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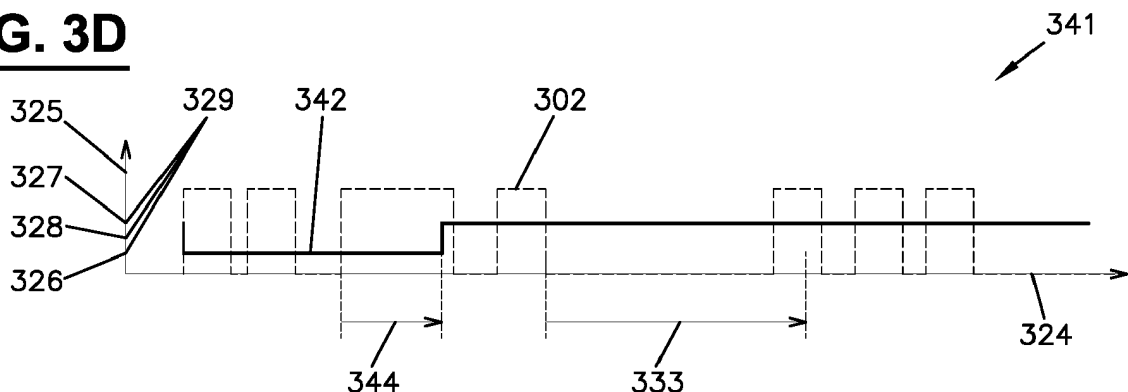
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(54) **METHOD OF OPERATING A HEARING DEVICE AND HEARING DEVICE COMPRISING AN ACTIVE VENT**

(57) The disclosure relates to a method of operating a hearing device configured to be at least partially worn inside an ear canal of a wearer, the hearing device comprising a venting passage (435) configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside the ear canal, wherein the method comprises providing a detection signal (302) comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from said ambient environment, and adjusting an effective size of the venting passage

(435) depending on the detection signal (302). The disclosure also relates to a computer-readable medium for storing instructions of the method, and a hearing device.

To allow an adjustment of the venting passage in a way in which a presumable impact on psychoacoustic effects is accounted for, the disclosure proposes determining an elapsed time during which the detection signal (302) satisfies a signal criterion, and adjusting the effective size of the venting passage (435) if the elapsed time exceeds a minimum duration (333, 344).

FIG. 3D**EP 3 627 848 A1**

Description

TECHNICAL FIELD

[0001] This disclosure relates to a method of operating a hearing device comprising an active vent, according to the preamble of claim 1. The invention also relates to a computer-readable medium for storing instructions of the method, according to claim 14. The invention further relates to a hearing device according to the preamble of claim 15.

BACKGROUND OF INVENTION

[0002] Hearing devices may be used to improve the hearing capability or communication capability of a user, for instance by compensating a hearing loss of a hearing-impaired user, in which case the hearing device is commonly referred to as a hearing instrument such as a hearing aid, or hearing prosthesis. A hearing device may also be used to produce a sound in a user's ear canal. Sound may be communicated by a wire or wirelessly to a hearing device, which may reproduce the sound in the user's ear canal. For example, earpieces such as earbuds, earphones or the like may be used to generate sound in a person's ear canal. Furthermore, hearing devices may be employed as hearing protection devices that suppress or at least substantially attenuate loud sounds and noises that could harm or even damage the user's sense of hearing.

[0003] When a hearing device is inserted at least partially into an ear canal, it may form an acoustical seal with an ear wall such that it blocks the ear canal so that an inner region of the ear canal between the earpiece and the eardrum is acoustically insulated from the ambient environment outside the ear canal to some extent. The acoustical seal between the hearing device and the ear canal can prevent sound waves, such as ambient sound, passing from an outer region of the ear canal lateral to the earpiece into the sealed inner region of the ear canal medial to the earpiece. Isolation provided by hearing devices may be desirable because it can prevent interference of ambient sound with the acoustic output of the hearing device. However, because ambient sound may be blocked from the eardrum, it may prevent a user of the hearing device from directly hearing external sounds such as someone trying to communicate with the user. In addition, sealing the ear canal can also create an occlusion effect in the ear canal, whereby the hearing device wearer may perceive "hollow" or "booming" echo-like sounds. The occlusion effect can be caused by bone-conducted sound vibrations reverberating in the sealed inner region of the ear canal, so that speaking, chewing, body movement, heart beat or the like may create echoes or reverberations in the inner region. Occlusion can occur when an atmospheric connection between the inner region of the ear canal and the ambient environment outside the ear canal is strongly reduced or cut off such that

no pressure equalisation in between the isolated regions can take place. Compared to a completely open ear canal, the occlusion effect can boost low frequency sound pressure in the ear canal by 20 decibels (dB) or more resulting in an undesirable loud perception of low frequencies, in particular below 500 Hertz (Hz).

[0004] A vent may be included in the hearing device comprising a venting passage extending at least partially through the hearing device. The venting passage may provide an atmospheric connection between the inner region of the ear canal and the ambient environment outside the ear canal. For instance, the venting passage may be provided as an air channel allowing a pressure compensation between the regions. In this way, the occlusion effect can be mitigated or circumvented by the pressure compensation between the inner region of the ear canal and the ambient environment outside the ear canal. Venting through the hearing device may also be desirable as it can be used to manage the humidity in the inner region of the ear canal. Humidity in the inner region may result in changed properties of the eardrum and the ear canal wall. These changes in property may result in a deteriorated hearing experience for the wearer of the earpiece. The venting passage may also provide an acoustic pathway for sound waves between the ambient environment outside the ear canal and the inner region of the ear canal. In this way, an ambient sound may be perceivable by the wearer of the hearing device, for instance in addition to a sound transported through a sound conduit of the hearing device from a sound source to the inner region of the ear canal. An undesired ambient sound, however, may not be blocked by the vent and can also reach the eardrum at the inner region of the ear canal.

[0005] An active vent may be employed in the hearing device allowing an adjustment of the venting passage. The adjustment may be activated by an acoustic valve configured to adjust an effective size of the venting passage. The adjustment may provide for enlarging or reducing of the effective size of the venting passage, in particular such that the venting passage is fully open, partially open, partially closed, or fully closed. When the venting passage is not fully closed, ambient sound may enter the ear canal. In such a case, both sound transmitted from a sound source through a sound tube of the hearing device and the ambient sound can be heard by the wearer, which may provide the user with a more natural hearing experience. In addition, the occlusion effect can be reduced, as a pressure equalisation can be provided through the venting passage and sound generated in the ear canal can be transmitted to the ambient environment. When the valve is closed, the wearer may be enabled to listen to the sounds generated by the sound source without interference from ambient sounds. In instances where the hearing device includes signal processing to provide the wearer with improved directionality, for instance by beamforming where the hearing device obtains input from more than one microphone,

the benefit of such signal processing and thus hearing performance may be improved due to the absence of sound from the ambient environment.

[0006] Patent application publication No. US 2017/0208382 A1 describes an in-ear speaker including an active vent comprising a venting passage extending through an aperture formed in a membrane and an acoustic valve comprising a coil in a magnetic field. The membrane is arranged inside an inner volume of the in-ear speaker. The aperture can be switched by the acoustic valve in between an open state and a closed state by which an effective size of the venting passage can be adjusted. Patent application publication no. EP 2 164 277 A2 discloses an earphone device comprising an active vent with vent openings in a sound tube and a leaf valve. The leaf valve comprises two conductive layers and an electroactive polymer layer. The leaf valve is provided around the vent openings such that an effective size of the venting passage can be adjusted by providing a current to the conductive layers. Patent application publication No. EP 2 536 167 A1 discloses an in-ear headphone in which an effective size of a venting passage can be enlarged or reduced by an acoustic valve positioned inside the venting passage. The acoustic valve comprises an electro-strictive material allowing a variable adjustment of the effective size of the venting passage by providing a current to the electro-strictive material. United States Patent No. US 6,549,635 B1 describes a hearing aid with an active vent comprising a venting passage adjustable in cross-section by an acoustic valve comprising a movable element provided at the cross section. The acoustic valve further comprises miniature electrical drives for displacing the movable element to either enlarge or reduce the effective size of the venting passage in cross section. The effective size of the venting passage of those hearing devices, however, can only be adjusted after the acoustic valve has received a control command from the user. A situation dependent venting adjustment without the requirement of a user interaction is not provided for.

[0007] The occlusion effect may be particularly disturbing in situations in which the wearer of the hearing device speaks and the sound of his/her own voice is perceived as unnaturally loud and/or distorted because of occlusion. Own voice detection can be applied in a hearing device to modify the perceived own voice sound in order to mitigate the occlusion effect. Various solutions for own voice detection have been proposed. Some solutions rely on a signal analysis of a sound signal detected by a microphone outside the ear canal. European Patent No. EP 2 242 289 B1 discloses two microphones arranged at different locations of the ear and an adaptive filter to process a difference signal of the signals obtained by the two microphones, wherein the presence of the wearer's own voice is determined by a comparison of the difference signal with the signal obtained by one of the microphones. Patent Application Publication No. EP 3 005 731 B1 proposes a comparison of a direct signal obtained from a

microphone with a recorded signal in order to identify the presence of an own voice sound. Other solutions are based on picking up the user's voice transmitted via bone conduction at the ear canal wall. For instance, a bone conductive microphone or a pressure sensor, as disclosed in European Patent No. EP 2 699 021 B1, may be employed to probe the bone conducted signal. In those solutions, a rather processing intensive analysis of a sound signal recorded outside the ear canal may be avoided, but the reliability of own voice detection may be compromised by the requirement of providing a good contact of the probe to the irregular shape of an ear canal wall.

[0008] The sound amplification in a hearing device may be attenuated when the own voice of the wearer is detected. Patent application publication No. WO 2010/140087 A1 discloses an earphone arrangement comprising an acoustic channel and an acoustic valve configured to control an attenuation of the acoustic channel. The acoustic valve can be controlled based on a speech detection from a microphone. Such an adjustment of the effective size of the venting passage occurring at any detection of the wearer's own voice, however, can be perceived as unfavourable by the wearer, for instance because the adjustment of the venting passage can be accompanied by adverse audible side effects such as switching noises, a sudden variation of the perceived sound level and/or signal to noise ratio, and an overall change of the sound perception.

SUMMARY

[0009] It is an object of the present disclosure to avoid at least one of the above mentioned disadvantages and to allow an automated control of the adjustment of the effective size of the venting passage, in particular such that varying preferences for the effective size in different hearing situations can be accounted for. It is another object to provide a controlled adjustment of the venting passage in which disturbances of the wearer's hearing can be ameliorated, in particular in which adverse side effects related to the venting adjustment can be restricted and/or minimized and/or avoided. It is a further object to control the venting adjustment in a way in which a presumable impact on psychoacoustic effects is accounted for, in particular such that psychoacoustic effects can be optimized for different hearing situations. It is another further object to allow a masking of acoustical artifacts caused by a venting adjustment, in particular to employ such a masking for an improved psychoacoustic perception in different hearing situations. It is a further object to reduce and/or suppress occlusion effects caused from a sealing of an ear canal region during wearing of the hearing device, in particular by taking into account different hearing situations in which a varying occlusion may occur. It is another object to allow an automated control of ambient sound entering the ear canal or to be blocked from the ear canal, in particular to provide for a varying transmis-

sion rate of ambient sound to the ear canal customized to different hearing situations.

[0010] At least one of these objects can be achieved in a method of operating a hearing device comprising the features of patent claim 1 and/or by a computer-readable medium comprising the features of patent claim 14 and/or by a hearing device comprising the features of patent claim 15. Advantageous embodiments of the invention are defined by the dependent claims.

[0011] The present disclosure proposes a method of operating a hearing device configured to be at least partially worn inside an ear canal of a wearer. The hearing device comprises a venting passage, wherein the venting passage is configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside the ear canal. The method comprises providing a detection signal comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from the ambient environment, and adjusting an effective size of the venting passage depending on the detection signal. The adjusting the effective size of the venting passage depending on the detection signal comprises determining an elapsed time during which the detection signal satisfies a signal criterion, and adjusting the effective size of the venting passage if the elapsed time exceeds a minimum duration.

[0012] The adjusting the effective size of the venting passage can thus be restricted to events in which the detection signal satisfies the signal criterion for an elapsed time exceeding the minimum duration, in particular such that an unfavourable and/or too frequent venting adjustment for an elapsed time shorter than the minimum duration can be avoided. A frequent venting adjustment, however, can also be desired in some hearing situations, for instance to avoid or reduce occlusion effects. The minimum duration can be provided such that the frequency of the venting adjustment balances positive and adverse effects of the venting adjustment in different hearing situations. In this way, psychoacoustic effects can be accounted for by matching the adjusting of the venting passage depending on said minimum duration to those hearing situations for which an improved sound perception for the wearer can be presumed or expected by the adjusting. Those hearing situations may include situations in which audible side effects of said adjusting, such as noises occurring during the adjusting and/or an altered sound perception during and/or after the adjusting, can be presumed to have a lesser negative influence on the psychoacoustic perception than an unaltered maintenance of a current effective size of the venting passage.

[0013] The disclosure further relates to a computer-readable medium, in particular a non-transitory computer-readable medium. The computer-readable medium is storing instructions that when executed by a processor cause a hearing device to perform operations of the method of operating the hearing device.

[0014] The disclosure also relates to a hearing device configured to be at least partially worn inside an ear canal of a wearer. The hearing device comprises a venting passage, an acoustic valve, a detection unit, and a processor. The venting passage is configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside the ear canal. The acoustic valve is configured to adjust an effective size of the venting passage. The detection unit is configured to provide a detection signal comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from the ambient environment. The processor is configured to process the detection signal and to provide a control signal to the acoustic valve. The processor is configured to determine an elapsed time during which the detection signal satisfies a signal criterion, and to provide the control signal to adjust the effective size of the venting passage if the elapsed time exceeds a minimum duration. Features regarding some implementations of the hearing device, in particular as further detailed in the subsequent description, may be correspondingly applied in some implementation of the method for operating a hearing device and/or the computer readable medium. Aspects regarding some implementations of the method for operating a hearing device, in particular as further detailed in the subsequent description, may be correspondingly applied in some implementations of the hearing device and/or the computer readable medium.

[0015] In some implementations, the venting passage extends at least partially through the hearing device. In some implementations, the venting passage extends at least partially through a part of the hearing device configured to be worn inside an ear canal of a wearer. In some implementations, the hearing device comprises an earpiece configured to be worn inside the ear canal and/or a receiver configured to be worn inside the ear canal and/or a sound tube, in particular in acoustic communication with a receiver, configured to be worn inside the ear canal. In some instances, the hearing device can be provided as an earphone, earplug, earbud, or the like. In some implementations, the hearing device can be provided as a hearing instrument, for instance a receiver-in-the-canal (RIC) hearing aid or a behind-the-ear (BTE) hearing aid or an in-the-ear (ITE) hearing aid.

[0016] In some implementations, the method comprises determining an own voice level from the detection signal. The own voice level can indicate at least one characteristic of the own voice activity. In some implementations, the detection unit is configured to provide the detection signal containing information about an own voice activity originating from a voice of the wearer, and the processor is configured to determine a characteristic of the own voice activity from the detection signal. The own voice characteristic can comprise at least one of a signal level of the own voice activity, a signal to noise ratio of the own voice activity, an occurrence of at least one linguistic feature in the own voice activity, an occurrence

of speech and/or pauses in speech in the own voice activity, an occurrence of at least one frequency range in the own voice activity, a frequency bandwidth of the own voice activity, and a temporal variation of the own voice activity. In this way, various hearing situations can be identified based on the own voice level for which the adjusting the effective size of the venting passage can be presumed to be beneficial or not beneficial for the momentary sound perception of the wearer.

[0017] The occurrence of at least one linguistic feature can comprise an occurrence of at least one of vowels, consonants, voiced phonemes, and unvoiced phonemes in the own voice activity and/or an occurrence of at least one of spoken words and phrases in the own voice activity. In particular, the occurrence of at least one linguistic feature can comprise a number and/or frequency of at least one of vowels, consonants, voiced phonemes, and unvoiced phonemes occurring in the own voice activity and/or a number and/or frequency of at least one of spoken words and phrases occurring in the own voice activity. The signal level can comprise at least one an amplitude of the characteristic of the own voice activity. The signal level can comprise a sound level of the own voice activity, an particular an amplitude of the sound level. The occurrence of speech and/or pauses in speech can comprise at least one of a duration, number, and frequency of the speech and/or pauses in speech in the own voice activity. The occurrence of at least one frequency range can comprise at least one frequency range of a spectrum of sound waves occurring in the own voice activity. In particular, the occurrence of at least one frequency range can comprise at least one of a duration, number, and frequency of occurrence of the at least one frequency range. The frequency bandwidth of the own voice activity can comprise at least one of the total width of the spectrum of sound waves occurring in the own voice activity, and a width of the spectrum of sound waves occurring in the own voice activity at a signal level of a characteristic of the own voice activity. The temporal variation can include the temporal variation of a characteristic of the own voice activity, in particular at least one of the above mentioned characteristics.

[0018] In some implementations, determining of the elapsed time exceeding a minimum duration comprises a time measurement of the elapsed time, in particular beginning from a start of the elapsed time at a starting time. For instance, the time measurement can be performed by a time counter. Determining the elapsed time can comprise resetting the elapsed time to the starting time, and determining the time elapsed since the starting time. Resetting the elapsed time can comprise resetting the time counter of the elapsed time to the starting time. In some implementations, the detection signal is provided at least at two instances of the elapsed time, in particular before the elapsed time exceeds the minimum duration. In some implementations, determining of the elapsed time exceeding a minimum duration comprises counting of at least one characteristic of the own voice activity,

wherein the minimum duration can be defined as time in which a minimum number of the characteristic occurs in the own voice activity, in particular beginning from a start of the elapsed time at a starting counting number. For instance, the time measurement can be performed by a counter of the number the characteristic occurs during the elapsed time. Determining the elapsed time can comprise resetting the elapsed time to the starting counting number, and determining the number the characteristic occurs since the starting counting number. Resetting the elapsed time can comprise resetting the number counter of the characteristic to the starting counting number.

[0019] Some implementations comprise setting the minimum duration based on at least one of the own voice level and the signal criterion. In particular, the processor can be configured to set the minimum duration based on at least one of the own voice level and the signal criterion. In this way, the minimum duration can be appropriately scaled on the basis of the own voice level and/or the signal criterion, in particular to select the minimum duration for improving the psychoacoustic perception in a hearing situation associated with the own voice level and/or the signal criterion. In some implementations, the minimum duration can thus depend on at least one of the own voice level and the signal criterion. The minimum duration can be set after determining the own voice level. The minimum duration can be set at a start of the elapsed time, in particular at a starting time at which the elapsed time is started being determined. The setting of the minimum duration can depend on an own voice level determined at the start of the elapsed time. In some implementations, a different value of the minimum duration is set for a different own voice level determined at the start of the elapsed time. In some implementations, the same value of the minimum duration is set for a different own voice level determined at the start of the elapsed time. The setting of the minimum duration can depend on a signal criterion, in particular a signal criterion for which the detection signal is selected to be evaluated at the start of the elapsed time. In some implementations, a different value of the minimum duration is set for a different signal criterion selected at the start of the elapsed time. In some implementations, the same value of the minimum duration is set for a different signal criterion selected at the start of the elapsed time.

[0020] In some implementations, the determining an elapsed time during which the detection signal satisfies the signal criterion comprises evaluating whether the own voice level satisfies the signal criterion within the elapsed time. In some implementations, the signal criterion comprises a threshold level, in particular an own voice threshold level. The own voice level can be evaluated relative to the threshold level. In this way, the evaluating of the own voice level may be implemented in an efficient and reliable way, in particular in a data processing of the detection signal. The threshold level can comprise a threshold of at least one characteristic of the own voice activity, in particular at least one of the above mentioned charac-

teristics. For instance, the threshold level can comprise an upper and/or lower threshold value of at least one of a signal level, a signal to noise ratio, a number and/or frequency of at least one linguistic feature, a duration of speech and/or pauses in speech, a number and/or frequency of at least one frequency range, a frequency bandwidth of the own voice activity, and a measure of a temporal variation occurring in the own voice activity.

[0021] In some implementations, the threshold level comprises at least one of an upper threshold level and a lower threshold level. The adjusting the effective size of the venting passage can be performed depending on at least one of whether the own voice level has a value larger or equal to the upper threshold level and depending on whether the own voice level has a value smaller or equal to the lower threshold level, in particular within the elapsed time. In some instances, the adjusting may comprise enlarging the effective size of the venting passage, in particular if the detection signal has a value larger or equal to the upper threshold level. In some instances, the adjusting may comprise reducing the effective size of the venting passage, in particular if the detection signal has a value smaller or equal to the lower threshold level. The venting passage may thus be adjusted between at least three values of the effective size of the venting passage, in particular between a reduced size, an enlarged size, and an intermediate size, depending on the detection signal. The reduced size can be associated with a value of the own voice level smaller or equal to the lower threshold level. The enlarged size can be associated with a value of the own voice level larger or equal to the upper threshold level. The intermediate size can be associated with a value of the own voice level between the lower threshold level and the upper threshold level.

[0022] In some other implementations, the threshold level is provided as a single threshold level. The adjusting the effective size of the venting passage can be performed depending on at least one of whether the own voice level has a value larger or equal, in particular larger, to the threshold level and depending on whether the own voice level has a value smaller or equal, in particular smaller, to the threshold level, in particular within the elapsed time. In some instances, the adjusting may comprise enlarging the effective size of the venting passage, in particular if the detection signal has a value larger or equal, in particular larger, to the threshold level. In some instances, the adjusting may comprise reducing the effective size of the venting passage, in particular if the detection signal has a value smaller or equal, in particular smaller, to the threshold level. The venting passage may thus be switched between two values of the effective size of the venting passage, in particular between a reduced size and an enlarged size, depending on the detection signal.

[0023] In some implementations, the signal criterion comprises a plurality of signal criteria, wherein each signal criterion is associated with an effective size of the venting passage, in particular a different effective size.

The threshold level, in particular at least one of the upper threshold level and the lower threshold level, can comprise a plurality of threshold levels, wherein each threshold level is associated with an effective size of the venting passage, in particular a different effective size. Some implementations can comprise setting the threshold level, in particular at least one of the upper threshold level and the lower threshold level, relative to a previously determined own voice level. The threshold level can be set to a larger value and/or a smaller value than the previously determined own voice level. The previously determined own voice level can be associated with a momentary effective size of the venting passage. The threshold level can be associated with an effective size of the venting passage different from the momentary effective size.

[0024] In some implementations, the signal criterion comprises a first criterion and a second criterion. The minimum duration can comprise a first duration and a second duration. The adjusting the effective size of the venting passage can comprise enlarging the effective size of the venting passage if the detection signal satisfies the first criterion within the elapsed time, in particular if the elapsed time exceeds the first duration. The adjusting the effective size of the venting passage can also comprise reducing the effective size of the venting passage if the detection signal satisfies the second criterion within the elapsed time, in particular if the elapsed time exceeds the second duration. In some implementations, the first duration and the second duration are selected to be different. In some implementations, the first duration and the second duration are selected to be equal. In some implementations, the first duration and the second duration can be selected to be different at one time and equal at another time. The first criterion can comprise an upper threshold level and the second criterion can comprise a lower threshold level. The first criterion can comprise a threshold level and the second criterion can comprise the same and/or a different threshold level.

[0025] Some implementations can comprise maintaining the effective size of the venting passage and resetting the elapsed time if the detection signal has at least once been determined to not satisfy the signal criterion during the elapsed time, in particular if the elapsed time is shorter or equal to the minimum duration. Some implementations can comprise maintaining the effective size of the venting passage and resetting the elapsed time if a mean value of an own voice level and/or ambient sound level determined from the detection signal has been determined to not satisfy the signal criterion after the elapsed time, in particular if the elapsed time is larger or equal to the minimum duration. The mean value of the own voice level and/or ambient sound level may be determined from the detection signal during at least two instants of the elapsed time. For instance, the mean value of the own voice level and/or ambient sound level may be determined from a continuously provided detection signal during at least two instants of a finite time interval of the elapsed time and/or from a continuously provided detec-

tion signal integrated over a time interval of the elapsed time. Resetting the elapsed time can comprise resetting the elapsed time to a starting time, in particular resetting a time counter of the elapsed time to a starting time.

[0026] The above described mode of operations in which the effective size of the venting passage is adjusted in dependence of a detection signal comprising at least information about an own voice activity can be particular advantageous in acoustical situations including a conversation in noise, e.g. in a restaurant, a communication in noise, e.g. a phone call in noisy environments, and a conversation while using the hearing device for streaming, e.g. streaming a television program or listening to music and simultaneously having a conversation with a partner. In some implementations, the effective size of the venting passage can be reduced, in particular such that the venting passage is closed, in acoustical situations including using the hearing device for streaming, e.g. music or a television program, to yield full bandwidth sound delivery, in noisy environments, e.g. during travelling in a plane, for optimal passive noise reduction and effective hearing aid sound cleaning, and in low input level scenes, in particular together with compressive settings where insertion gain can be large, wherein a reduced and/or closed venting passage can help to avoid feedback. In some implementations, the effective size of the venting passage can be enlarged, in particular such that the venting passage is open, can be applied in acoustical situations including acoustical environments with low ambient noise and/or a rather high signal to noise ratio, wherein an enlarged and/or open venting passage may help to improve a natural perception of own voice and the ambient sound.

[0027] More generally, changes in perception may occur during an adjustment of the effective size of the ventilation channel, which can be at least partially reduced by some configurations of the above disclosed hearing device, in which the effective size of the venting passage is adjusted depending on the detection signal comprising own voice information and also depending on a minimum duration in which a signal criterion must be satisfied. The changes in perception that can be improved by the venting adjustment depending on the minimum duration in which the signal criterion must be satisfied can include: ambient sound level changes, in particular direct sound changes, especially at lower frequencies; comb filter effect changes due to a change of a sound ratio of a sound provided by a hearing instrument and a direct sound ratio; spatial perception changes since direct sound and a hearing instrument microphone may pick up sound exhibiting different spatial cues; occlusion effects of own voice changes; changes of a signal to noise ratio due to a different masking of hearing instrument sound cleaning features by direct sound; changes of a bandwidth of delivered streamed signals changes, in particular at lower frequencies; and low frequency insertion gain changes. For instance, a modulated perception of at least one of those negative effects can be at least partially avoided

by the venting adjustment depending on the minimum duration.

[0028] Some implementations can comprise determining an ambient sound level from the detection signal. The ambient sound level can indicate at least one characteristic of the ambient sound. In this way, the adjusting the effective size of the venting passage can be adapted to a presumed psychoacoustic perception of the ambient sound. In some implementations, the detection unit is configured to provide the detection signal containing information about an ambient sound originating from the ambient environment, and the processor is configured to determine a characteristic of ambient sound from the detection signal.

[0029] The characteristic of the ambient sound can comprise at least one of a signal level of the ambient sound, a signal to noise ratio of the ambient sound, an occurrence of at least one frequency range of the ambient sound, a frequency bandwidth of the ambient sound, and a temporal variation of the ambient sound. The signal level can comprise a sound level of the ambient sound, in particular an amplitude of the sound level. The occurrence of at least one frequency range can comprise at least one frequency range of a spectrum of sound waves occurring in the ambient sound. The occurrence of at least one frequency range can comprise at least one of a duration, number, and frequency of occurrence of the at least one frequency range. The frequency bandwidth of the ambient sound can comprise at least one of the total width of the spectrum of sound waves occurring in the ambient sound, and a width of the spectrum of sound waves at a signal level of the ambient sound. The frequency bandwidth can indicate an occurrence of a rather narrow and/or a rather broad bandwidth of the ambient sound. The temporal variation can include the temporal variation of a characteristic of the ambient sound, in particular at least one of the above mentioned characteristics. The temporal variation can indicate a rather stationary and/or a rather modulated behaviour of at least one characteristic of the ambient sound.

[0030] In some implementations, the determining an elapsed time during which the detection signal satisfies the signal criterion comprises evaluating whether the ambient sound level satisfies the signal criterion within the elapsed time. In some implementations, the signal criterion comprises a threshold level, in particular an ambient sound threshold level. The ambient sound level can be evaluated relative to the threshold level. In this way, the evaluating of the ambient sound level may be implemented in an efficient and reliable way, in particular in a data processing of the detection signal. The threshold level can comprise a threshold of at least one characteristic of the ambient sound, in particular at least one of the above mentioned characteristics. For instance, the threshold level can comprise an upper and/or lower threshold value of at least one of a signal level, a signal to noise ratio, a number and/or frequency of at least one frequency range, a frequency bandwidth of the ambient

sound, and a measure of a temporal variation occurring in the ambient sound.

[0031] In some implementations, the determining an elapsed time during which the detection signal satisfies the signal criterion can comprise evaluating whether the own voice level satisfies a first signal criterion within the elapsed time and whether the ambient sound level satisfies a second signal criterion within the elapsed time. In this way, the adjusting the effective size of the venting passage can be adapted to a presumed psychoacoustic perception of the ambient sound in combination with a presumed psychoacoustic perception of an own voice activity of the wearer. In some implementations, the adjusting the effective size of the venting passage comprises reducing the effective size of the venting passage if the ambient sound level has a value larger or equal to the ambient sound threshold level within the elapsed time, and the own voice level has a value smaller or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration. In some implementations, the adjusting the effective size of the venting passage comprises enlarging the effective size of the venting passage if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time, and the own voice level has a value larger or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration.

[0032] In some implementations, the adjusting the effective size of the venting passage after determining an ambient sound level from the detection signal is applied to provide a venting adjustment for a humidity regulation between the inner region of the ear canal and the ambient environment at the outer region of the ear canal, in particular a humidity regulation balanced with a presumed psychoacoustic perception during different hearing situations. An atmospheric connection between the inner region of the ear canal and the ambient environment may be provided through the venting passage. A pressure equalization between the inner region of the ear canal and the ambient environment can be increased by an enlarged effective size of the venting passage, which can advantageously provide a humidity transport between the inner ear region and the ambient environment. Humidity inside the ear canal might lead to increased cerumen production and also to inflammation of the ear canal skin commonly referred to as otitis externa. Another negative side effect of humidity in the ear canal is that water might condense inside the hearing device and can lead to corrosion or malfunctioning of the hearing device. Venting through the venting passage can at least reduce those negative effects of humidity in the ear canal.

[0033] In some implementations, a hearing situation, in which a presumed psychoacoustic perception can be balanced with an enlarged size of the venting passage required for the humidity transport, is recognized if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time,

and the own voice level has a value larger or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration. In some implementations, a hearing situation, in which a presumed psychoacoustic perception cannot be balanced with an enlarged size of the venting passage required for the humidity transport, is recognized if the ambient sound level has a value larger or equal to the ambient sound threshold level within the elapsed time, and the own voice level has a value smaller or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration. In such a hearing situation, the effective size of the venting passage can be adjusted to a reduced size to avoid a presumed negative effect on the psychoacoustic perception.

[0034] In some implementations, the hearing device comprises a humidity detector configured to detect a humidity level in the inner region of the ear canal. In this way, an improved monitoring of the humidity in the ear canal can be provided which can be exploited for the humidity control. The processor can be operatively connected to the humidity detector and configured to receive a humidity indication signal from the humidity detector. The acoustic valve can be controlled to enlarge the effective size of the venting passage if the humidity indication signal has a level larger or equal to a threshold level of the humidity indication signal. In some implementations, the adjusting the effective size of the venting passage comprises enlarging the effective size of the venting passage if the humidity indication signal has a level larger or equal to a threshold level of the humidity indication signal and if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time. In some implementations, the adjusting the effective size of the venting passage comprises enlarging the effective size of the venting passage if the humidity indication signal has a level larger or equal to a threshold level of the humidity indication signal, if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time, and if the own voice level has a value larger or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration. In this way, the humidity control can be restricted to hearing situations in which a presumed effect on the psychoacoustic perception is also accounted for.

[0035] In some implementations, the hearing device comprises a first humidity detector configured to detect a humidity level in the inner region of the ear canal, and a second humidity detector configured to detect a humidity level in the ambient environment. This can allow a further improvement of the humidity monitoring in the ear canal by relating the humidity in the inner ear canal region to a humidity outside the ear canal. The processor can be operatively connected to the humidity detectors. The processor can be configured to evaluate a humidity difference signal based on the humidity level detected by

the humidity detectors. The humidity difference signal may indicate a deviation of the humidity level of the inner region of the ear canal with respect to the ambient environment. The effective size of the venting passage can be enlarged if the humidity difference signal has been determined to be larger or equal to a threshold level of the humidity difference signal. In some implementations, the adjusting the effective size of the venting passage comprises enlarging the effective size of the venting passage if the humidity difference signal has a level larger or equal to a threshold level of the humidity difference signal and if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time. In some implementations, the adjusting the effective size of the venting passage comprises enlarging the effective size of the venting passage if the humidity difference signal has a level larger or equal to a threshold level of the humidity difference signal, if the ambient sound level has a value smaller or equal to the ambient sound threshold level within the elapsed time, and if the own voice level has a value larger or equal to the own voice threshold level within the elapsed time, in particular if the elapsed time exceeds the minimum duration. Thus, the humidity control may be only carried out during hearing situations in which a presumed effect on the psychoacoustic perception is also accounted for.

[0036] In some implementations, the setting of the minimum duration comprises selecting the minimum duration such that a masking of acoustical artifacts during and/or after an adjustment of the effective size of the venting passage can be provided, in particular such that the adjustment is less perceivable and/or unperceivable for the wearer. On the one hand, such a setting can be determined based on at least one characteristic of the own voice activity indicated by the own voice level. The characteristics of the own voice activity can be distinguished in characteristics providing a superior masking of the acoustical artifacts, such that the minimum duration can be set to a shorter value, and in characteristics providing an inferior masking of the acoustical artifacts, such that the minimum duration can be set to a larger value. The characteristics providing a superior masking can include voiced phonemes, in particular vowels, and/or a large amplitude of an own voice sound. The characteristics providing an inferior masking can include unvoiced phonemes, in particular consonants, and/or a small amplitude of an own voice sound. In particular, the minimum duration can be selected to be shorter after determining an own voice level indicating a characteristic of the own voice activity including for instance a rather frequent occurrence of voiced phonemes, in particular vowels, and/or a comparatively large amplitude of a sound signal of the own voice characteristic. Inversely, the minimum duration can be selected to be longer after determining an own voice level indicating a characteristic of the own voice activity including for instance a rather frequent occurrence of unvoiced phonemes, in particular consonants, and/or a comparatively small amplitude of a sound

signal of the own voice characteristic.

[0037] On the other hand, such a setting can be determined based on at least one characteristic of the ambient sound indicated by the ambient sound level. The characteristics of the ambient sound can be distinguished in characteristics providing a superior masking of the acoustical artifacts, such that the minimum duration can be set to a shorter value, and in characteristics providing an inferior masking of the acoustical artifacts, such that the minimum duration can be set to a larger value. The characteristics providing a superior masking can include a rather large temporal variation of the ambient sound such as a rather fluctuating ambient sound level, in particular a varying background noise. The characteristics providing an inferior masking can include a small temporal variation of the ambient sound such as a rather stationary ambient sound level, in particular a constant background noise. In particular, the minimum duration can be selected to be shorter after determining an ambient sound level indicating a characteristic of the ambient sound including for instance a rather large temporal variation of the ambient sound. The minimum duration can be selected to be larger after determining an ambient sound level indicating a characteristic of the ambient sound including for instance a rather small temporal variation of the ambient sound. Moreover, such a setting can be determined based on both at least one characteristic of the own voice activity indicated by the own voice level and at least one characteristic of the ambient sound indicated by the ambient sound level.

[0038] In some implementations, the setting of the minimum duration comprises selecting the minimum duration such that a perceived occlusion is at least reduced during varying hearing situations. The characteristics of the own voice activity can be distinguished in characteristics leading to a less disturbing psychoacoustic perception of the occlusion such that the minimum duration can be set to a larger value, in particular such that a frequent venting adjustment for avoiding the occlusion can be avoided, and in characteristics leading to a more disturbing psychoacoustic perception of the occlusion such that the minimum duration can be set to a smaller value, in particular such that the occlusion can be reduced by a rather frequent venting adjustment. The characteristics providing a less disturbing occlusion perception can include unvoiced phonemes, in particular consonants, and/or a small amplitude of an own voice sound. The characteristics providing a more disturbing occlusion perception can include voiced phonemes, in particular vowels, and/or a large amplitude of an own voice sound. In particular, the minimum duration can be selected to be shorter after determining an own voice level indicating a characteristic of the own voice activity including for instance a rather frequent occurrence of voiced phonemes, in particular vowels, and/or a comparatively large amplitude of a sound signal of the own voice characteristic. Inversely, the minimum duration can be selected to be longer after determining an own voice level indicating a

characteristic of the own voice activity including for instance a rather frequent occurrence of unvoiced phonemes, in particular consonants, and/or a comparatively small amplitude of a sound signal of the own voice characteristic.

[0039] In some implementations, the setting of the minimum duration comprises selecting the minimum duration such that an adjustment of the effective size of the venting passage is performed after an own voice activity exceeding a predetermined minimum duration. In some implementations, the minimum duration comprises a predetermined time period. In some implementations, the minimum duration comprises a predetermined number of linguistic features, in particular a number of at least one of vowels, consonants, voiced phonemes, unvoiced phonemes, words, and phrases, occurring in the own voice activity such that the elapsed time exceeds the minimum duration. In some implementations, the minimum duration comprises a minimum duration of speech and/or pauses in speech.

[0040] In some implementations, the minimum duration is set to a value of at least 1 millisecond. In some implementations, the minimum duration is set to a time interval which allows to exploit the circumstance that acoustical variations can be less perceivable for the wearer at an onset of own voice activity and/or during an own voice activity, for instance when the wearer starts to speak and/or during spoken words and/or phrases. Thus, acoustical variations related to the venting adjustment can be masked at the onset of own voice occurrence and/or during the own voice occurrence. In these implementations, the minimum duration can be set for instance to a value of 500 milliseconds or below. In some implementations, the minimum duration can be set to a value of at least 100 milliseconds and/or at least 500 milliseconds, for instance for an own voice characteristic indicating a pause in between spoken words. In some implementations, the minimum duration can be set to a value of at least 1 second, for instance for an own voice characteristic indicating a pause in between spoken phrases. In some implementations, the minimum duration can be set to a value of at least 2 seconds, for instance for an own voice characteristic indicating a minimum number of a plurality of spoken words. In some implementations, the minimum duration can be set to a value of at least 10 seconds, for instance for an own voice characteristic indicating a minimum number of spoken phrases and/or sentences.

[0041] In some implementations, the detection signal is provided at least at two instances of the elapsed time, in particular before the elapsed time exceeds the minimum duration. The detection signal can be continuously and/or discontinuously provided during the elapsed time. A continuous detection signal may provide an enhanced temporal resolution of the information contained in the detection signal. A discontinuous detection signal can be provided at temporally separated intervals, in particular at periodical intervals, for instance as a pulsed signal

provided in a pulsed detection mode. Such a discontinuous detection can contribute to a reduced energy consumption. A discontinuous detection signal may also be beneficial when a signal processing of the detection signal is required to evaluate the detection signal, in particular with respect to identify and/or process said information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from the ambient environment. For instance, the detection signal may be provided such that a period of the detection signal matches a processing time of the detection signal, in particular such that the period is larger or equal to the processing time.

[0042] In some implementations, the processor is configured to control the venting actuator to adjust the venting passage in between a plurality of effective sizes. Such a configuration can be advantageous to allow an adaptation to various gradations of the own voice activity which may be applied to further balance positive and negative side effects of a venting adjustment. The plurality of adjustable effective sizes of the venting passage can comprise at least two effective sizes, in particular at least three effective sizes. The processor can be configured to operate the adjustment of the venting passage in between an open state, a closed state and at least one intermediate state of the venting passage, in which intermediate state the effective size of the venting passage is in between a fully reduced size and a fully enlarged size. For instance, a substantially continuous number of adjustable effective sizes may be provided. Each effective size of the plurality of effective sizes can be associated with a different own voice level. An larger own voice level may be associated with an enlarged effective size as compared to a smaller level of own voice sound which may be associated with a reduced effective size. In some implementations, the venting passage can be adjusted to have a larger effective size after a larger level of own voice sound has been determined, in particular at least for a minimum duration, and/or to have a smaller effective size after a larger level of own voice sound has been determined, in particular at least for a minimum duration.

[0043] The acoustic valve can be configured to provide an adjustment of the venting passage within each of said plurality of effective sizes of the venting passage each corresponding to an own voice level. A pair of own voice levels can comprise an increased level of own voice sound and a decreased level of own voice sound, the increased level and the decreased level having a difference in the level of own voice sound. A pair of effective sizes of the venting passage can comprise two effective sizes having a different value. In some implementations, each pair of effective sizes can be associated with a pair of own voice levels. The venting passage can be adjusted in between the pair of effective sizes after determining an associated pair of own voice levels in a chronological sequence. The pair of own voice levels can comprise a first own voice level and a second own voice level, wherein each own voice level has been determined to satisfy

a signal criterion for an elapsed time exceeding a minimum duration. In this way, by providing a sufficiently large number of adjustable effective sizes of the venting passage, a continuous adaption of the venting adjustment to various gradations of an own voice activity can be provided.

[0044] The venting passage can comprise any passage providing a pathway through the earpiece, in particular between an inner region of the ear canal and an ambient environment at an outer region of the ear canal and/or outside the ear. The pathway may be provided as a ventilation channel for sound waves, such that sound waves can propagate through the venting passage, and/or a ventilation channel for a medium, such that a medium can be transported through the venting passage. An effective size of the venting passage can be defined as any parameter or combination of parameters on which an efficiency of the venting through the venting passage may depend. The expression venting may refer to a venting of soundwaves through the venting passage and/or a venting of a medium through the venting passage, for instance air, another atmospheric medium, a propagation medium for sound waves, and/or any other medium, in particular such that a pressure equalisation in between an inner region of the ear canal and an outer region of the ear canal and/or an ambient environment outside the ear can be at least increased and/or provided by the venting. A reduced effective size of the venting passage can be defined as any parameter value or combination of parameter values which can lead to a less efficient venting through the venting passage. An enlarged effective size of the venting passage can be defined as any parameter value or combination of parameter values which can lead to a more efficient venting through the venting passage.

[0045] The adjustment of the venting passage can comprise an enlarging and/or reducing of the cross sectional size of the venting passage. In some implementations, at least one parameter of the effective size of the venting passage comprises a cross sectional size and/or length of the venting passage. The adjustment of the venting passage can comprise an enlarging and/or reducing of the cross sectional size and/or length of the venting passage. In some implementations, at least one parameter of the effective size can be a ratio between a cross section and a length of the ventilation channel. The adjustment of the venting passage can comprise an enlarging and/or reducing of the ratio. In some implementations, at least one parameter of the effective size can be a parameter determining an acoustic mass and/or an acoustic impedance inside the venting passage. The adjustment of the venting passage can comprise an enlarging and/or reducing of the acoustic mass and/or an acoustic impedance. In some implementations, at least one parameter of the effective size can be a parameter determining the mobility of a medium inside the ventilation channel. The adjustment of the venting passage can comprise an enlarging and/or reducing of the mobility of

the medium. The adjustment of the effective size of the venting passage can comprise at least any combination of an enlarging and/or reducing of these parameters of the effective size.

[0046] The detection unit can comprise at least one detector configured to provide a detection signal comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from said ambient environment. In some implementations, the detection unit comprises at least a sound detector, in particular a microphone, configured to provide a detection signal comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from said ambient environment. In some implementations, the detection unit comprises at least an own voice detector configured to provide a detection signal comprising information about an own voice activity originating from a voice of the wearer. In some implementations, the detection unit comprises at least a sound detector and an own voice detector. In some implementations, the detection unit comprises at least one humidity detector. In some implementations, the detection signal comprises a signal provided by at least one detector, in particular a sound detector or an own voice detector. In some implementations, the detection signal comprises a signal provided by at least two detectors, in particular a sound detector and an own voice detector. In some implementations, the detection signal further comprises a signal provided by at least one humidity detector. In some implementations, the detection signal can be transmitted from the detection unit to a processor via at least one signal line. In some implementations, the detection signal can be transmitted from the detection unit to a processor via a plurality of signal lines, in particular signal lines connected to different detectors such as a sound detector and/or an own voice detector and/or a humidity detector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047] Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the drawings:

- Figs. 1A-E** schematically illustrate hearing devices including a detection unit, a processor, an acoustic transducer, and an active vent, in accordance with some embodiments of the present disclosure;
- Figs. 2A-F** are flowcharts of methods of operating a hearing device, in accordance with some embodiments of the present disclosure;
- Fig. 3A** schematically represents an own voice detection signal, in accordance with some embodiments of the present disclosure;

- closure;
- Figs. 3B-D schematically represent various vent operation signals in dependence of the own voice detection signal illustrated in Fig. 3A, in accordance with some embodiments of the present disclosure;
- Figs. 4A, 4B each schematically illustrates a hearing device comprising an own voice detector and an active vent, in accordance with some embodiments of the present disclosure; and
- Figs. 5A, 5B each schematically illustrates an own voice detector, in accordance with some embodiments of the present disclosure, which may be included in one or more of the hearing devices shown in Figs. 1A-H and the hearing devices shown in Figs. 4A, 4B.

DETAILED DESCRIPTION OF THE DRAWINGS

[0048] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the subject matter herein. However, it will be apparent to one of ordinary skill in the art that the subject matter may be practiced without these specific details. In other instances, well known methods, techniques, procedures, processes, algorithms, components, circuits, structures and systems have not been described in detail so as not to unnecessarily obscure features of the embodiments. In the following description, it should be understood that features of one embodiment may be used in combination with features from another embodiment where the features of the different embodiment are not incompatible. The ensuing description provides some embodiment(s) of the invention, and is not intended to limit the scope, applicability or configuration of the invention or inventions. Various changes may be made in the function and arrangement of elements without departing from the scope of the invention as set forth herein.

[0049] Figure 1A illustrates a hearing device 1 in accordance with some embodiments of the present disclosure. Hearing device 1 is configured to be at least partially worn inside an ear canal of a wearer. Hearing device 1 comprises a detection unit 2 operatively connected to a processor 4 via a detection signal line 3. Detection unit 2 is configured to provide a detection signal comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from an ambient environment outside the ear canal. The detection signal can be transmitted to processor 4 via detection signal line 3. Processor 4 can be configured to determine an own voice level from the detection signal. The own voice level can indicate at least

one characteristic of the own voice activity. Detection signal line 3 can be provided as a single signal line configured to transmit the detection signal, or detection signal line 3 can comprise a plurality of signal lines each configured to transmit a respective detection signal, as further described below, wherein at least one of the detection signals comprises information about the own voice activity of the wearer. Processor 4 is configured to process the at least one detection signal.

[0050] Processor 4 is operatively connected to an acoustic transducer 6 via an audio signal line 5. Processor 4 is configured to transmit an audio signal to acoustic transducer 6 via signal line 5. The audio signal can include at least a part of the detection signal, in particular a signal obtained after processing of at least part of the detection signal. Acoustic transducer 6 is configured to convert the audio signal into sound waves and to output the sound waves into an ear canal of the wearer when hearing device 11 is inserted into the ear canal, for instance through a sound tube of hearing device 11 inserted into the ear canal and in acoustic communication with acoustic transducer 6.

[0051] Processor 4 is operatively connected to an active vent 8 via a control signal line 7. Active vent 8 comprises a venting passage and an acoustic valve. The venting passage extends at least partially through hearing device 1 and is configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside the ear canal of the wearer of hearing device 1. The acoustic valve is configured to adjust an effective size of the venting passage, in particular to enlarge and/or reduce the effective size of the venting passage. Processor 4 is operatively connected to the acoustic valve of active vent 8 via control signal line 7 such that processor 4 is configured to provide a control signal to the acoustic valve. Processor 4 is thus configured to control the adjusting of the effective size of the venting passage by providing a respective control signal to the acoustic valve.

[0052] When inserted into the ear canal of the wearer, hearing device 1 may form an acoustical seal with an ear canal wall such that an inner region of the ear canal between hearing device 1 and the eardrum is acoustically insulated from the ambient environment, at least to some extent. In particular, hearing device 1 may comprise an earpiece, an earplug, or the like configured to suppress sound from an ambient environment when inserted into the ear canal of the wearer. The acoustical seal of the inner region of the ear canal can lead to occlusion effects, in particular when the wearer is using his own voice such that the own voice may be perceived as undesirable loud in a lower frequency range. The venting passage of active vent 8, and in particular the adjustment of the effective size of the venting passage controlled by processor 4 in dependence of the detection signal provided by detection unit 2, can at least reduce those occlusion effects, in particular by providing a more efficient pressure equalisation in between the inner region of the ear canal and the am-

bient environment when the effective size of the venting passage is enlarged. Moreover, ambient sound can enter the ear canal, in particular during own voice activity of the wearer which may be desired by the wearer during his own speech. An at least partially open venting passage can be particularly beneficial in hearing situations including a low ambient noise and a high signal to noise ratio, in particular when a natural perception of own voice and of ambient sound shall be improved.

[0053] A more reduced effective size of the venting passage, in particular a closed venting passage, can be perceived as more pleasant in hearing situations involving a low or no own voice activity by the wearer. Those hearing situations can include streaming, for instance streaming of music or a television program, to yield full bandwidth sound delivery; noisy scenes, for instance during travelling in a plane and/or streaming in noisy scenes, for optimal passive noise reduction and effective hearing aid sound cleaning; and low input level scenes, in particular in conjunction with compressive settings in which insertion gain can be large, wherein a reduced or fully closed effective size of the venting passage can help to avoid feedback. Some hearing situations, however, may not qualify for a constantly open or closed effective size of the venting passage of active vent 8 over a longer period but may require a continued adjustment of the effective size of the venting passage, in particular a rather fast and frequent switching in between various adjustment states. Those hearing situations may include a conversation in noise, for instance a communication in a restaurant; a communication in noise, for instance during a phone call in noisy environments; and a conversation during streaming, for instance during watching a television program and/or listening to music while having a conversation with a partner.

[0054] More generally, the effective size of the venting passage can be decisive for the acoustic coupling of the direct sound transmitted through the venting passage and the sound provided by acoustic transducer 6. The acoustic coupling may define a main working point of the hearing device and thus may be crucial for its audiological performance. A distinction can be made between rather open couplings, in which the effective size of the venting passage is rather enlarged, and rather closed couplings, in which the effective size of the venting passage is rather reduced. In rather closed couplings, direct sound can be rather attenuated. The wearer can thus benefit more from a sound signal detected by detection unit 2 and processed by processor 4, in particular at the whole frequency bandwidth. For instance, the processed sound signal may provide a clarity increase of the perceived sound by a beamforming and/or other sound cleaners and/or an insertion gain. Closed couplings can also provide a broad band sound experience during streaming, for instance a streaming of music and/or a television program, that can be largely superior to open couplings. On the other hand, an own voice perception can be rather poor in closed couplings, in particular due to an enhanced occlusion

effect, and may not be acceptable for many users. Rather open couplings can mitigate the occlusion effect and can also improve a more natural perception of own voice and ambient sound. Yet the bandwidth of the thus provided sound can be reduced. Therefore, an audiological benefit may not be delivered over the entire frequency range. During a typical hearing situation involving an open coupling, the user may perceive direct sound in a frequency range below 1 kHz mostly by an unprocessed signal, which potentially involves a low signal to noise ratio and a poor intelligibility during communication in noisy scenes. Hence, at least during a communication involving noisy scenes and/or streaming it would be desirable to unite the benefits of a rather closed and a rather open coupling while mitigating the respective drawbacks of the open and closed coupling.

[0055] A combination of those benefits may be envisaged by a rather quick and continuous adjusting of the effective size of the venting passage, in particular depending on the respective hearing situation. But the adjusting of the effective size of the venting passage can implicate a number of perceptual changes in the hearing sensation of the wearer, which may not be desired by the wearer. In particular, the following changes in the sound perception can occur:

- changes of a perceived sound level of direct sound entering the ear canal from the ambient environment through the venting passage, especially at lower frequencies, which may in particular not be fully compensated by a gain adjustment of the hearing device;
- comb filter effect changes due to a perceived change of a sound ratio in between the sound produced by acoustic transducer 6 and the direct sound;
- spatial perception changes, in particular because the direct sound and the sound detected by detection unit 2, for instance an ambient sound picked up by a microphone of a hearing aid, can exhibit different spatial cues;
- changes in which a degree of occlusion occurs, in particular when an own voice activity of the wearer changes;
- perceived changes of the signal to noise ratio, in particular because sound cleaning features implemented in the hearing device, for instance by a signal processing of the detection signal by processor 4, can be masked differently by the direct sound;
- perceived changes of the frequency bandwidth of signals delivered to the hearing device, in particular streamed signals, especially at lower frequencies; and
- perceived changes of a low frequency insertion gain.

[0056] A fast and frequent adjusting of the effective size of the venting passage, for instance by a repetitive switching in between an open state and a closed state of the venting passage or by a continuous enlarging and/or reducing of the effective size of the venting passage, can lead to a modulated perception of those perceived sound changes. It is therefore desirable to provide operational schemes for the adjustment of the effective size of the venting passage which are perceptually acceptable for the user. In order to provide such an operational scheme, processor 4 is configured to determine an elapsed time during which the detection signal satisfies a signal criterion, and to provide the control signal to the acoustic valve of active vent 8 to adjust the effective size of the venting passage of active vent 8 if the elapsed time exceeds a minimum duration. Such a requirement of a minimum duration, and in particular an appropriate setting of the minimum duration relative to a respective hearing situation, can prevent an adjusting of the effective size of the venting passage in hearing situations in which the venting adjusting can be presumed to be unfavourable for the wearer and/or can avoid negative impacts of a too frequent venting adjusting. In this way, psychoacoustic effects of the adjustment can be advantageously accounted for, in particular such that a presumed psychoacoustic perception of the wearer can be adapted to different hearing situations and/or optimized for those hearing situations.

[0057] Figure 1B illustrates a hearing device 11 in accordance with some embodiments of the present disclosure. Corresponding features with respect to embodiments of hearing device 1 illustrated in Fig. 1A are illustrated by the same reference numerals. A detection unit 12 of hearing device 11 comprises a sound detector 15. Sound detector 15 is operatively connected to processor 4 via a sound detection signal line 13. Sound detector 15 is configured to provide a sound detection signal to processor 4 via sound signal line 13. The sound detection signal can comprise at least one of information about an own voice activity originating from the voice of the wearer and information about an ambient sound originating from the ambient environment. Processor 4 can be configured to determine an own voice level from the sound detection signal. The sound detection signal can comprise additional sound information, in particular information about an ambient sound originating from the ambient environment. Processor 4 can be configured to determine an ambient sound characteristic of the ambient sound from the detection signal. Processor 4 can be configured to transmit an audio signal based on the sound detection signal to acoustic transducer 6 via audio signal line 5, in particular after a processing of the sound detection signal to obtain the audio signal.

[0058] Sound detector 15 can comprise at least one microphone. The microphone can be configured to be located outside the ear canal during wearing of the hearing device such that it is adapted to pick up the information about the own voice activity and/or ambient sound from

the ambient environment. The microphone can be configured to be located inside the ear canal during wearing of the hearing device such that it is adapted to pick up the information about the own voice activity inside the ear canal, for instance from the ear canal wall. Sound detector 15 can comprise a plurality of microphones, in particular a first microphone configured to be located outside the ear canal during wearing of the hearing device and a second microphone configured to be located outside or inside the ear canal during wearing of the hearing device. Sound detection signal line 13 can comprise a separate signal line for each of the at least two microphones, wherein the detection signal transmitted to processor 4 can comprise the signal transmitted from each microphone via the respective signal line. The information about the own voice activity may be contained in at least one of the signals transmitted from each microphone and/or it may be contained in a combination of the signals. Processor 4 can be configured to evaluate the detection signal comprising the signals transmitted from the microphones to obtain the information about the own voice activity and/or to determine an own voice level from the sound detection signal. For instance, the hearing device may be a binaural hearing device comprising two hearing units configured to be inserted into both ears of the wearer and each comprising a microphone configured to be located outside the ear canal. The detection signal comprising the information about the own voice activity can be provided to processor 4 as the combined signals obtained by the two microphones, for instance by a binaural beam forming.

[0059] In some implementations, processor 4 is configured to provide the control signal to the acoustic valve to adjust the venting passage such that the venting passage is not closed when a sound level of the ambient sound originating from the ambient environment has been determined by processor 4 to be below a threshold sound level. In this way, the venting adjustment may be appropriately chosen to be adapted to hearing situations in which an at least partially open venting passage does not have a negative impact on the sound perception of the wearer in order to take advantage of the benefits of an at least partially open venting passage in those situations. For instance, those hearing situations may include environments with low ambient noise and/or a rather high signal to noise ratio. In those situations, an enlarged and/or open venting passage may help to improve a natural perception of own voice and the ambient sound. Moreover, an appropriate venting adjustment for a humidity regulation between the inner region of the ear canal and the ambient environment may be provided by the at least partially open venting passage below the threshold sound level of the ambient sound.

[0060] Figure 1C illustrates a hearing device 21 in accordance with some embodiments of the present disclosure. Corresponding features with respect to embodiments of hearing devices 1, 11 illustrated in Figs. 1A and 1B are illustrated by the same reference numerals. A

detection unit 22 of hearing device 21 comprises sound detector 15 and an own voice detector 25. Sound detector 15 is configured to provide a sound detection signal to processor 4 via sound detection signal line 13, in accordance with the previous description. Own voice detector 25 is operatively connected to processor 4 via an own voice detection signal line 23. Own voice detector 25 is configured to provide an own voice detection signal to processor 4 via own voice detection signal line 23. The detection signal provided by detection unit 22 thus comprises the sound detection signal provided by sound detector 15 and the own voice detection signal provided by own voice detector 25. Processor 4 can be configured to determine an own voice level from the detection signal comprising the sound detection signal and the own voice detection signal. The own voice detection signal comprises information about an own voice activity originating from the voice of the wearer. In particular, own voice detector 25 can be configured to detect bone vibrations caused by the own voice activity in order to provide the own voice detection signal. For instance, own voice detector 25 can be configured to detect an onset and/or offset of the own voice activity of the wearer. In some implementations, the detection signal comprising information about the own voice activity originating from the voice of the wearer is provided by the own voice detection signal. Processor 4 can be configured to determine an own voice level from the own voice detection signal. In some implementations, the information about the own voice activity originating from the voice of the wearer in the detection signal is provided by a combination of the sound detection signal and the own voice detection signal. Processor 4 can be configured to determine an own voice level from the detection signal provided by the sound detection signal and the own voice detection signal.

[0061] Figure 1D illustrates a hearing device 31 in accordance with some embodiments of the present disclosure. Corresponding features with respect to embodiments of hearing devices 1, 11, 21 illustrated in Figs. 1A - 1C are illustrated by the same reference numerals. A detection unit 32 of hearing device 31 comprises sound detector 15 and a humidity detector 35. Sound detector 15 is configured to provide a sound detection signal to processor 4 via sound detection signal line 13, in accordance with the previous description. Humidity detector 35 is operatively connected to processor 4 via a humidity detection signal line 33. Humidity detector 35 is configured to provide a humidity indication signal to processor 4 via humidity detection signal line 33. The humidity indication signal may indicate a humidity level in the inner region of the ear canal detected by humidity detector 35. The humidity indication signal may also be provided as a humidity difference signal indicating a deviation of the humidity level of the inner region of the ear canal with respect to the ambient environment. Processor 4 comprises an operation configuration in which the acoustic valve of active vent 8 is operated to adjust the effective

size of the venting passage depending on the humidity indication signal. In particular, processor 4 can be configured to provide a control signal to the acoustic valve to enlarge the effective size of the venting passage if the humidity indication signal has been determined by processor 4 to be above a threshold value of the humidity indication signal.

[0062] In some implementations, processor 4 is configured to provide the control signal to the acoustic valve to enlarge the effective size of the ventilation channel if the humidity indication signal has been determined by processor 4 to be above the threshold value of the humidity indication signal, and if a sound level of the sound detection signal of sound detector 26 has been determined by processor 4 to be below a threshold sound level, in particular below a threshold sound level for ambient sound. In some implementations, processor 4 is configured to provide the control signal to the acoustic valve to enlarge the effective size of the ventilation channel if the humidity indication signal has been determined by processor 4 to be above the threshold value of the humidity indication signal, and if the elapsed time during which the detection signal comprising information about the own voice activity originating from the voice of the wearer and satisfying the signal criterion exceeds a minimum duration. In this way, a humidity regulation between the inner region of the ear canal and the ambient environment at the outer region of the ear canal can be provided by taking into account those situations in which a humidity level inside the ear canal may have exceeded a critical value, such that an adjusting of the effective size of the venting passage may be determined as required by processor 4.

[0063] Figure 1E illustrates a hearing device 41 in accordance with some embodiments of the present disclosure. Corresponding features with respect to embodiments of hearing devices 1, 11, 21, 31 illustrated in Figs. 1A - 1D are illustrated by the same reference numerals. A detection unit 42 of hearing device 31 comprises sound detector 15, own voice detector 25, and humidity detector 35 in accordance with the previous description.

[0064] Figure 2A is a flowchart 100 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. When starting the method, as illustrated at 101, a time measurement can be initiated allowing to subsequently estimate a time elapsed since the time of starting. At the time of starting, providing a detection signal is performed at 102. The detection signal can comprise at least one of information about an own voice activity originating from the voice of the wearer and information about an ambient sound originating from the ambient environment. At 103, it is determined if the detection signal satisfies a signal criterion. The determining if the detection signal satisfies a signal criterion can comprise determining an own voice level from the detection signal and evaluating whether the own voice level satisfies the signal criterion. The own voice level can indicate at least one characteristic of the own

voice activity. The signal criterion can comprise a threshold, wherein the own voice level can be evaluated relative to the threshold.

[0065] In a case in which the detection signal does not satisfy the signal criterion, the method is restarted at 101. In a case in which the detection signal satisfies the signal criterion, it is determined at 104 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the signal criterion at 103 exceeds a minimum duration. The minimum duration can be predetermined and/or set after the determining at 103 if the detection signal satisfies a signal criterion. In a case in which the elapsed time does not exceed the minimum duration, the providing of a detection signal at 102 is repeated until it is determined at 104 that the elapsed time during which the detection signal satisfies the signal criterion at 103 exceeds the minimum duration. In a case in which the elapsed time exceeds the minimum duration at 104, the venting passage is adjusted at 105 before restarting the method at 101.

[0066] Figure 2B is a flowchart 110 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. Corresponding operations with respect to the method illustrated in Fig. 2A are indicated by the same reference numerals. After the providing a detection signal at 102 at the time of starting at 101, it is determined at 113 if the detection signal satisfies a first signal criterion. The first signal criterion comprises an upper threshold level. The determining if the detection signal satisfies the first signal criterion comprises determining an own voice level from the detection signal and evaluating whether the own voice level has a value larger or equal to the upper threshold level.

[0067] In a case in which the detection signal satisfies the first signal criterion at 113, it is determined at 114 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the first signal criterion exceeds a minimum duration. In a case in which the elapsed time does not exceed the minimum duration, providing a detection signal is performed again at 116, wherein the detection signal comprises information about an own voice activity originating from the voice of the wearer. At 117, it is determined again if the detection signal satisfies the first signal criterion. In a case in which the detection signal does not satisfy the first signal criterion, the method is restarted at 101. In a case in which the detection signal satisfies the first signal criterion, it is determined again at 114 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the first signal criterion at 117 exceeds the minimum duration. In a case in which the elapsed time does not exceed the minimum duration, the providing a detection signal at 116 is repeated until it is determined at 114 that the elapsed time during which the detection signal satisfies the first signal criterion at 117 exceeds the minimum duration. In a case in which the elapsed time exceeds the minimum duration at 114, the venting passage is adjusted at 115 by enlarging the effective size of the

venting passage before restarting the method at 101.

[0068] In a case in which the detection signal does not satisfy the first signal criterion at 113, it is determined at 123 if the detection signal satisfies a second signal criterion. The second signal criterion comprises a lower threshold level. The determining if the detection signal satisfies the second signal criterion comprises determining an own voice level from the detection signal and evaluating whether the own voice level has a value smaller or equal to the lower threshold level. In a case in which the detection signal does not satisfy the second signal criterion, the method is restarted at 101. In a case in which the detection signal satisfies the second signal criterion, the venting passage is adjusted at 125 by reducing the effective size of the venting passage before restarting the method at 101.

[0069] Figure 2C is a flowchart 120 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. Corresponding operations with respect to the methods illustrated in Figs. 2A and 2B are indicated by the same reference numerals. After the providing a detection signal at 102 at the time of starting at 101 and the determining at 113 if the detection signal satisfies the first signal criterion, the venting passage is adjusted at 115 by enlarging the effective size of the venting passage if the detection signal satisfies the first signal criterion, before restarting the method at 101. If the detection signal does not satisfy the first signal criterion at 113, the determining at 123 if the detection signal satisfies the second signal criterion is performed.

[0070] In a case in which the detection signal does not satisfy the second signal criterion, the method is restarted at 101. In a case in which the detection signal satisfies the second signal criterion, it is determined at 124 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the second signal criterion exceeds a minimum duration. In a case in which the elapsed time does not exceed the minimum duration, providing a detection signal is performed again at 126, wherein the detection signal comprises information about an own voice activity originating from the voice of the wearer. At 127, it is determined again if the detection signal satisfies the second signal criterion. In a case in which the detection signal does not satisfy the second signal criterion, the method is restarted at 101. In a case in which the detection signal satisfies the second signal criterion, it is determined again at 124 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the second signal criterion at 127 exceeds the minimum duration. In a case in which the elapsed time does not exceed the minimum duration, the providing of a detection signal at 126 is repeated until it is determined at 124 that the elapsed time during which the detection signal satisfies the second signal criterion at 127 exceeds the minimum duration. In a case in which the elapsed time exceeds the minimum duration at 124, the venting passage is adjusted at 125 by reducing the effective size of the venting passage before restarting

the method at 101. Figure 2D is a flowchart 130 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. Corresponding operations with respect to the methods illustrated in Figs. 2A - 2C are indicated by the same reference numerals. After the providing a detection signal at 102 at the time of starting at 101 and the determining at 113 if the detection signal satisfies the first signal criterion, the determining at 114 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the first signal criterion exceeds a minimum duration is performed if the first signal criterion is satisfied by the detection signal. The minimum duration can be set as a first minimum duration. If the elapsed time does not exceed the first minimum duration, the providing a detection signal at 116 is repeated until it is determined at 114 that the elapsed time during which the detection signal satisfies the first signal criterion at 117 exceeds the first minimum duration. In a case in which the elapsed time exceeds the first minimum duration at 114, the venting passage is adjusted at 115 by enlarging the effective size of the venting passage before restarting the method at 101.

[0071] If the detection signal does not satisfy the first signal criterion at 113, the determining at 123 if the detection signal satisfies the second signal criterion is performed. If the detection signal does not satisfy the second signal criterion at 123, the method is restarted at 101. If the detection signal satisfies the second signal criterion at 123, the determining at 124 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the second signal criterion exceeds a minimum duration is performed. The minimum duration can be set as a second minimum duration. If the elapsed time does not exceed the second minimum duration, the providing a detection signal at 126 is repeated until it is determined at 124 that the elapsed time during which the detection signal satisfies the first signal criterion at 127 exceeds the second minimum duration. In a case in which the elapsed time exceeds the second minimum duration at 124, the venting passage is adjusted at 125 by reducing the effective size of the venting passage before restarting the method at 101.

[0072] Figure 2E is a flowchart 140 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. Corresponding operations with respect to the methods illustrated in Figs. 2A - 2D are indicated by the same reference numerals. After the providing a detection signal at 102 at the time of starting at 101, wherein the detection signal comprises information about an own voice activity originating from the voice of the wearer and information about an ambient sound originating from an ambient environment outside the ear canal of the wearer, it is determined at 141 if the detection signal satisfies a signal criterion related to the ambient sound. The determining if the detection signal satisfies a signal criterion related to the ambient sound can comprise determining an ambient sound level. The

ambient sound level can indicate an ambient sound characteristic of the ambient sound. The signal criterion related to the ambient sound can comprise a threshold level of the ambient sound. The determining if the detection signal satisfies a signal criterion related to the ambient sound can comprise determining if the ambient sound level is larger or equal to the threshold level of the ambient sound. In a case in which the detection signal does not satisfy the signal criterion related to the ambient sound, the method is restarted at 101.

[0073] In a case in which the detection signal satisfies the signal criterion related to the ambient sound, the determining at 123 if the detection satisfies a signal criterion related to the own voice activity is performed. The signal criterion related to the own voice activity can comprise a lower threshold level. The determining if the detection signal satisfies the signal criterion related to the own voice activity can comprise determining an own voice level from the detection signal and evaluating whether the own voice level has a value smaller or equal to the lower threshold level. In a case in which the detection signal does not satisfy the signal criterion related to the own voice activity, the method is restarted at 101. In a case in which the detection signal satisfies the signal criterion related to the own voice activity, the determining at 124 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the signal criterion related to the ambient sound and the signal criterion related to the own voice activity exceeds a minimum duration is performed. If the elapsed time does not exceed the minimum duration, the providing a detection signal at 102 is repeated until it is determined at 124 that the elapsed time during which the detection signal satisfies the signal criterion related to the ambient sound at 141 and the signal criterion related to the own voice activity at 123 exceeds the minimum duration. In a case in which the elapsed time exceeds the minimum duration at 124, the venting passage is adjusted at 125 by reducing the effective size of the venting passage before restarting the method at 101.

[0074] In particular, the method illustrated in Fig. 2E can be applied to provide a humidity regulation for an inner ear canal region through the venting passage. In order to provide such a humidity regulation, an enlarged effective size of the venting passage can be beneficial for a more efficient humidity exchange between the inner ear canal and the ambient environment outside the ear canal in any hearing situation in which such an enlarged venting passage would not disturb the sound perception of the wearer. Such a hearing situation can be presumed at a sound level of the ambient sound below the threshold level of the ambient sound, and at an own voice level larger or equal to the upper threshold level. The method illustrated in Fig. 2E can thus be applied to reduce and/or to end such a humidity regulation by an enlarged venting passage in cases in which negative consequences of the humidity regulation for the hearing perception of the wearer can be expected. The method can also comprise

the reversed operations of enlarging the effective size of the venting passage at 115 if the sound level of the ambient sound is determined to be smaller than the threshold level of the ambient sound, and/or if an own voice level smaller or equal to a lower threshold level is determined at 123 in order to increase and/or to start the humidity regulation. In some implementations, the method comprises providing a humidity indication signal indicating a humidity level in the inner region of the ear canal and determining if the humidity indication signal has a value larger than a threshold level of the humidity. If this is the case, a humidity regulation may be provided by the enlarging the effective size of the venting passage, wherein the method illustrated in Fig. 2E can be applied to provide the humidity regulation only during adequate hearing situations. In the contrary case, the humidity regulation may not be provided.

[0075] Figure 2F is a flowchart 140 illustrating a method of operating a hearing device in accordance with some embodiments of the present disclosure. Corresponding operations with respect to the methods illustrated in Figs. 2A - 2E are indicated by the same reference numerals. After the providing a detection signal at 102 at the time of starting at 101 and the determining at 103 if the detection signal satisfies a signal criterion, a minimum duration is set at 151. The minimum duration can be set based on the signal criterion satisfied by the detection signal. In particular, the signal criterion can be selected from a number of signal criteria, wherein each signal criterion of the number of signal criteria is associated with a respective minimum duration. The minimum duration can be set based on the detection signal, in particular based on an own voice level determined from the detection signal. In particular, a different minimum duration can be associated with a different own voice level. The minimum duration can also be set based on the signal criterion and the detection signal.

[0076] After setting the minimum duration at 151, it is determined at 104 if the time elapsed since the time of starting at 101 during which the detection signal satisfies the signal criterion at 103 exceeds the minimum duration. In a case in which the elapsed time does not exceed the minimum duration, a detection signal is provided again at 152 and it is determined again at 153 if the detection signal satisfies the signal criterion until it is determined at 104 that the elapsed time during which the detection signal satisfies the signal criterion at 153 exceeds the minimum duration. In a case in which the elapsed time exceeds the minimum duration at 104, the venting passage is adjusted at 105 before restarting the method at 101.

[0077] Figure 3A illustrates a detection signal 302 in accordance with some embodiments of the present disclosure. In some implementations, as depicted in Fig. 3A, detection signal 302 comprises information about an own voice activity originating from a voice of the wearer. In some other implementations, detection signal 302 comprises information about an ambient sound originat-

ing from the ambient environment or information about both an own voice activity and an ambient sound. For instance, detection signal 302 may correspond to a detection signal provided by detection unit 2, 12, 22, 32, 42 of hearing device 1, 11, 21, 31, 41 illustrated in Figs. 1A - 1E. Detection signal 302 may also correspond to a signal obtained after a processing of the detection signal provided by detection unit 2, 12, 22, 32, 42 by processor 4 of hearing device 1, 11, 21, 31, 41. An own voice level may be determined from detection signal 302 by processor 4 of hearing device 1, 11, 21, 31, 41, the own voice level indicating at least one characteristic of the own voice activity.

[0078] Fig. 3A illustrates detection signal 302 in a graph 301 showing a functional dependence of the own voice level 305 relative to a detection time 304. Detection time 304 is represented by a horizontal axis of graph 301. Own voice level 305 is represented by a vertical axis of graph 301. Detection time 304 can be a time during which detection signal 302 is provided by detection unit 2, 12, 22, 32, 42 to processor 4 of hearing device 1, 11, 21, 31, 41. In some implementations, detection signal 302 is continuous during detection time 304, as illustrated in Fig. 3A. For instance, detection signal 302 can be continuously provided by detection unit 2, 12, 22, 32, 42 to processor 4 during detection time 304. In some other implementations, detection signal 302 is discontinuous during the detection time 304. In particular, detection signal 302 can comprise a pulsed signal. The pulsed signal can comprise a number of signal pulses comprising the information about own voice activity and/or ambient sound separated in time by a signal interruption period. Detection signal 302 may take a baseline value during the signal interruption period. The signal interruption period can be substantially constant between the signal pulses or can be different between different signal pulses. For instance, detection signal 302 can be discontinuously provided by detection unit 2, 12, 22, 32, 42 to processor 4 during detection time 304, in particular as a pulsed signal.

[0079] In the exemplary detection signal illustrated in Fig. 3A, own voice level 305 varies in between a plurality of discrete levels 309. Discrete levels 309 comprise a lower level 306 and an upper level 307. Lower level 306 can represent a decreased level of at least one characteristic of the wearer's own voice relative to upper level 307. Upper level 307 can represent an increased level of at least one characteristic of the wearer's own voice relative to lower level 306. In some implementations, as illustrated in Fig. 3A, own voice level 305 only varies in between lower level 306 and upper level 307. In particular, lower level 306 can represent any level that has been determined to be smaller or equal to a threshold level of the own voice characteristic, and upper level 307 can represent any level that has been determined to be larger than the threshold level of the own voice characteristic.

[0080] In some implementations, own voice level 305

varies in between at least three discrete levels 309 comprising lower level 306, upper level 307, and an intermediate level 308. Intermediate level 308 can represent an increased level of at least one characteristic of the wearer's own voice relative to lower level 306, and a decreased level of the at least one characteristic of the wearer's own voice relative to upper level 307. In particular, lower level 306 can represent any level smaller than a lower threshold level of the own voice characteristic, upper level 307 can represent any level larger than an upper threshold level of the own voice characteristic, and intermediate level 308 can represent any level larger or equal to the lower threshold level and smaller or equal to the upper threshold level.

[0081] In some implementations, own voice level 305 varies in between at least four discrete levels 309 comprising lower level 306, upper level 307, and at least two intermediate levels 308. Each intermediate level 308 can represent a different level of the at least one characteristic of the wearer's own voice, in particular such that each intermediate level 308 represents an increased level or a decreased level of the at least one characteristic of the wearer's own voice relative to the other levels 306, 307, 308. In particular, each intermediate level 308 can represent any level larger or equal to a lower threshold level and smaller or equal to an upper threshold level. Each intermediate level 308 can be associated with a different lower threshold level and a different upper threshold level. The upper threshold level and lower threshold level of two successive intermediate levels 308 can be provided as the same level. In some implementations, own voice level 305 varies in between lower level 306, upper level 307, and a plurality of intermediate levels 308. In this way, when a sufficient large number of intermediate levels 308 is provided, a substantially continuous function may be provided as detection signal 302. Lower level 306, upper level 307, and intermediate levels 308 can thus be provided substantially as a continuum of levels of the at least one characteristic of the wearer's own voice. Each intermediate level 308 can be associated with a lower threshold level corresponding to a closest decreased level of levels 306, 308, and an upper threshold level corresponding to a closest increased level of levels 307, 308.

[0082] Figures 3B - 3D each illustrate a control signal 322, 332, 342 in accordance with some embodiments of the present disclosure. Control signal 322, 332, 342 is illustrated in a graph 321, 331, 341 showing a functional dependence of a control signal amplitude 325 of control signal 322, 332, 342 relative to a control time 324. Control time 324 is represented by a horizontal axis of graphs 321, 331, 341. Control signal amplitude 325 is represented by a vertical axis of graphs 321, 331, 341. Moreover, own voice detection signal 302 illustrated in graph 301 of Fig. 3A is indicated by dashed lines in graphs 321, 331, 341 of Figs. 3B - 3D. For instance, control signal 322, 332, 342 may correspond to a control signal provided by processor 4 to the acoustic valve of active vent 8

of hearing device 1, 11, 21, 31, 41 illustrated in Figs. 1A - 1E. Control time 324 can be a time during which an adjustment of the venting passage of active vent 8 by the acoustic valve is controlled by processor 4.

[0083] In the exemplary control signals 322, 332, 342 illustrated in Figs. 3B - 3D, control signal amplitude 325 varies in between a plurality of discrete levels 329. Each level 329 of control signal amplitude 325 can be associated with an own voice level 305 of detection signal 302, in particular a different own voice level 305. Discrete levels 329 comprise a lower level 326 and an upper level 327. Lower level 326 can correspond to a control command to the acoustic valve to reduce an effective size of the venting passage. Upper level 327 can correspond to a control command to the acoustic valve to enlarge an effective size of the venting passage. In some implementations, as illustrated in Figs. 3B - 3D, control signal amplitude 325 only varies in between lower level 326 and upper level 327. In particular, lower level 326 can represent a control command to reduce the effective size of the venting passage to a closed state of the venting passage, and upper level 327 can represent a control command to enlarge the effective size of the venting passage to an open state of the venting passage. The venting passage may thus be switched in between the open state and the closed state by the acoustic valve depending on control signal amplitude 325 of control signal 322, 332, 342 varying over control time 324.

[0084] In some implementations, control signal amplitude 325 varies in between at least three discrete levels 329 comprising lower level 326, upper level 327, and at least one intermediate level 328. In particular, lower level 326 can represent a control command to adjust the effective size of the venting passage to a fully reduced state, upper level 327 can represent a control command to adjust the effective size of the venting passage to a fully enlarged state, and each of intermediate levels 328 can represent a control command to adjust the venting passage to a respective effective size between the fully reduced state and the fully enlarged state. In some implementations, control signal amplitude 325 varies in between lower level 326, upper level 327, and a plurality of intermediate levels 328. In particular, when a sufficient large number of intermediate levels 328 is provided, a substantially continuous adjustment of the effective size of the venting passage by the acoustic valve can be controlled by control signal 322, 332, 342. Active vent 8 may be configured to provide substantially continuously varying effective sizes of the venting passage depending on control signal 322, 332, 342.

[0085] Control signal 322, 332, 342 is provided depending on detection signal 302. Processor 4 of hearing device 1, 11, 21, 31, 41 illustrated in Figs. 1A - 1E can be configured to provide control signal 322, 332, 342 based on detection signal 302, in particular after processing of a detection signal provided by detection unit 2, 12, 22, 32, 42. Processor 4 can be configured to determine own voice level 305 of detection signal 302 at different

detection times 304 and to evaluate own voice level 305 relative to a signal criterion. The signal criterion can comprise at least one threshold level. In particular, the signal criterion can be determined to be satisfied by processor 4 if own voice level 305 is smaller or equal to the threshold level. For instance, such a signal criterion may be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes lower level 306, and may not be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes upper level 307. The signal criterion can also be determined to be satisfied by processor 4 if own voice level 305 is larger or equal to the threshold level. For instance, such a signal criterion may be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes upper level 307, and may not be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes lower level 306.

[0086] The signal criterion can also comprise at least an upper threshold level and a lower threshold level. In particular, the signal criterion can be determined to be satisfied by processor 4 if own voice level 305 is smaller or equal to the lower threshold level. For instance, assuming the lower threshold level larger or equal to at least one intermediate level 308 of detection signal 302, such a signal criterion may be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes lower level 306 and/or said at least one intermediate level 308, and may not be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes upper level 307. The signal criterion can also be determined to be satisfied by processor 4 if own voice level 305 is larger or equal to the upper threshold level. For instance, assuming the upper threshold level larger or equal to at least one intermediate level 308 of detection signal 302, such a signal criterion may be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes upper level 307, and may not be satisfied at a detection time 304 during which own voice level 305 of detection signal 302 takes lower level 306 and/or said at least one intermediate level 308.

[0087] Control signal 322, 332, 342 further depends on whether an elapsed time, during which detection signal 302 satisfies the signal criterion, exceeds a minimum duration. Processor 4 can be configured to provide control signal 322, 332, 342 based on whether or not detection signal 302 satisfies the signal criterion for a time period exceeding the minimum duration. The minimum duration can depend on at least one of the respective own voice level 305 and the respective signal criterion. Processor 4 can be configured to set the minimum duration accordingly, in particular depending on own voice level 305 of detection signal 302 at a detection time 304 corresponding to a beginning of the minimum duration and/or a signal criterion associated with the own voice level 305 at the beginning of the minimum duration. In particular, the signal criterion associated with the own voice level 305 at the beginning of the minimum duration

can be provided by a signal criterion satisfied by the own voice level 305 at the beginning of the minimum duration.

[0088] Control signal 322 schematically indicated in Fig. 3B depends on whether an elapsed time, during which detection signal 302 satisfies a first signal criterion, exceeds a first minimum duration 344. The first signal criterion is determined to be satisfied by processor 4 if own voice level 305 of detection signal 302 is larger or equal to a threshold level. The first signal criterion can thus be satisfied by an own voice level 305 taking upper level 307 and/or at least one intermediate level 308 larger or equal to the threshold level. Processor 4 is configured to set first minimum duration 344 after determining that own voice level 305 satisfies the first signal criterion. Processor 4 is further configured to determine an elapsed time during which own voice level 305 satisfies the first signal criterion and if the elapsed time exceeds the first minimum duration. Processor 4 is also configured to provide control signal amplitude 325 of control signal 322 at upper level 327 if the elapsed time exceeds the first minimum duration.

[0089] In the exemplary detection signal 302 illustrated in Fig. 3A, own voice level 305 of detection signal 302 takes upper level 307 only once for a period longer than first minimum duration 344. In consequence, first signal criterion is determined to be satisfied by processor 4 only once in detection signal 302 for an elapsed time exceeding first minimum duration 344. Control signal 322, as illustrated in Fig. 3B, thus comprises one signal portion in which control signal amplitude 325 of control signal 322 is changed by processor 4 from lower level 326 to upper level 327. An adjusting of the effective size of the venting passage by the acoustic valve of active vent 8 corresponding to an enlarging of the effective size is controlled by this changing signal portion of control signal 322.

[0090] Control signal 322 further depends on whether detection signal 302 satisfies a second signal criterion. The second signal criterion is determined to be satisfied by processor 4 if own voice level 305 of detection signal 302 is smaller than the threshold level. The second signal criterion can thus be satisfied by an own voice level 305 taking lower level 306 and/or at least one intermediate level 308 smaller than the threshold level. Processor 4 is configured to provide control signal amplitude 325 of control signal 322 at lower level 326 after determining that own voice level 305 satisfies the second signal criterion, in particular without a requirement of a minimum duration during which the second signal criterion is satisfied by own voice level 305. Control signal 322, as illustrated in Fig. 3B, is thus immediately changed by processor 4 from upper level 327 to lower level 326 after determining that own voice level 305 satisfies the second signal criterion. An adjusting of the effective size of the venting passage by the acoustic valve of active vent 8 corresponding to a reducing of the effective size is controlled by this changing signal portion of control signal 322, and to keep the momentary effective size by the

remaining constant signal portion.

[0091] Control signal 332 schematically indicated in Fig. 3C depends on whether an elapsed time, during which detection signal 302 satisfies the second signal criterion, exceeds a second minimum duration 333. Processor 4 is configured to set second minimum duration 333 after determining that own voice level 305 satisfies the second signal criterion. Processor 4 is further configured to determine an elapsed time during which own voice level 305 satisfies the second signal criterion and if the elapsed time exceeds second minimum duration 333. Processor 4 is also configured to provide control signal amplitude 325 of control signal 332 at lower level 326 if the elapsed time exceeds the second minimum duration.

[0092] Detection signal 302 illustrated in Fig. 3A, however, does not include a signal portion comprising own voice level 305 at lower level 306 for a longer time than second minimum duration 333. In consequence, second signal criterion is not determined to be satisfied by processor 4 in detection signal 302 for an elapsed time exceeding second minimum duration 333. Control signal 332, as illustrated in Fig. 3C, is thus not changed by processor 4 from upper level 327 to lower level 326. No adjusting of the effective size of the venting passage corresponding to a reducing of the effective size is controlled by control signal 332.

[0093] Control signal 332 also depends on whether detection signal 302 satisfies the first signal criterion. Processor 4 is configured to provide control signal amplitude 325 of control signal 332 at lower level 326 after determining that own voice level 305 satisfies the first signal criterion, in particular without a requirement of a minimum duration during which the first signal criterion is satisfied by own voice level 305. Control signal 332, as illustrated in Fig. 3C, is thus immediately changed by processor 4 from lower level 326 to upper level 327 after determining that own voice level 305 satisfies the first signal criterion. An adjusting of the effective size of the venting passage corresponding to an enlarging of the effective size is controlled by this changing signal portion of control signal 332, and to keep the momentary effective size by the remaining constant signal portion.

[0094] Control signal 342 schematically indicated in Fig. 3D depends on whether an elapsed time, during which detection signal 302 satisfies a first signal criterion, exceeds first minimum duration 344, and whether an elapsed time, during which detection signal 302 satisfies the second signal criterion, exceeds second minimum duration 333. Processor 4 is configured to set first minimum duration 344 after determining that own voice level 305 satisfies the first signal criterion, and to set second minimum duration 333 after determining that own voice level 305 satisfies the second signal criterion. Processor 4 is further configured to determine an elapsed time during which own voice level 305 satisfies the first signal criterion and if the elapsed time exceeds the first minimum duration, and to determine an elapsed time during

which own voice level 305 satisfies the second signal criterion and if the elapsed time exceeds second minimum duration 333. Processor 4 is also configured to provide control signal amplitude 325 of control signal 342 at upper level 327 if the elapsed time exceeds first minimum duration 344, and to provide control signal amplitude 325 of control signal 342 at lower level 326 if the elapsed time exceeds second minimum duration 333.

[0095] Detection signal 302 illustrated in Fig. 3A, includes one signal portion comprising own voice level 305 at upper level 307 for a longer time than first minimum duration 344, and no signal portion comprising own voice level 305 at lower level 306 for a longer time than second minimum duration 333. In consequence, first signal criterion is determined to be satisfied by processor 4 once in detection signal 302 for an elapsed time exceeding first minimum duration 344, and second signal criterion is not determined to be satisfied by processor 4 in detection signal 302 for an elapsed time exceeding second minimum duration 333. Control signal 342, as illustrated in Fig. 3D, thus comprises a signal portion in which control signal amplitude 325 of control signal 342 is changed by processor 4 from lower level 326 to upper level 327 and no signal portion changed by processor 4 from upper level 327 to lower level 326. Accordingly, an adjusting of the effective size of the venting passage corresponding to an enlarging of the effective size is controlled by this changing signal portion of control signal 342, and to keep the effective size by the remaining constant signal portion.

[0096] Figures 4A and 4B illustrate a cross-sectional view of a hearing device 411, 412 in accordance with some embodiments of the present disclosure. Hearing device 411, 412 comprises an earpiece 413 inserted in an ear canal 401. Ear canal 401 comprises an ear canal wall 402 and extends from an ear opening of the ear located downstream of earpiece 413 to an eardrum located upstream of earpiece 413. The term upstream is used to refer to an inner region 403 of ear canal 401 located between earpiece 413 and the ear drum, and the term downstream is used to refer to an outer region 404 of the ear canal between earpiece 413 and the ambient environment, in particular at the ear canal opening. Earpiece 413 is configured to create a seal with ear canal wall 402. The seal may be formed by earpiece 413 blocking ear canal 401. The hearing device may comprise a flexible member 415 comprising a contact surface 416 that contacts ear canal wall 402 when sealing ear canal 401. Flexible member 415 may comprise an ear tip, a dome, or the like. Flexible member 415 may be formed from a flexible material that conforms to the shape of ear canal 401 when earpiece 413 is inserted in ear canal 401, creating a seal between earpiece 413 and ear canal wall 402. By sealing ear canal 401, inner region 403 of ear canal 401 between flexible member 415 and the eardrum can be acoustically sealed from outer region 404 of ear canal 401 between flexible member 415 and the ambient environment outside the ear. Sealing ear canal

401 may prevent ambient sound from passing down the ear canal to the ear drum.

[0097] Earpiece 413 comprises a housing 420 enclosing an acoustic transducer 421. An input circuit 451 is operatively connected with acoustic transducer 421 via an input signal line 452. A sound output 422 of acoustic transducer 421 is in acoustic communication with a sound conduit 425. Sound conduit 425 comprises a side wall 424 delimiting a sound conduit chamber 426 in parallel to a central axis 427 of sound conduit 425. Sound waves can propagate from sound output 422 in a direction of central axis 427 through sound conduit chamber 426 toward inner region 403 of ear canal 401. Earpiece 413 comprises an active vent 430. Vent 430 comprises a venting passage 435. Venting passage 435 extends from inner region 403 through sound conduit 425 and through vent openings 431, 432 toward outer region 404 of ear canal 401. Vent openings 431, 432 are provided in side wall 424 of sound conduit 425. Venting passage 435 provides a pathway for sound waves and/or air contained inside ear canal 401 between inner region 403 and outer region 404 of ear canal 401. In this way, venting passage 435 is configured to provide a ventilation channel through vent openings 431, 432 between inner region 403 and outer region 404 of ear canal 401.

[0098] Active vent 430 comprises an acoustic valve 441. Acoustic valve 441 comprises a valve body 444 and a valve drive 445. Valve drive 445 is configured to move valve body 444 relative to vent openings 431, 432. Thus, acoustic valve 441 is configured to enlarge or reduce an opening size of vent openings 431, 432. In this way, acoustic valve 441 is configured to adjust an effective size of venting passage 435. Fig. 4A illustrates valve body 444 in a position in which vent openings 431, 432 are open such that they have a fully enlarged effective size. In this position, venting passage 435 is adjusted such that an effective size of venting passage 435 is enlarged. The seal between inner region 403 and outer region 404 of ear canal 401 can thus be bypassed through venting passage 435. Fig. 4B illustrates valve body 444 in a position in which vent openings 431, 432 are closed such that they have a fully reduced effective size. In this position, venting passage 435 is adjusted such that the effective size of venting passage 435 is fully reduced. The seal between inner region 403 and outer region 404 of ear canal 401 can thus not be bypassed through venting passage 435. In some implementations, valve body 444 may also be provided in at least one position in which vent openings 431, 432 are not open corresponding to a fully enlarged effective size and are not closed corresponding to a fully reduced effective size but in which vent openings 431, 432 are provided with at least one intermediate effective size. In such a position, venting passage 435 is adjusted such that an effective size of venting passage 435 through vent openings 431, 432 is reduced with respect to the fully enlarged effective size of the venting passage illustrated in Fig. 4A and enlarged with respect to the fully reduced effective size of the vent-

ing passage illustrated in Fig. 4B. The seal between inner region 403 and outer region 404 of ear canal 401 can thus be bypassed through venting passage 435, but less efficiently as compared to a fully enlarged effective size of the venting passage.

[0099] The above description of vent 430 has the illustrative purpose to exemplify by means of a concrete example some embodiments of a venting passage and an acoustic valve configured to adjust an effective size of the venting passage. The above description of vent 430 based on this concrete example, however, is not intended to limit the scope of the present disclosure to those embodiments. As will be understood by a skilled person, any other venting passage and any other acoustic valve configured to adjust an effective size of the venting passage can be employed in place of vent 430. For instance, an active vent comprising such a venting passage and acoustic valve is also disclosed in patent application No. PCT/EP2018/069105 and in publications Nos. US 6,549,635 B1, US 2017/0208382 A1, EP 2 164 277 A2, EP 2 835 987 A1, and EP 2 536 167 A1, wherein each of those vents could be equally employed in the place of vent 430 illustrated in Figs. 4A and 4B.

[0100] Hearing device 411, 412 further comprises a processor 454. Processor 454 is operatively connected to acoustic valve 441 via a control signal line 449. Acoustic valve 441 is configured to adjust venting passage 435 after receiving a vent operation signal 322, 332, 342, as schematically exemplified in Figs. 3B - 3D, from processor 454. Processor 454 is operatively connected to input circuit 451 via a sound control signal line 457. Processor 454 can be configured to adjust a gain of input circuit 451 via sound control signal line 457.

[0101] Hearing device 411, 412 further comprises a detection unit 455. Detection unit 455 comprises a sound detector 456. Sound detector 456 is configured to provide a detection signal comprising information about an ambient sound originating from the ambient environment and/or an own voice activity originating from a voice of the wearer. Sound detector 456 can comprise at least one microphone. Sound detector 456 is operatively connected to input circuit 451 via a sound signal line 453. Processor 454 is operatively connected to sound detector 456 via a sound detection signal line 458.

[0102] Detection unit 455 further comprises an own voice detector 462. Own voice detector 462 is configured to provide a detection signal comprising information about an own voice activity originating from a voice of the wearer. Processor 454 is operatively connected to own voice detector 462 via an own voice detection signal line 463. Own voice detector 462 is sensitive to bone vibrations caused by an own voice activity. Own voice detector 462 is provided on an inner surface 417 of flexible member 415. In some other implementations, own voice detector 462 is provided on an outer surface of flexible member 415, in particular at contact surface 416 of flexible member 415. In this way, when earpiece 413 is inserted into ear canal 401, own voice detector 462 is

positioned in ear canal 401 such that own voice detector 462 can pick up the bone vibrations caused by own voice activity from ear canal wall 402, in particular the bone vibrations the bone vibrations passing from ear canal wall 402 through flexible member 415 to own voice detector 462.

[0103] Hearing device 412 illustrated in Fig. 4B comprises a detection unit 481 including sound detector 456 and an own voice detector 472. Processor 454 is operatively connected to own voice detector 472 via an own voice detection signal line 473. Own voice detector 472 is sensitive to bone vibrations caused by an own voice activity. Own voice detector 472 is provided on an outer surface of a flexible member 475 configured to contact ear canal wall 402 when earpiece 413 is inserted into ear canal 401 such that flexible member 475 is also in contact with ear canal wall 402. Flexible member 475 is provided with elastic properties such that a tensioning force is provided for own voice detector 472, by which tensioning force own voice detector 472 is pushed against ear canal wall 402. In this way, own voice detector 472 can pick up the bone vibrations caused by own voice activity directly from ear canal wall 402. Flexible member 475 is provided downstream with respect to flexible member 415 providing the sealing of ear canal 401. Another flexible member 475 and own voice detector 472 may be provided upstream with respect to flexible member 415 providing the sealing of ear canal 401, in order to further improve the own voice detection at ear canal wall 402. Own voice detectors 462, 472 can offer the advantage that a detection signal may be provided almost instantly at the time of occurrence and/or non-occurrence of an own voice activity, such that it can be quickly received by processor 454. In particular, no additional processing time or a comparatively small processing time may be required by own voice detectors 462, 472 to generate detection signal 302.

[0104] The above description of own voice detectors 462, 472 in hearing 411, 412 has an illustrative purpose to exemplify the detector by means of a concrete example some. The description of own voice detectors 462, 472 based on this example, however, is not intended to limit the scope of the present disclosure to those embodiments. As will be understood by a skilled person, any other detector configured to provide a detection signal containing information about an own voice activity can be employed in place of detectors 462, 472. For instance, own voice detectors as disclosed in European Patents No. EP 2 242 289 B1 and No. EP 2 699 021 B1, and Patent Application Publication No. EP 3 005 731 B1 can be also applied.

[0105] Detection unit 481 further comprises a humidity detector 482. Humidity detector 482 is provided at an inner end of earpiece 413, in particular at an inner end of sound conduit 425, such that humidity detector 482 is positioned inside inner region 403 of ear canal 401 when earpiece 413 is inserted into ear canal 401. In this way, humidity detector 482 is configured to detect a humidity

level in inner region 403 of ear canal 401. Processor 454 is operatively connected to humidity detector 482 via a humidity detection signal line 483. Hearing device 412 also comprises a second humidity detector 484. Second humidity detector 484 is provided at an outer end of earpiece 413, in particular at an outer end of housing 420, such that second humidity detector 484 is positioned at outer region 404 of ear canal 401 when earpiece 413 is inserted into ear canal 401. In this way, humidity detector 484 is configured to detect a humidity level in outer region 404 of ear canal 401, in particular in the ambient environment outside ear canal 401. Processor 454 is operatively connected to second humidity detector 484 via a humidity detection signal line 485. Processor 454 is configured to evaluate a humidity difference signal based on the humidity level detected by humidity detectors 482, 484. An adjustment of venting passage 435 by acoustic valve 441 can thus be operated in dependence of the humidity difference signal.

[0106] Figure 5A illustrates an own voice detector 512 in accordance with some embodiments of the present disclosure. Own voice detector 512 is a strain gauge configured to measure strain variations. Strain gauge 512 comprises a strain sensitive layer 513. When in contact with ear canal wall 402, layer 513 is receptive to bone conducted vibrations of ear canal wall 402 caused by an own voice activity. Strain gauge 512 further comprises a signal output 519 configured to produce an own voice detection signal from the vibrations received by layer 513. Signal output 519 is a conductor provided on layer 513. Conductor 519 is configured to change its electrical resistance when vibrations are received by layer 513. By the changing electrical resistance upon own voice activity, an own voice detection signal can be provided.

[0107] Strain sensitive layer 513 is formed from a flexible material such that it is configured to adapt to a non-planar surface 502. Layer 513 is thus configured to conform its surface to a curvature of surface 502, as indicated by arrow 503 in Fig. 5B, in particular to be bent along the curvature of surface 502. Surface 502 can be provided as a surface inside ear canal 401, in particular ear canal wall 402, and/or a surface of earpiece 413, in particular inner surface 417 and/or outer surface 416 of flexible member 415. Various flexible materials are conceivable from which layer 513 may be formed. Those materials may include piezoresistive composites, as published by Stassi, Stefano, Valentina, Cauda, Canavese, Giancarlo, and Fabrizio Pirri, Candido in "Flexible Tactile Sensing Based on Piezoresistive Composites: A Review", Sensors (Basel, Switzerland), 14, 5296-332. doi: 10.3390/s140305296, a parylene film, a carbon paper, in particular prepared from tissue paper, and/or a polydimethylsiloxane elastomer, as published by Yuanqing Li, Yarjan Abdul Samad, Tarek Taha, Guowei Cai, Shao-Yun Fu, and Kin Liao in "Highly Flexible Strain Sensor from Tissue Paper for Wearable Electronics", ACS Sustainable Chemistry & Engineering 2016 4 (8), 4288-4295, doi: 10.1021/acssuschemeng.6b00783.

[0108] Figure 5B illustrates an own voice detector 522 in accordance with some embodiments of the present disclosure. Own voice detector 522 is a strain gauge configured to measure strain variations. Strain gauge 522 comprises two vibration receptive layers 523, 525. Layers 523, 525 adjoin each other at their inner surface. Each layer 523, 525 comprises a matrix of fibers 524, 526 at its inner surface. Thus, fibers 524, 526 interlock in between the inner surfaces of layers 523, 525. When layers 523, 525 are subjected to strain variations, in particular compression, shear loading or torsion, the interaction between fibers 524, 526 changes. When in contact with ear canal wall 402, layers 523, 525 are thus receptive to bone conducted vibrations of ear canal wall 402 caused by an own voice activity. Strain gauge 522 further comprises a signal output 529 configured to produce an own voice detection signal from the vibrations received by layers 523, 525. Fibers 524, 526 may be provided as polymeric nanofibers supported on polydimethylsiloxane layers 523, 525, as published by Changhyun Pang, Gil-Yong Lee, Tae-il Kim, Sang Moon Kim, Hong Nam Kim, Sung-Hoon Ahn, and Kahp-Yang Suh, in "A flexible and highly sensitive strain-gauge sensor using reversible interlocking of nanofibers", Nature Materials 11, 795-801 (2012), doi:10.1038/nmat3380. Those materials are highly flexible such that strain sensitive layers 523, 525 can be configured to adapt to non-planar surface 502.

[0109] Own voice detector 512 and/or own voice detector 522 as described above can be provided in some implementations of hearing device 411 and/or of hearing device 412 in the place of own voice detectors 462, 472. In this way a comparatively fast and nonetheless reliable detection of an own voice activity can be provided. Own voice detectors 512, 522 may be placed at a location in ear canal 401 where a speech-induced vibrational deflection of ear canal wall 402 is large and/or a deflection of ear canal wall 402 induced by a jaw-movement is comparatively small. Thus, the own voice sensitivity can be enhanced. The latter aspect may be applied to avoid detection of an ear canal wall deflection induced by yawning and/or eating. In some implementations, those processes that are not related to an own voice activity may be derived by signal processing, in particular by an algorithm that distinguishes such processes from speech. In some implementations, processor 454 may be configured to perform such a processing of the own voice detection signal. In some implementations, processes that are not related to an own voice activity may be separated from the own voice detection signal by a frequency filter, in particular by employing a high-pass filter. In such a manner, the own voice detection signal may be provided almost instantly at the time of occurrence and/or non-occurrence of an own voice activity.

[0110] An orientation of own voice detector 512, 522 with respect to ear canal wall 402 may be chosen such that a maximum sensitivity with respect to a deflection of ear canal wall 402 is provided. In some implementations, layer 513, 523, 525 is oriented in a circumferential direc-

tion of ear canal wall 402, in particular such that vibrations tangentially to ear canal wall 402 can be detected. In some implementations, layer 513, 523, 525 is oriented in an axial direction of ear canal wall 402, in particular such that vibrations in an axial direction of ear canal 401 can be detected. In some implementations, layer 513, 523, 525 is configured to be sensitive to vibrations in two dimensions, in particular such that own voice detector 512, 522 is provided as a two dimensional strain gauge, in order to obtain vibration detection in a tangential and axial direction of ear canal wall 402.

[0111] Own voice detector 512, 522 may be integrated in a dome, in a flexible section of the earpiece, in particular a flexible section of an in the ear shell or an earmold, such that it can be provided inside the ear canal 401. In some implementations, own voice detector 512, 522 is provided in a tensioning member. The tensioning member may be provided as a pre-tensioned flexible structure configured to press own voice detector 512, 522 against ear canal wall 402. The tensioning member may be curved, in particular bent, to facilitate mounting and removing on ear canal wall 402. The tensioning member may comprise a flexible strip configured to be attached to ear canal 402. The tensioning member may comprise a flexible base structure mounted on a housing of the earpiece, in particular such that own voice detector 512, 522 is provided in between the housing and the base structure. The base structure may be configured to be prestressed against ear canal wall 402. Own voice detector 512, 522 may further be provided inside a support member configured to contact ear canal wall 402 after insertion, in particular in a support tube and/or a stent-like structure configured to sit in the ear canal.

[0112] While the principles of the disclosure have been described above in connection with specific devices and methods, it is to be clearly understood that this description is made only by way of example and not as limitation on the scope of the invention. The above described preferred embodiments are intended to illustrate the principles of the invention, but not to limit the scope of the invention. Various other embodiments and modifications to those preferred embodiments may be made by those skilled in the art without departing from the scope of the present invention that is solely defined by the claims.

Claims

1. A method of operating a hearing device configured to be at least partially worn inside an ear canal of a wearer, the hearing device comprising a venting passage (435) configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside the ear canal, wherein the method comprises providing a detection signal (302) comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from said ambient

environment, and adjusting an effective size of the venting passage (435) depending on the detection signal (302), **characterized by** determining an elapsed time during which the detection signal (302) satisfies a signal criterion, and adjusting the effective size of the venting passage (435) if the elapsed time exceeds a minimum duration (333, 344).

2. The method according to claim 1, **characterized in that** said signal criterion comprises a first criterion and a second criterion, and said minimum duration (333, 344) comprises a first duration and a second duration, wherein the adjusting the effective size of the venting passage (435) comprises enlarging the effective size of the venting passage (435) if the detection signal (302) satisfies the first criterion within the elapsed time and the elapsed time exceeds the first duration (333, 344), and reducing the effective size of the venting passage (435) if the detection signal (302) satisfies the second criterion within the elapsed time and the elapsed time exceeds the second duration (333, 344).
3. The method according to any of the preceding claims, **characterized by** determining an own voice level (305) from the detection signal (302), the own voice level (305) indicating at least one characteristic of the own voice activity.
4. The method according to claim 3, **characterized by** setting said minimum duration (333, 344) based on at least one of the own voice level (305) and the signal criterion.
5. The method according to claim 3 or 4, **characterized in that** said characteristic of the own voice activity comprises at least one of a signal level of the own voice activity; a signal to noise ratio of the own voice activity; an occurrence of at least one of vowels, consonants, voiced phonemes, and unvoiced phonemes in the own voice activity; an occurrence of at least one of spoken words and phrases in the own voice activity; an occurrence of at least one of speech and pauses in speech in the own voice activity; an occurrence of at least one frequency range in the own voice activity; a frequency bandwidth of the own voice activity; and a temporal variation of the own voice activity.
6. The method according to any of claims 3 to 5, **characterized in that** the signal criterion comprises an own voice threshold level, wherein the own voice level (305) is evaluated relative to the own voice threshold level.
7. The method according to claim 6, **characterized in that** the own voice threshold level comprises an upper threshold level, wherein the adjusting the effective

size of the venting passage (435) is performed depending on whether the own voice level (305) has a value larger or equal to the upper threshold level.

8. The method according to claim 6 or 7, **characterized in that** the own voice threshold level comprises a lower threshold level, wherein the adjusting the effective size of the venting passage (435) is performed depending on whether the own voice level (305) has a value smaller or equal to the lower threshold level.
9. The method according to any of the claims 6 to 8, **characterized by** setting the own voice threshold level relative to a previously determined own voice level (305).
10. The method according to any of the preceding claims, **characterized by** determining an ambient sound level from the detection signal (302), the ambient sound level indicating at least one characteristic of the ambient sound.
11. The method according to claim 10, **characterized in that** said characteristic of the ambient sound comprises at least one of a signal level of the ambient sound; a signal to noise ratio of the ambient sound; an occurrence of at least one frequency range of the ambient sound; a frequency bandwidth of the ambient sound; and a temporal variation of the ambient sound.
12. The method according to claim 10 or 11, **characterized in that** the signal criterion comprises an ambient sound threshold level, wherein the ambient sound level is evaluated relative to the ambient sound threshold level.
13. The method according to any of the claims 6 to 9 and claim 12, **characterized in that** the adjusting the effective size of the venting passage (435) comprises reducing the effective size of the venting passage if the ambient sound level has a value larger or equal to the ambient sound threshold level within the elapsed time, and the own voice level (305) has a value smaller or equal to the own voice threshold level within the elapsed time.
14. A computer-readable medium storing instructions that, when executed by a processor, cause a hearing device to perform operations of the method according to any of claims 1 to 13.
15. A hearing device configured to be at least partially worn inside an ear canal of a wearer, the hearing device comprising a venting passage (435) configured to provide a ventilation between an inner region of the ear canal and an ambient environment outside

the ear canal; an acoustic valve (441) configured to adjust an effective size of the venting passage (435); a detection unit (2, 12, 22, 32, 42, 455, 481) configured to provide a detection signal (302) comprising information about at least one of an own voice activity originating from a voice of the wearer and an ambient sound originating from said ambient environment; and a processor (4, 454) configured to process the detection signal (302) and to provide a control signal (322, 332, 342) to the acoustic valve (441), **characterized in that** the processor (4) is configured to determine an elapsed time during which the detection signal (302) satisfies a signal criterion, and to provide the control signal (322, 332, 342) to adjust the effective size of the venting passage (435) if the elapsed time exceeds a minimum duration (333, 344).

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FIG. 1A

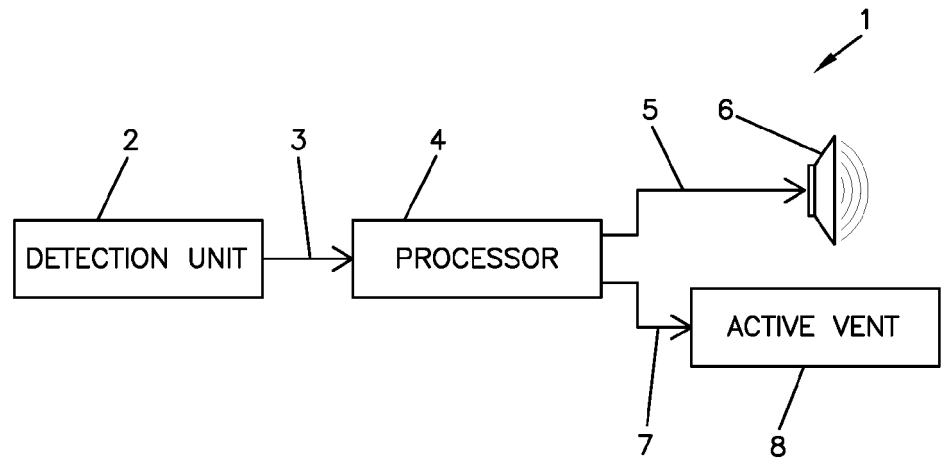


FIG. 1B

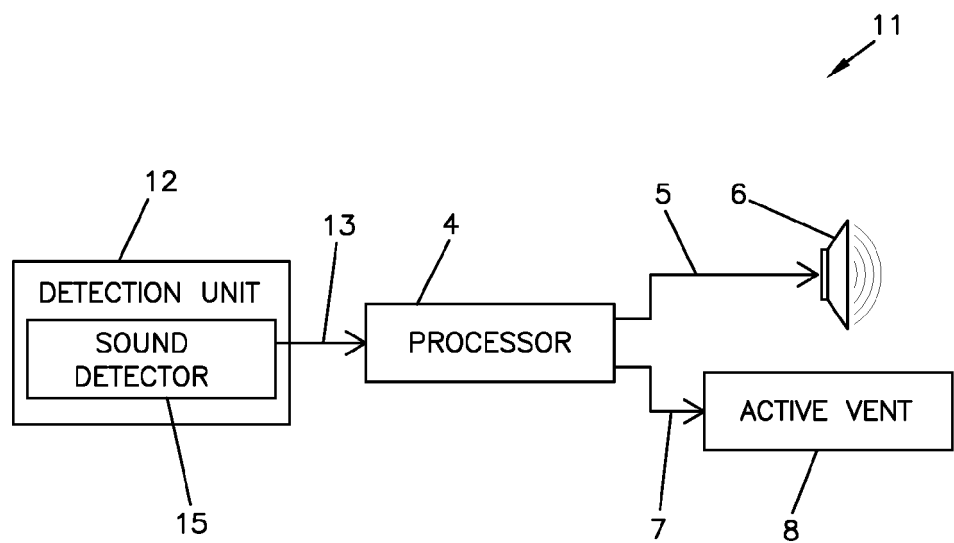


FIG. 1C

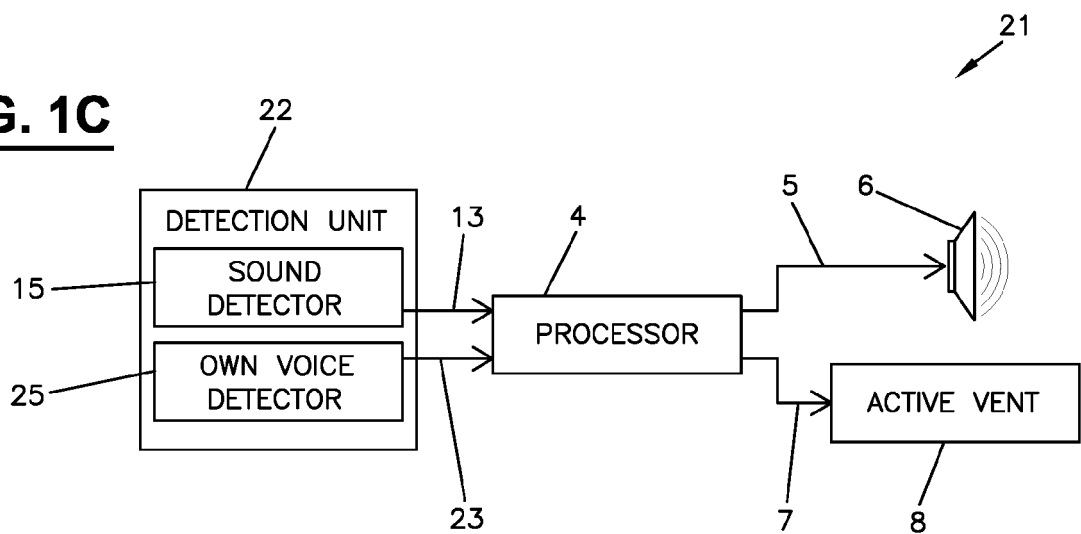


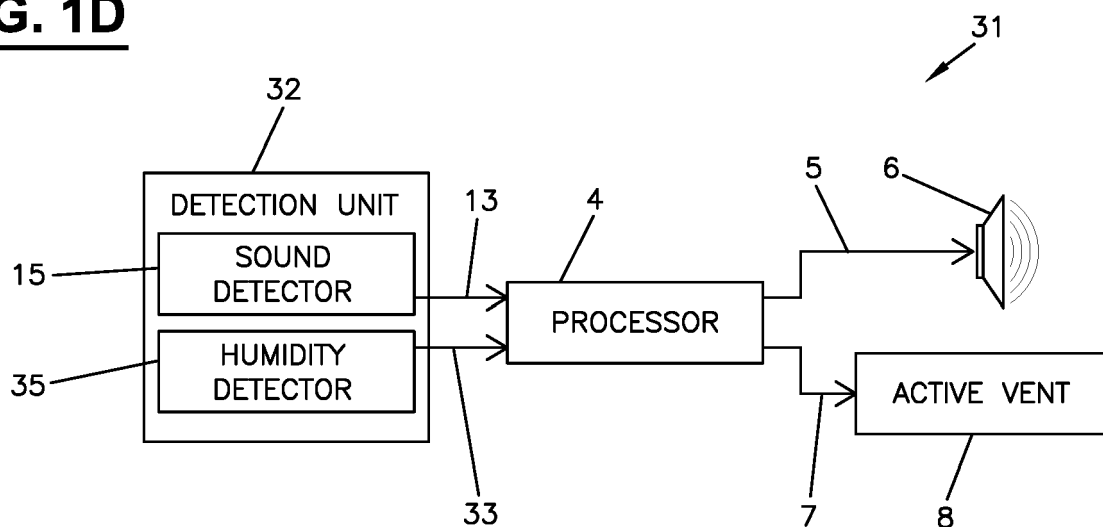
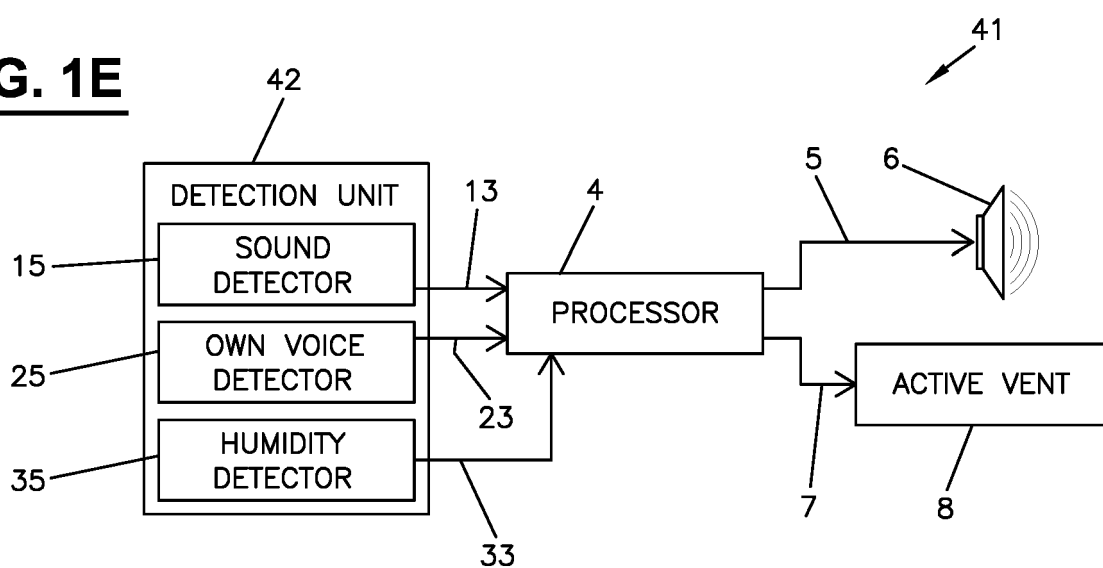
FIG. 1D**FIG. 1E**

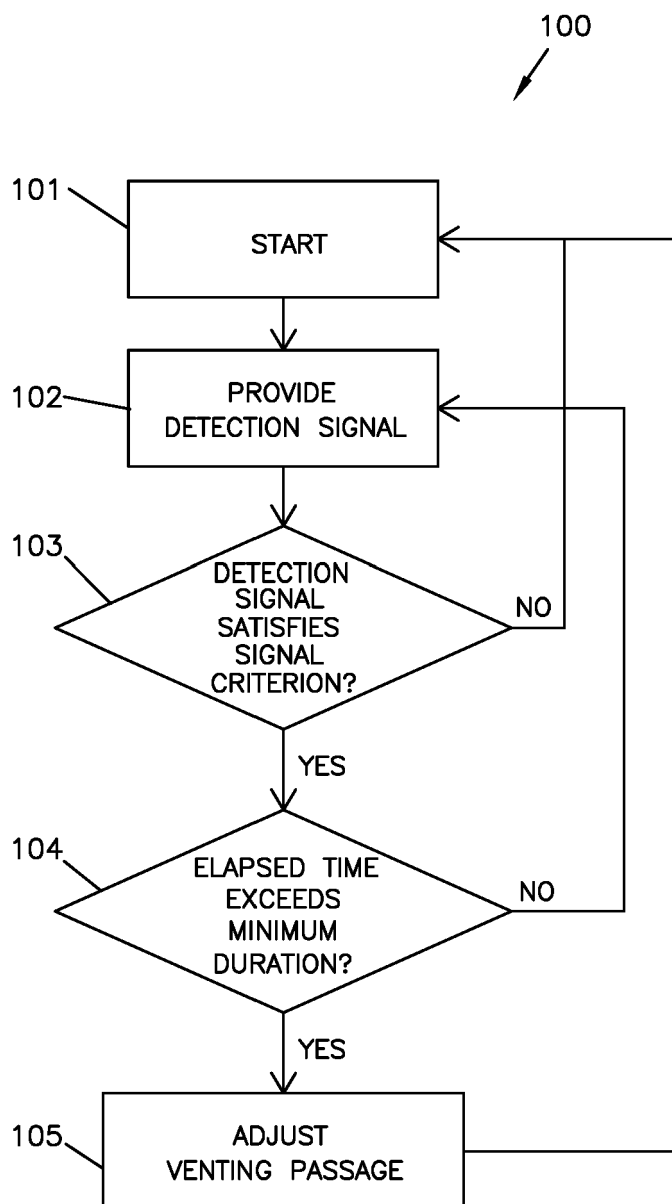
FIG. 2A

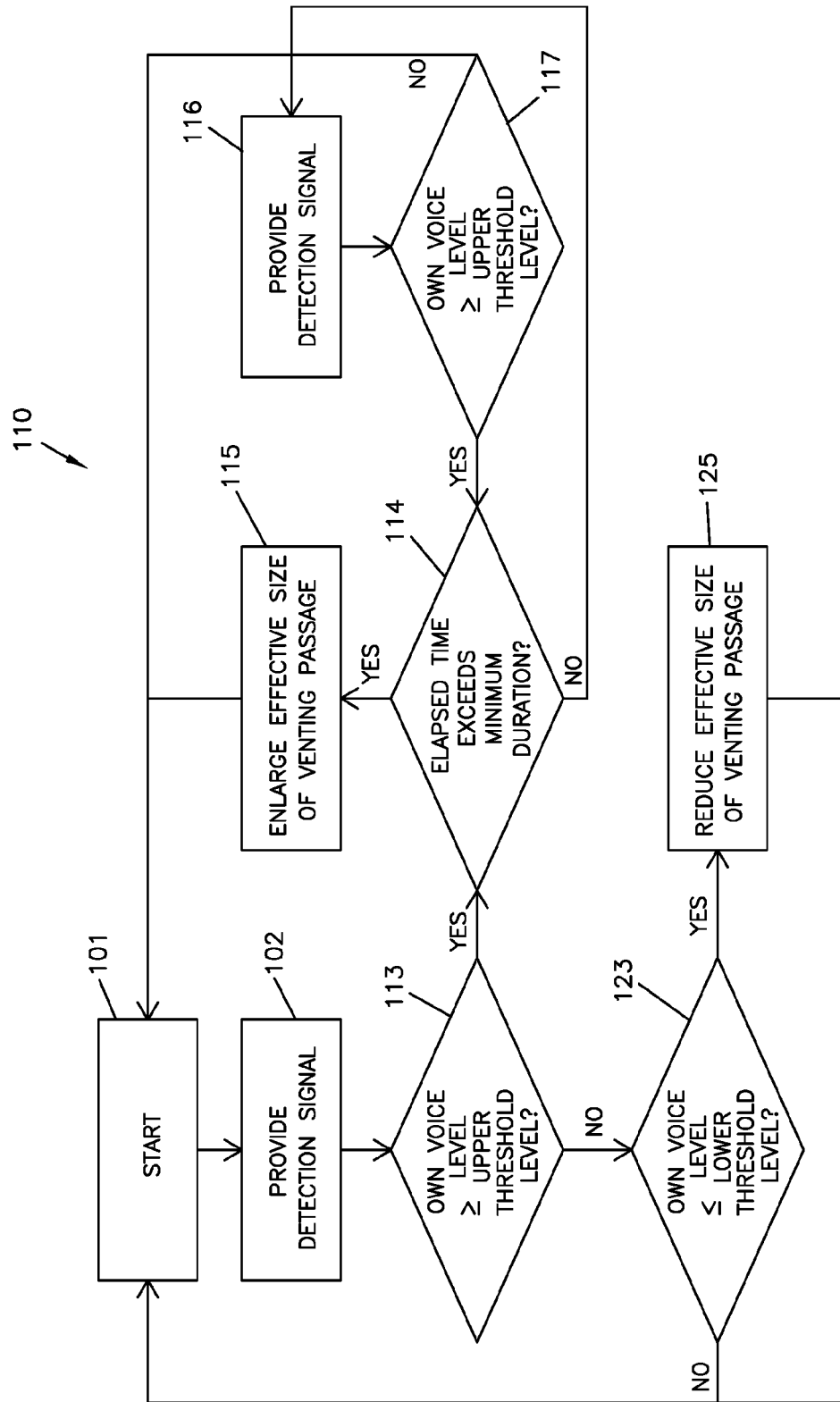
FIG. 2B

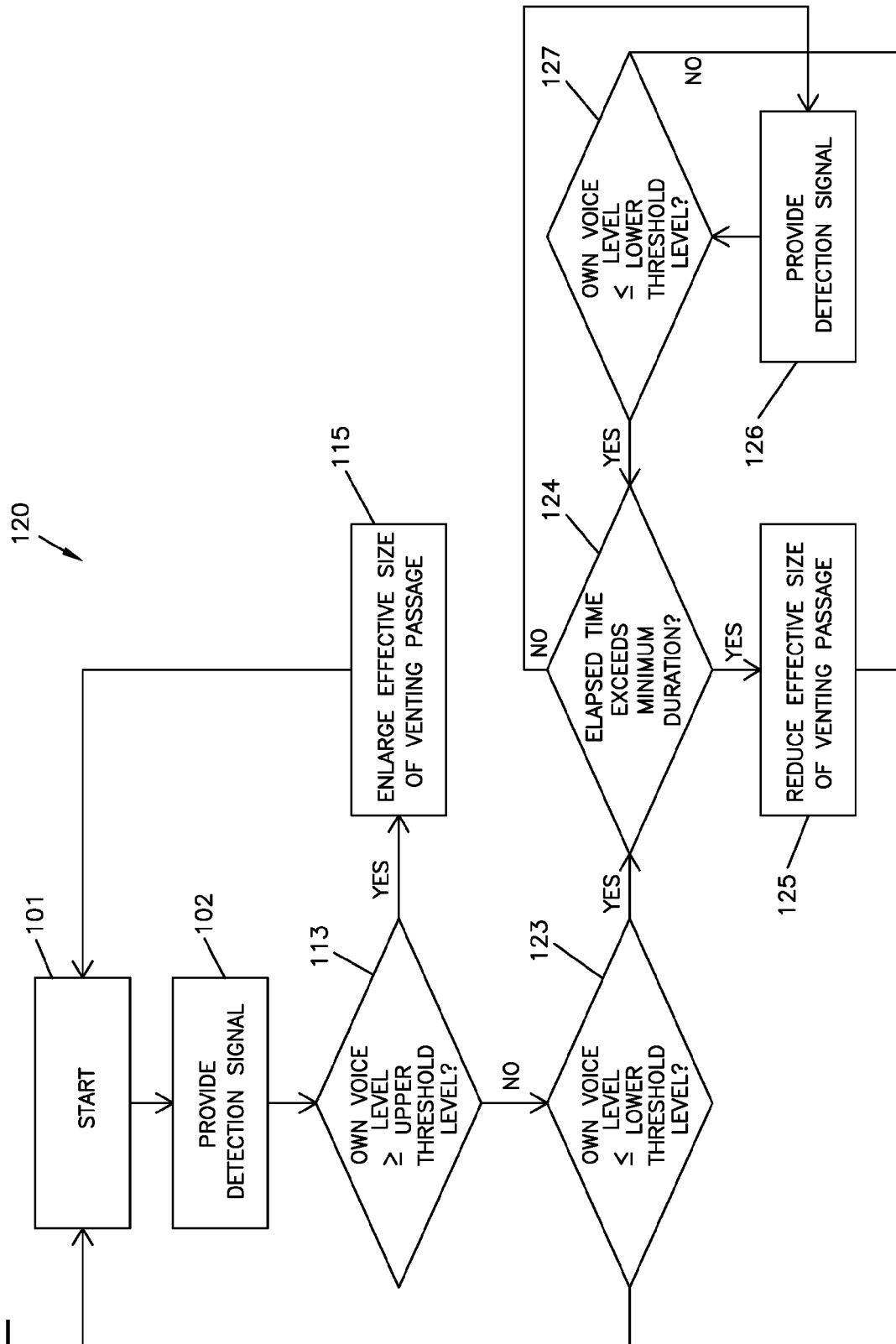
FIG. 2C

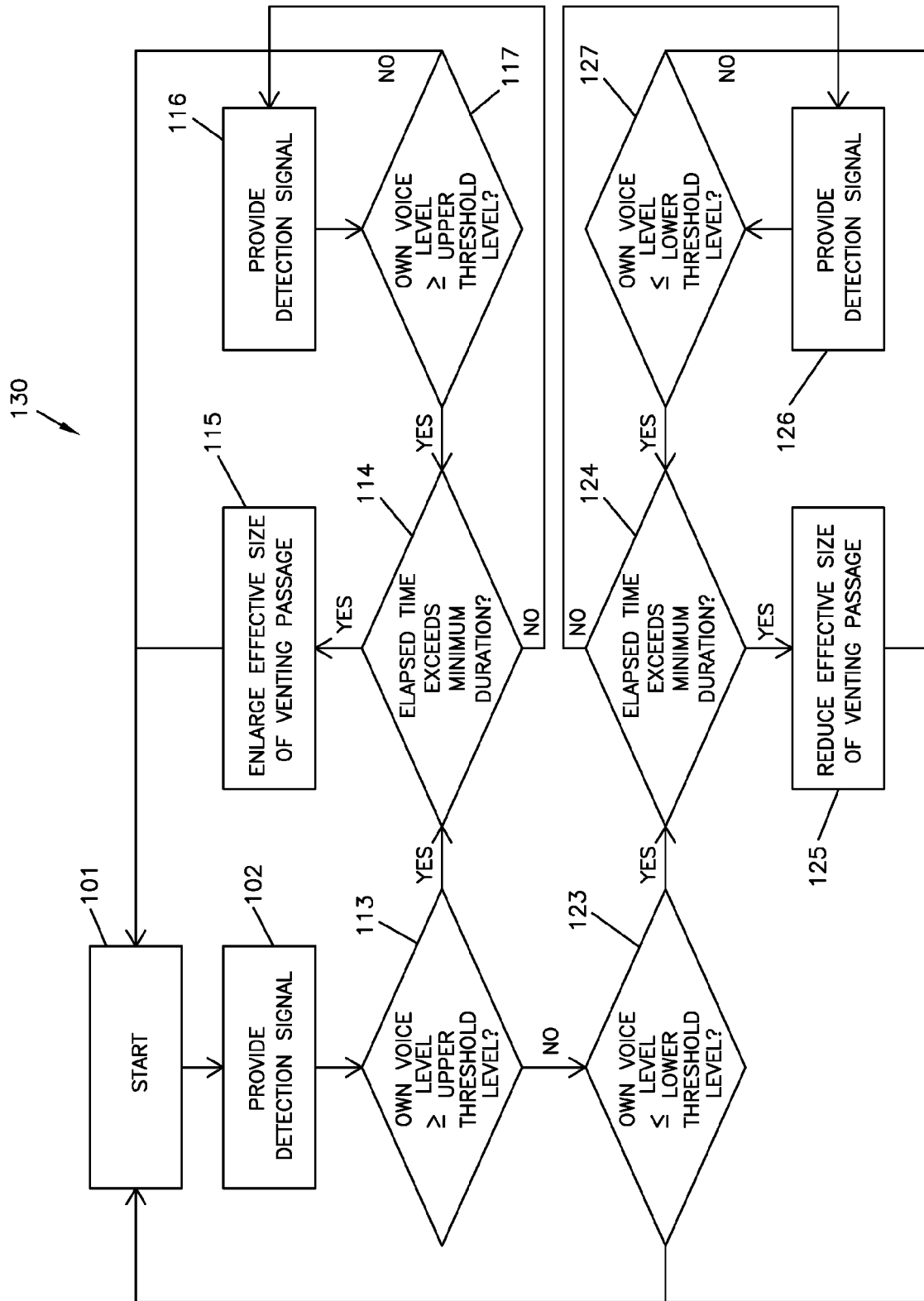
FIG. 2D

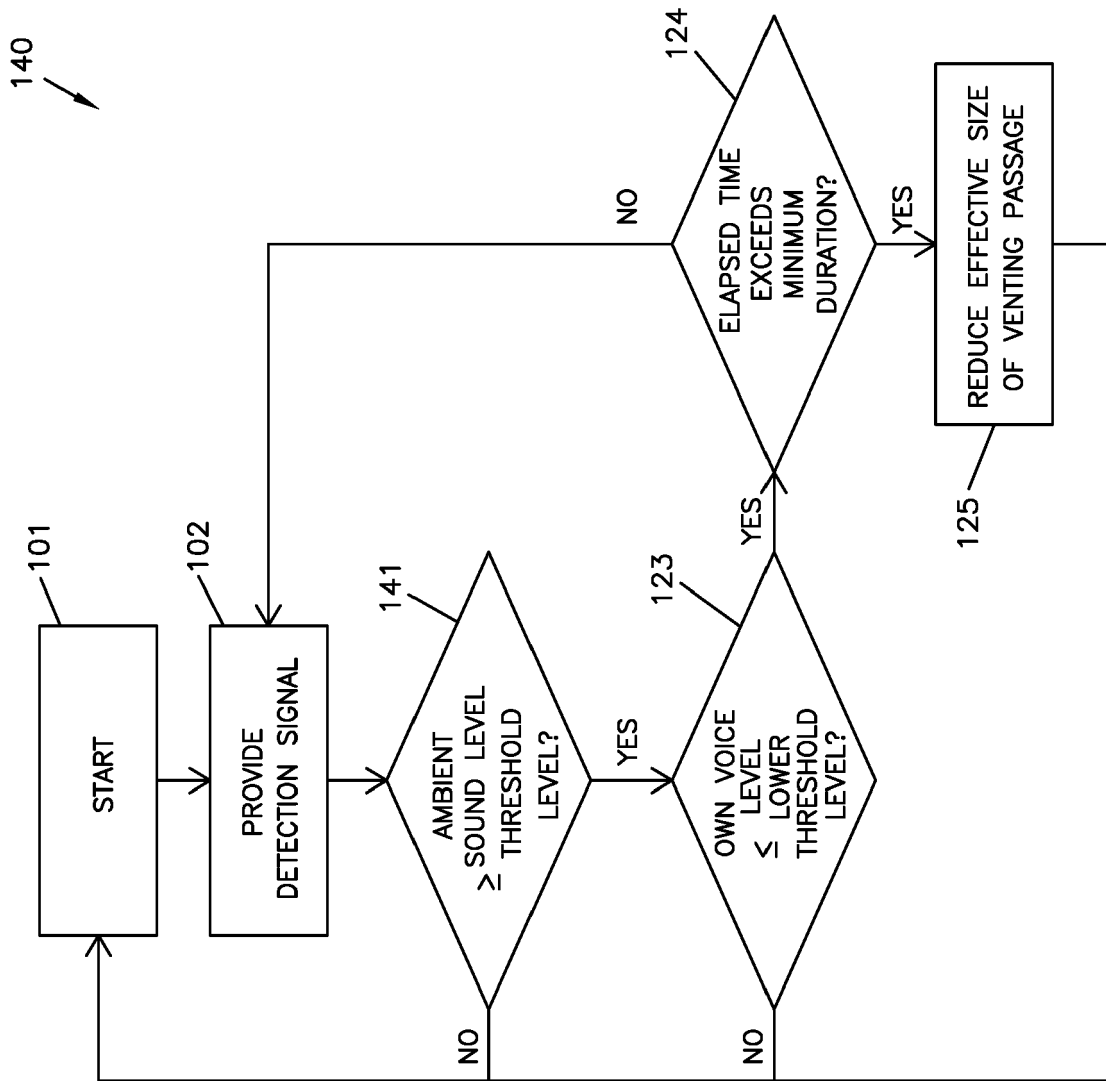
FIG. 2E

FIG. 2F

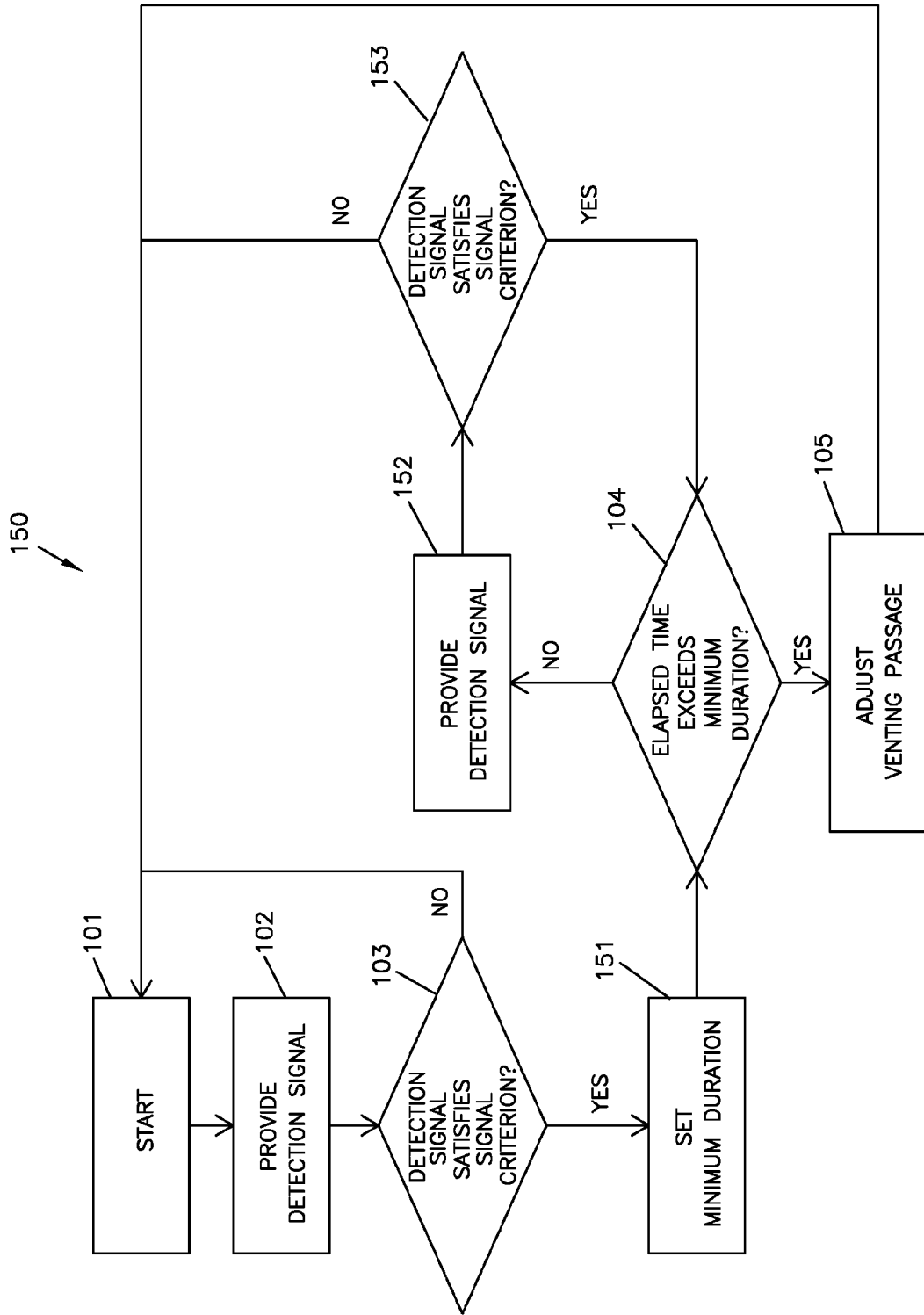


FIG. 3A

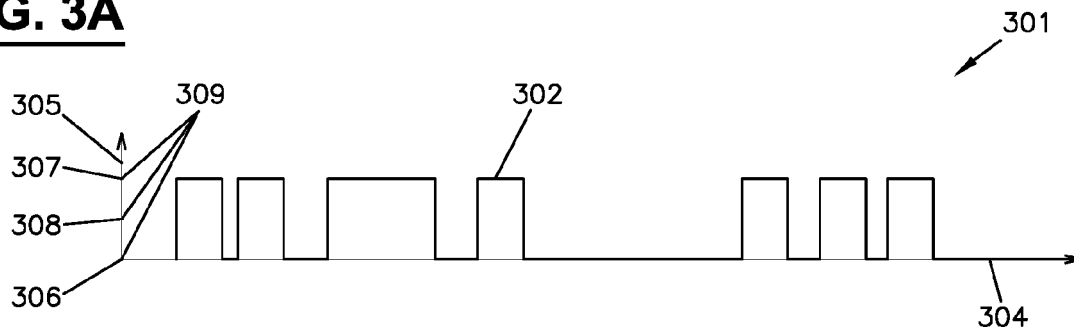


FIG. 3B

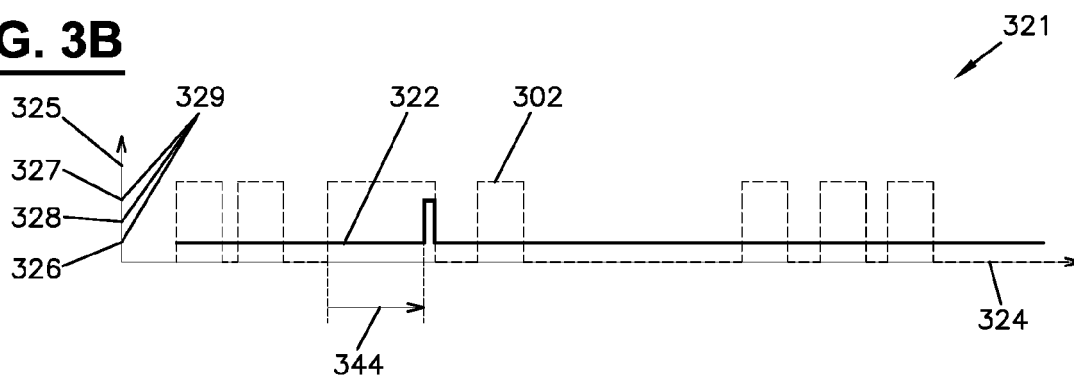


FIG. 3C

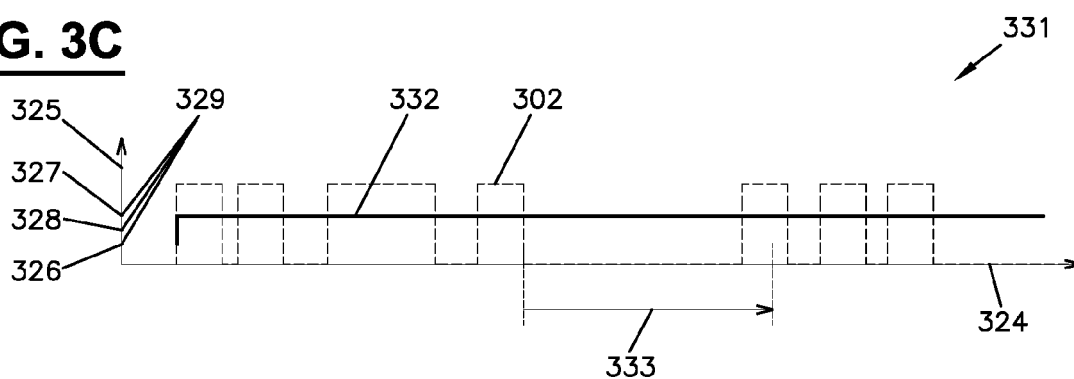


FIG. 3D

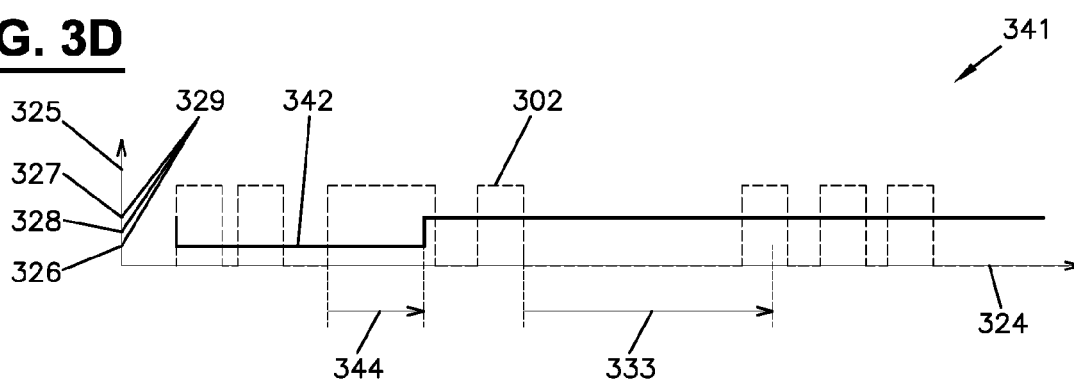


FIG. 4A

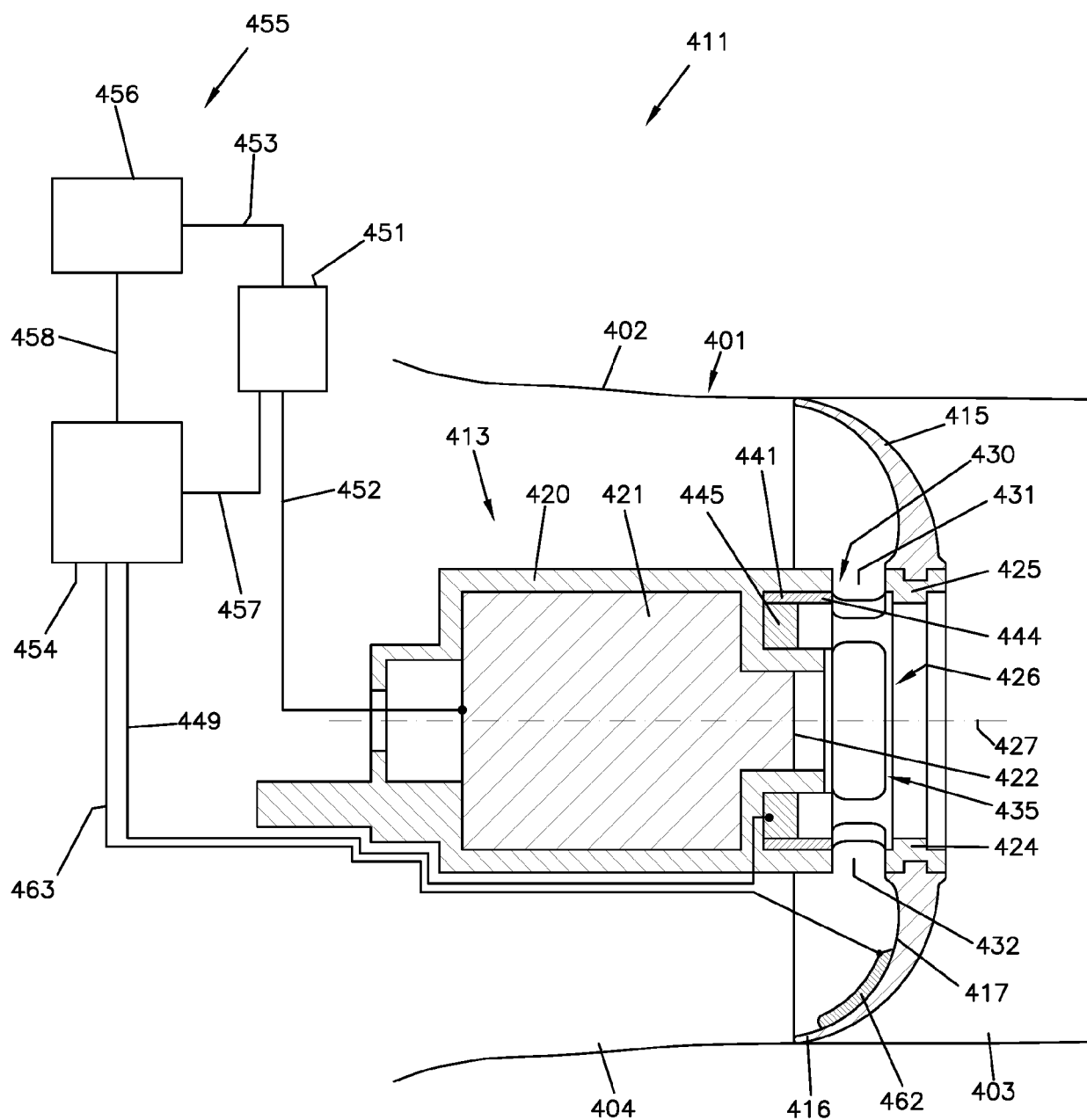


FIG. 4B

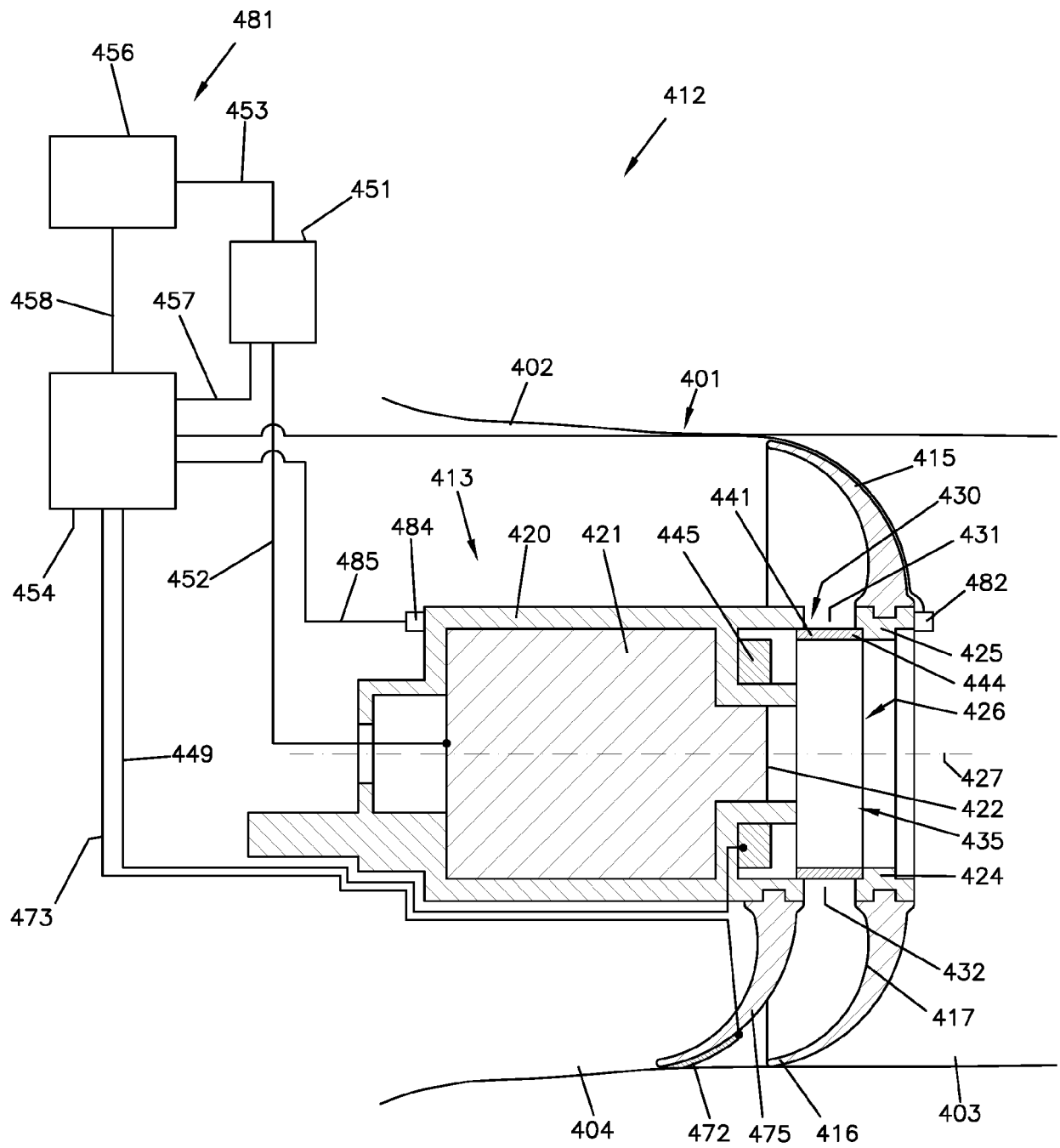


FIG. 5A

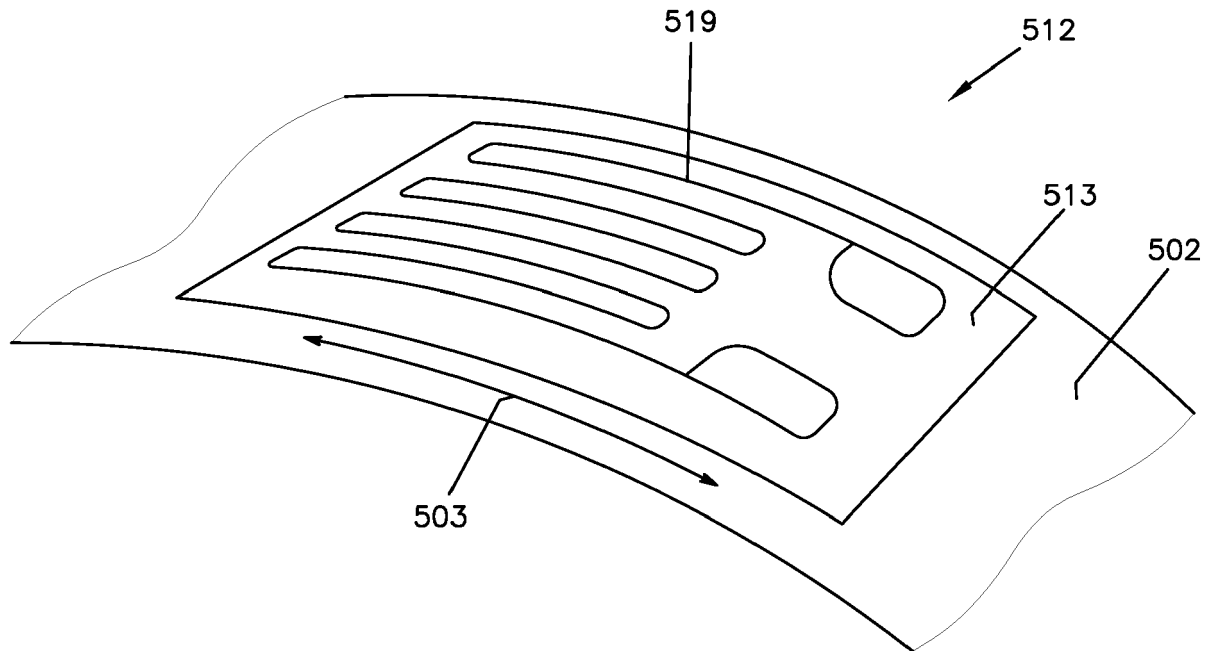
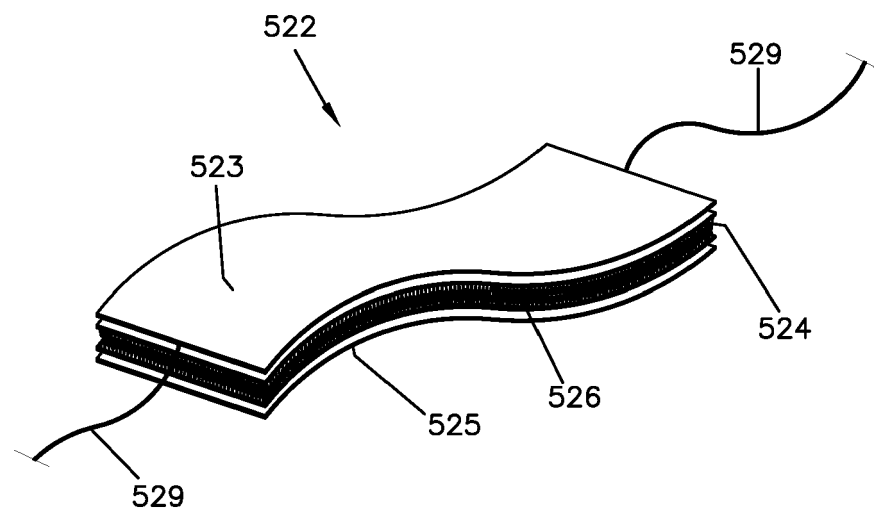


FIG. 5B





EUROPEAN SEARCH REPORT

Application Number
EP 18 19 5686

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2017/208382 A1 (GRINKER SCOTT C [US]) 20 July 2017 (2017-07-20) * paragraph [0041] - paragraph [0161] * -----	1-15	INV. H04R1/10 H04R25/00
X	EP 3 328 097 A1 (OTICON AS [DK]) 30 May 2018 (2018-05-30) * paragraph [0026] - paragraph [0126] * -----	1,15	
A,D	EP 2 835 987 A1 (OTICON AS [DK]) 11 February 2015 (2015-02-11) * the whole document * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H04R
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 February 2019	Examiner Coda, Ruggero
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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