e. when there is no need for hearing protection, and in the transparent mode a close to natural hearing impression is desired, including localization cues, etc.

The transparent mode will be selected when the analyzed audio signal level is below a given threshold, with the attenuation mode being selected when the determined audio signal level is
20 above that threshold. In the most simple case, such threshold corresponds to a level averaged, respectively integrated, over the entire or part of the audible frequency range (as already mentioned above, in order to ensure that the right ear device and the left ear device provide for the same amplification, such part of the audible frequency range preferably is a low-frequency range, preferably below 1kHz).

25 According to an alternative embodiment, the threshold value may be determined separately for at least some of the spectral classes, with the audio signal processing unit 44 operating in the attenuation mode when the audio signal level in one of the spectral classes is found to be above the respective threshold value.

Examples of audio signal processing modes in a dynamic hearing protection system are described, for example, in EP 1 674 061 A1.

The hearing protection device 30 may comprise a switching unit 80 acting on the audio signal processing unit 44 and serving as an interface to an external remote control 82, with the
5 switching unit 80 being operated in a contactless manner by the remote control 82. For example, the switching unit 80 may comprise at least one magnetic switch to be operated by a magnet of the remote control 82. The switching unit 80 can be used for switching between different operation modes of the hearing protection device 30, for example to actuate a volume control or to switch the device off, with the device then acting as a passive hearing
10 protector.

According to one embodiment, the signal processing circuits are provided as analog circuits, thereby achieving low delay signal processing and low power consumption.

According to an alternative embodiment, the audio signal processing unit 44 comprises an active noise reduction unit 84 for creating anti-sound audio signals which are phase-shifted
15 with regard to the audio signals captured by the microphone 42 and which are supplied as input to the amplifier 46 and the loudspeaker 52 in order to achieve destructive interference with sound leaking through the damping element 70. Such active noise reduction is particularly helpful for being used for a hearing protection device comprising a vent channel, such as the vent channel 74 of Fig. 2, for pressure equalization with the atmosphere, since
20 low-frequency sound leaking through the vent channel then can be easily removed by corresponding active noise reduction via the active noise reduction unit 84. Typically, such active noise reduction will be applied to frequencies below 1kHz. Thus enhanced wearing comfort due to the venting provided by the vent channel is enabled, thereby reducing occlusion effects, while still sufficient noise attenuation may be provided at all audible
25 frequencies.

In order to extend the wearing time of the hearing protection device 30, the battery 48 may be rechargeable, typically via an inductive power link, from an external device.

Optionally, the hearing protection device 30 may comprise a wireless interface 86 comprising an antenna 88 and a transceiver 90 for wireless communication with a body-worn communication device, such as a wireless audio signal receiver (and/or transmission) device or a remote control. The wireless interface 86 may serve for remote control purposes and/or
5 for receiving audio signals from an external source and/or for transmitting audio signals captured by the microphone 42 and an optional second microphone 92 to an external device. Such second microphone 92 may be provided as an acoustically inwardly oriented, i.e. facing the tympanic membrane 12, microphone for picking up the voice of the user of the hearing protection device 30.

- 10 In all embodiments, the vent channel 74 of the damping element 70 may be omitted in order to achieve an essentially complete acoustic sealing.

The present invention provides for the following benefits:

- Due to the location of the device deeply within the ear canal, high noise attenuation can be achieved without the need for a individually shaped shell; rather, the shape of the hearing
15 protection device may be generic. Further, high wearing comfort is achieved, since nothing which could interfere with head gear stands out of the ears. The microphone is relatively close to the tympanic membrane and inside the ear canal, so that excellent localization both with regard to horizontal and elevation directions can be achieved. Compatibility with standard headphones, both of the circumaural as well as the intra-aural type is achieved. The
20 arrangement deep in the ear canal enables enhanced robustness to environmental conditions. Due to the acoustic sealing deeply inside the ear canal no or only very little occlusion effect is present. No wax protection is required on the speaker side since it is placed beyond the wax glands within the ear canal. Since the speaker is close to the tympanic membrane, with the residual volume between the acoustic sealing and the tympanic membrane being very small,
25 large audio bandwidth can be obtained. Since the device is designed for being continuously worn, continuous noise protection, even during night, is provided. Also impulse noise attenuation is provided.

Claims

1. A dynamic hearing protection device to be worn completely in a user's ear canal (10), comprising: a lateral part (32, 36) and a medial part (34, 36) flexibly connected in such a manner that the lateral part and the medial part can bend relative to each other so as to follow the shape of the ear canal, wherein the medial part is to be inserted at least in part into the bony part (16) of the ear canal and comprises an acoustic damping element (70) at its periphery which is adapted to touch the wall (18) of the bony part of the ear canal for attenuating sound impinging on the hearing protection device, wherein the lateral part includes a microphone arrangement (42) including a microphone port (41) for capturing audio signals from ambient sound, wherein the microphone port is to be located at least 1 mm inside the ear canal, wherein the hearing protection device includes a non-replaceable battery (48) and an audio signal processing unit (44) for processing the audio signals captured by the microphone assembly, wherein the medial part includes a loudspeaker (52) for stimulating the user's hearing according to the processed audio signals, and wherein the audio signal processing unit is adapted to provide at least for an attenuation mode in which the gain applied to the audio signals is less than the mechanical acoustic damping provided by the hearing protection device when worn in the ear canal.
2. The device of claim 1, wherein the lateral part comprises a lateral module (32) and the medial part comprises a medial module (34), which modules are connected by an elastic connection assembly (36).
3. The device of one of claims 1 and 2, wherein the acoustic damping element (70) is adapted to provide for acoustic attenuation of at least 10dB in the audible frequency range.
4. The device of one of the preceding claims, wherein the acoustic damping element (70) is made of an elastomeric foam material or of a silicone material.
5. The device of claim 4, wherein the elastomeric foam material is selected from the group consisting of polyurethanes, silicones, polyethylenes, fluoropolymers, and copolymers thereof.

6. The device of one of the preceding claims, wherein the acoustic damping element (70) includes lamella-like and/or ring-like structures.
7. The device of one of the preceding claims, wherein the acoustic damping element (70) includes a resilient shell having a dome-like / bell-like shape and surrounding at least a portion of a central body of the medial part, with the apex portion (72) of the shell being located towards the medial end of the medial part, and wherein the shell is adapted to exert elastic forces onto the wall (18) of the bony part (16) of the ear canal when having been inserted in the ear canal (10).
8. The device of one of the preceding claims, wherein the acoustic damping element (70) comprises a vent channel (74) for enabling pressure equalization of the ear canal volume between the medial part (34, 36) and the tympanic membrane (12) with the atmosphere.
9. The device of one of the preceding claims, wherein the audio signal processing unit (44) comprises a classifier unit (78) for analysing the audio signals as captured by the microphone assembly (42) and wherein the audio signal processing unit is adapted to select the gain applied to the audio signals is selected according to the result of an analysis by the classifier unit.
10. The device of claim 9, wherein the classifier unit (78) is adapted to determine a level of the audio signals, with the gain applied to the audio signals being selected according to that audio signal level.
11. The device of claim 10, wherein the audio signal processing unit (44) is adapted to select the gain applied to the audio signals according the level of the signals at frequencies below 1kHz.
12. The device of one of claims 9 to 11, wherein the audio signal processing unit (44) is adapted to provide a transparent mode in which the gain applied to the audio signals equals the mechanical acoustic damping provided by the hearing protection device (30) when worn in the ear canal (10).
13. The device of claim 12, wherein the audio signal processing unit (44) is adapted to operate in the transparent mode when the audio signal level is below a given threshold

and to operate in the attenuation mode when the audio signal level is above said threshold.

14. The device of claim 13, wherein the threshold corresponds to a level averaged over an audible frequency range.
15. The device of claim 13, wherein audio signal processing unit (44) is adapted to divide the audio signals into spectral classes for analysis of the audio signals by the classifier unit (34).
16. The device of claim 15, wherein the threshold includes separate values for at least some of the spectral classes, with the audio signal processing unit (44) operating in the attenuation mode when the audio signal level in one of spectral classes is above the respective threshold value.
17. The device of one of the preceding claims, wherein the audio signal processing unit (44) is implemented by analog circuitry.
18. The device of one of the preceding claims, wherein the audio signal processing unit (44) comprises an active noise reduction unit (84) for creating anti-sound audio signals which are phase-shifted with regard to the audio signals captured by the microphone assembly (42) and which are supplied as input to the loudspeaker (52).
19. The device of claim 18, wherein the anti-sound audio signals are created only for frequencies below 1kHz.
20. The device of one of the preceding claims, wherein the battery (48) is rechargeable.
21. The device of one of the preceding claims, further comprising a wireless interface (86) to a body worn communication device.
22. The device of claim 21, wherein the wireless interface (86) is an inductive interface.
23. The device of one of the preceding claims, further comprising switching means (80) to be operated in a contact-less manner by the user when the hearing protection device has been inserted into the ear canal (10).
24. The device of claim 23, wherein the switching means (80) comprise at least one magnetic switch to be operated by an external magnet (82).

25. The device of one of claims 23 and 24, wherein the switching means (80) are provided for switching between different operation modes of the hearing protection device (30), such as a manual volume control mode.
26. The device of one of the preceding claims, further comprising, in addition to the microphone assembly (42), a microphone (92) which is acoustically inwardly oriented towards the tympanic membrane (12) for picking-up the voice of the user.
27. A method of providing dynamic hearing protection to a user, comprising:
- inserting a hearing protection device (30) into the user's ear canal (10), the hearing protection device comprising a non-replaceable battery (48), a lateral part (32, 36) and a medial part (34, 36) flexibly connected in such a manner that the lateral part and the medial part can bend relative to each other so as to follow the shape of the ear canal, wherein the medial part is inserted at least in part into the bony part (16) of the ear canal and comprises an acoustic damping element (70) at its periphery which touches the wall (18) of the bony part of the ear canal which attenuates sound impinging on the hearing protection device, wherein the lateral part includes a microphone arrangement (42) including a microphone port (41) for capturing audio signals from ambient sound, wherein the microphone port is located at least 1 mm inside the ear canal;
- capturing audio signals from ambient sound by a microphone arrangement of the hearing protection device;
- processing the captured audio signals, wherein, in an attenuation mode, the gain applied to the audio signals is less than the mechanical acoustic damping provided by the hearing protection device when worn in the ear canal; and
- stimulating the user's hearing via a loudspeaker (52) provided in the medial part of the hearing protection device according to the processed audio signals.

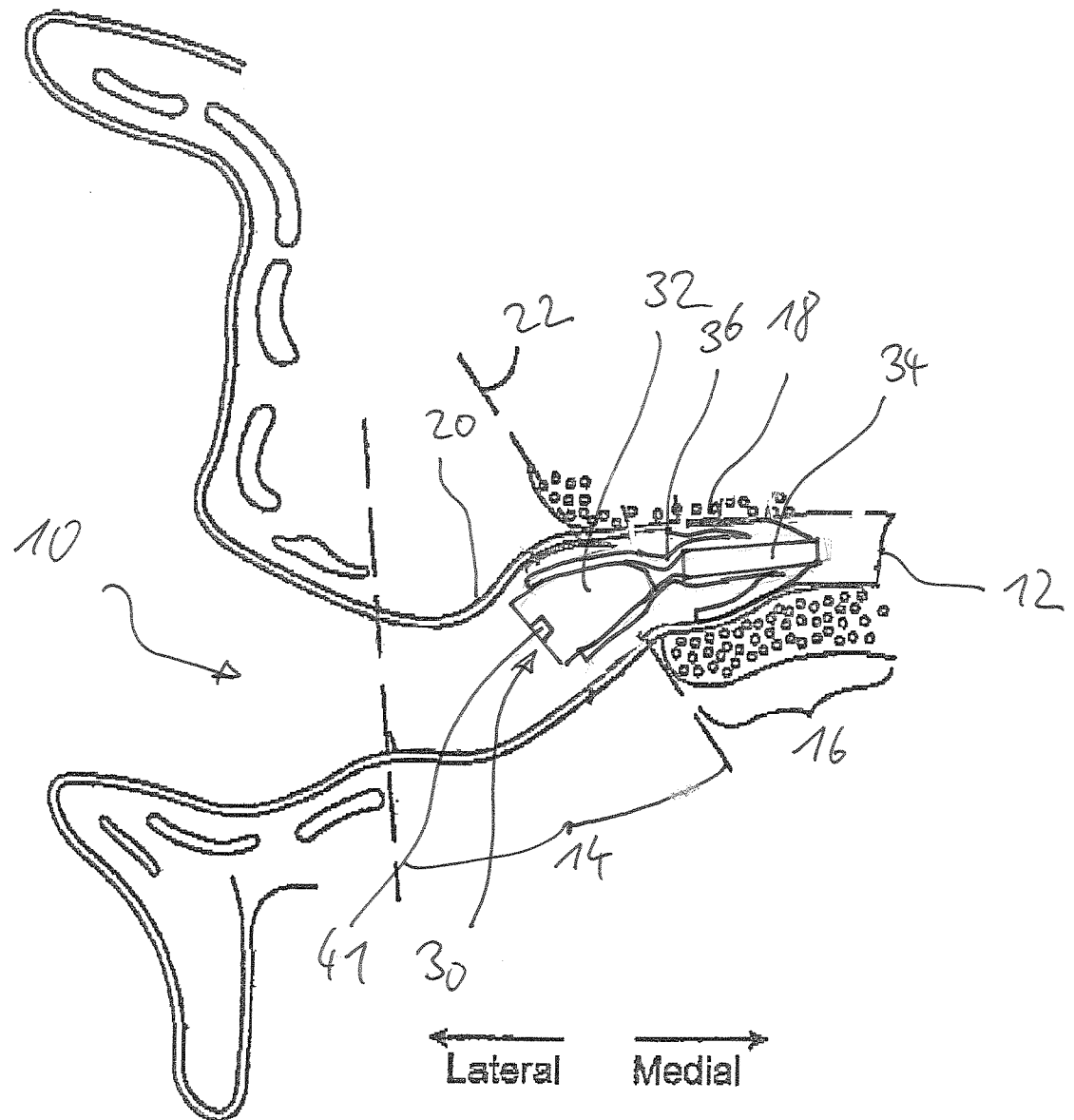


FIG. 1

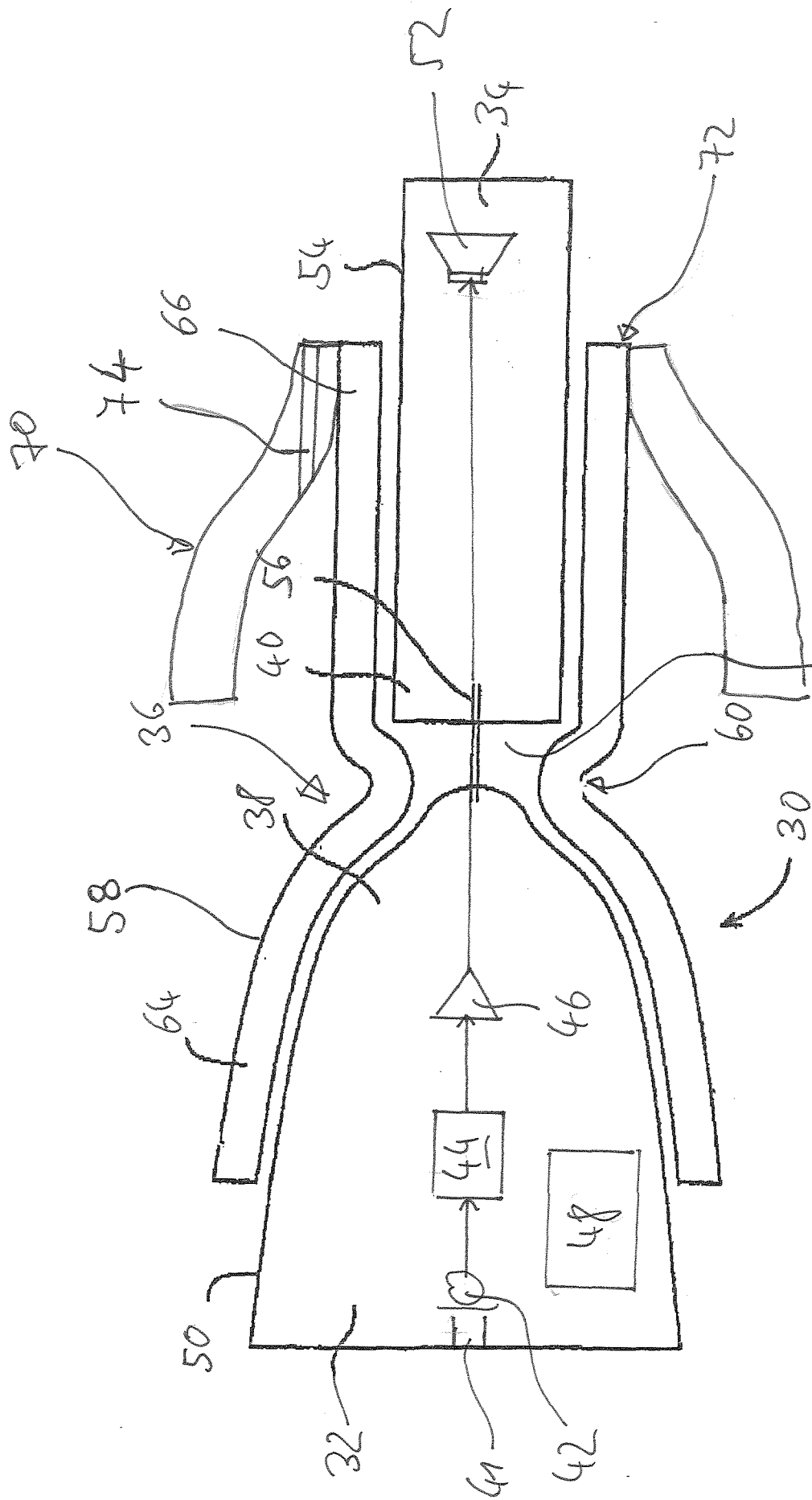


FIG. 2

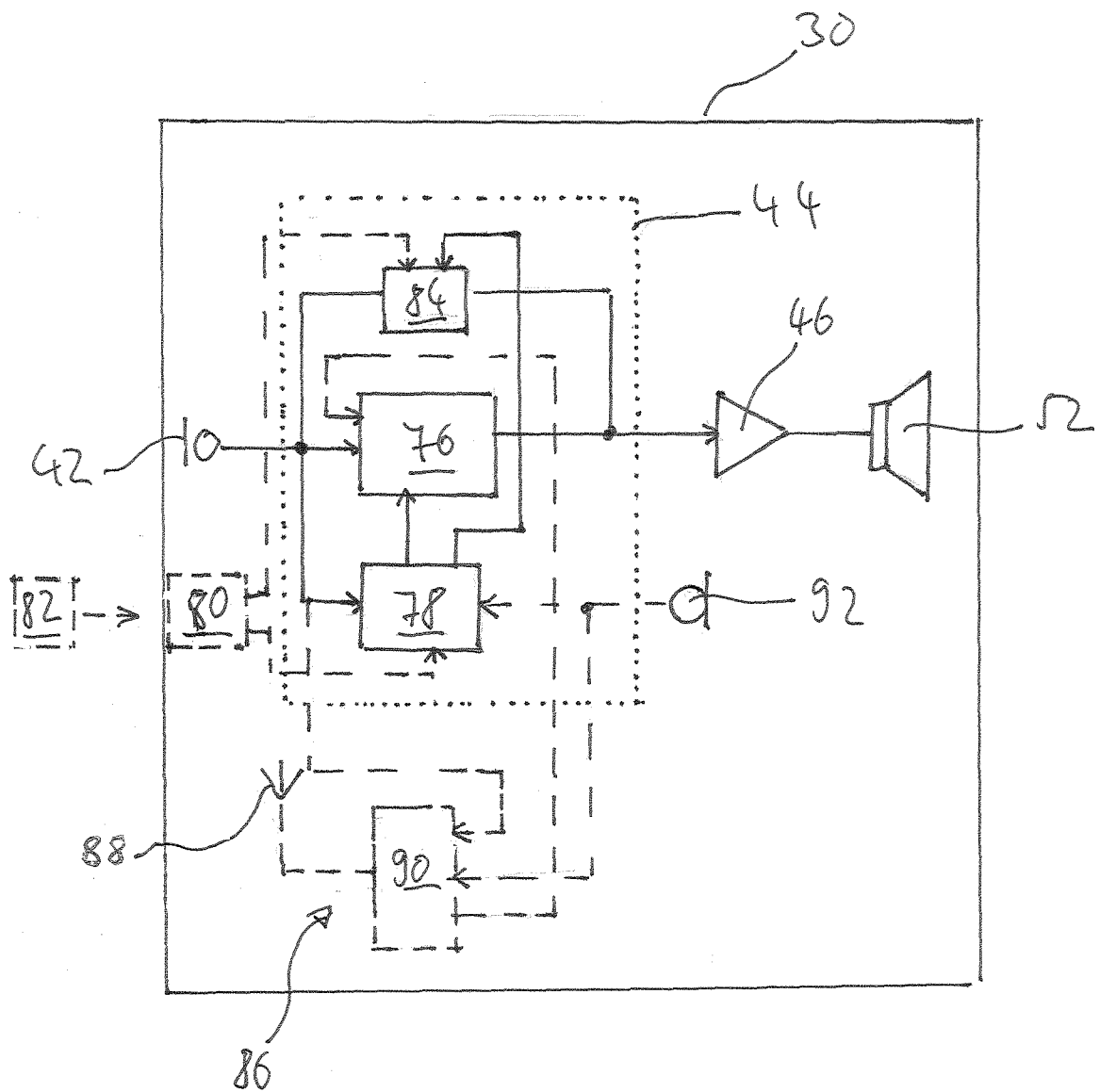


Fig. 3