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(54) USING SPECIFIC HEAD TILT TO CONTROL HEARING AID FUNCTIONALITY

(57) A method, in particular performed by at least one hearing device, a hearing device, a binaural hearing system, and a hearing system are disclosed. The method comprises: detecting at least one movement and/or acceleration of at least one hearing device; determining at least one tilt, in particular a movement pattern, of the at least one hearing device based on the detected movement and/or acceleration; and controlling and/or regulating operation of the at least one hearing device and/or a connected mobile device based on the determined tilt, in particular the determined movement pattern.

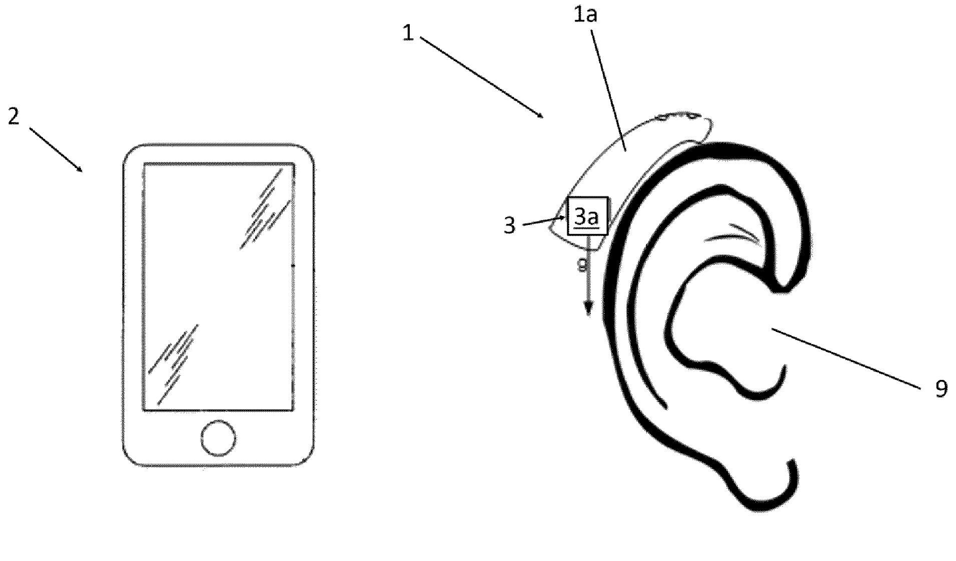

Fig. 1

EP 4 300 996 A1

Description

FIELD

[0001] The present disclosure generally relates to a method, in particular a method performed by at least one hearing device, a hearing device, in particular a hearing aid, a binaural hearing system comprising a first and a second hearing device, in particular a first and a second hearing aid, and a hearing system comprising at least one hearing device, in particular at least one hearing aid, and at least one mobile device connected with the hearing device. The disclosure more particularly relates to a method for e.g. using an intended head tilt to control operation of a hearing device, a hearing device being configured to and/or comprising at least one means for performing the method, a binaural hearing system comprising a first and a second hearing device being configured to and/or comprising at least one means for performing the method, and a hearing system comprising at least one hearing device being configured to and/or comprising at least one means for performing the method and at least one mobile device connected with the hearing device.

BACKGROUND

[0002] In the field of hearing devices, there is an increasing awareness towards individual adaptation of the hearing device settings in order to provide wearers with an optimum sound experience. All hearing device producers aim for providing hearing devices that are capable of taking into account the user's individual preferences so that the hearing devices can deliver a just-right sound amplification.

[0003] In particular, modern hearing aids are capable of applying directional noise reduction in terms of beamforming and spatially informed post filtering. For example, this might be helpful when the user needs to increase his or her attention to a specific talker. The full amount of noise reduction may, however, not be needed in all situations. Therefore, some automatic system is typically provided in order to apply the correct amount of noise reduction for a given situation.

[0004] Nevertheless, as a consequence of e.g. applying a high amount of noise reduction in situations where noise reduction might not be needed, the automatic system rarely applies the optimal amount of noise reduction in extreme and rare situations, where a very high amount of noise reduction might be needed. Such optimization may thus be insufficient and the benefit of the hearing device may not be as high as it could have been. In particular in complex sound environments, hearing device users sometimes may need extra help in terms of signal processing. Here, it is hard to know where exactly the user is paying his or her attention. For those extreme input, it needs to be ensured that and when a high amount of noise reduction is needed.

[0005] Therefore, there is a need to provide a solution that addresses at least some of the above-mentioned problems.

SUMMARY

[0006] According to a first aspect, the method may comprise detecting at least one movement and/or acceleration of at least one hearing device. A "movement" may refer to a motion of the hearing device, in particular a change of position with respect to space and time. "Acceleration" may refer to the rate of change of the velocity of the hearing device with respect to time. Acceleration may be a vector quantity having a magnitude and direction. The term "movement and/or acceleration" may include both linear and angular position, velocity and acceleration. Thus, "movement and/or acceleration" may include position, orientation as well as the first and second derivative (e.g. with respect to time) of these. The method may comprise detecting a plurality of movements and/or accelerations of the hearing device during its wearing time. For example, head movements, e.g. a nod or rotation of the head to a side, or a combination thereof, may be detected. Detection may be performed by at least one detection means. The at least one detection means may e.g. be integrated in and/or attached to the hearing device.

[0007] The method may further comprise determining at least one tilt of the at least one hearing device based on the detected movement and/or acceleration. The tilt may be determined as the deviation between a reference orientation and/or position and a current orientation and/or position. The reference orientation and/or position of the hearing device may serve as a basis for determining deviations in orientation and/or position. The current orientation and/or position of the hearing device may be determined based on a current movement and/or acceleration of the hearing device. The current orientation and/or position of the hearing device may in particular differ from the reference orientation and/or position of the hearing device.

[0008] The deviation between the reference orientation and/or position and the deviating orientation and/or position may be indicated by a deviation angle. In particular, the method may comprise determining at least one tilt angle θ of the at least one hearing device based on the detected movement and/or acceleration. A tilt of the hearing device may be caused by the user bending his or her head towards the left, right, upwards and/or downwards. A tilt may be measured in one, two or three axes. The tilt angle θ may be determined as the deviation angle between the direction of gravitational force g and a deviation vector ref_d. The deviation vector ref_d may e.g. point to a side when the hearing device is tilted to the right or left side and/or to the front or back when the hearing device is tilted up or down. If the deviation vector ref_d points to a side it may be referred to as ref_{side}. The tilt angle 0 may then be determined as the angle θ_{side} between the vector g and the deviation vector $ref_{side.}$ If the deviation vector ref_d points to the back or front, it may be referred to as ref_{updown}. The tilt angle θ may then be determined as the angle θ_{updown} between the vector g and the deviation vector $ref_{updown.}$

[0009] Determination of the at least one tilt may be performed by the hearing device itself. For example, the hearing device may comprise at least one determination means for determining the at least one tilt of the hearing device, e.g. at least one sensor and/or controller. A reference position and/or orientation of the sensor may be known, such as the gravitational force g e.g. when the hearing device is positioned such that at least two input units are aligned in a substantially horizontal plane, and a deviating orientation and/or position of the hearing device may be determined based on sensor data.

[0010] In particular, the method may comprise determining at least one movement pattern (e.g., comprising or constituting a tilt pattern) of the at least one hearing device based on the detected tilt, movement, and/or acceleration. A movement pattern may comprise at least one tilt or movement. Preferably, a movement pattern may include two or more movements and/or tilts measured in one, two or three axes. A movement pattern may take into account intensity, duration, and/or direction of at least one tilt and/or a sequence of at least two tilts. A movement pattern may e.g. comprise a short nod of the user. In particular, a movement pattern may comprise a short nod to the front and/or to the side.

[0011] For example, the at least one hearing device may comprise a neural network, such as a deep neural network.

[0012] The neural network may be configured to detect and/or receive the at least one movement pattern.

[0013] For example, the method may comprise training the neural network based on a database of movement patterns. The method may comprise training the neural network on the specific movement pattern provided by the user, i.e., on said determined at least one movement pattern.

[0014] The method may comprise adding variation to the determined movement pattern by data augmentation, such as time stretching and/or intensity scaling.

[0015] The tilt and/or movement pattern may be characterized by at least one intentional movement and/or acceleration. In particular, detection and determination of a movement pattern may ensure for intentional movement and/or acceleration performed by the user. A movement pattern may allow for classifying as intentional tilting.

[0016] A predefined movement pattern may be stored in the hearing device. The method may comprise predefining at least one movement pattern of the at least one hearing device, and storing the predefined movement pattern in the at least one hearing device and/or the connected mobile device. The at least one movement pattern may be configurable, e.g. defined by the user him or herself. The at least one movement pattern may be programmed by a hearing care professional who provides e.g. a list of movement patterns to the end user in a clinic, alternatively, or in addition to that, the user could program movement patterns personally, e.g. via an interactive session using a mobile device, e.g. a smartphone or tablet or other electronic device with a screen. This screen could be used to illustrate to the user a range of suitable movement patterns that the system easily recognizes.

[0017] The method may further comprise controlling and/or regulating operation of the at least one hearing device and/or a connected mobile device based on the determined tilt, in particular the determined movement pattern. The method may comprise assigning a predefined tilt, in particular a predefined movement pattern, to an operation of the hearing device and/or the connected mobile device. The at least one tilt and/or the at least one movement pattern may be assigned to an operation, in particular at least one setting, of the hearing device and/or the connected mobile device. A setting may be one or more of volume, program, noise reduction, feedback management, wired or wireless connection, flight mode or any other suitable setting in a hearing device. The tilt- and/or movement pattern-based operation may be set individually based on the user's preferences. A sensor controller could be adapted to analyze signals from a sensor in order to recognize a movement pattern of the hearing device corresponding to the predefined movement pattern. The sensor controller could be part of a controller configured for controlling the operation of the processor or it could be separate.

[0018] In this context, "regulating" means that the actual value of a parameter is changed by suitable process action in the event of deviation from the desired set point so that the actual value approaches the set point and ideally reaches it. Because the drift from the set point is counteracted, the feedback is a negative feedback. In the case of "controlling", on the other hand, there is no feedback and consequently no closed-loop effect. Control is understood to be the influencing of the behavior of a system, whereby the system is brought into a different state by the control. The control or regulation can take place by influencing selected parameters, for example by reducing or increasing a value.

[0019] The method according to the first aspect may be performed by at least one hearing device. A hearing device (or hearing instrument, hearing assistance device) may be or include a hearing aid, a listening device or an active ear-protection device that is adapted to improve, augment and/or protect the hearing capability of a user by receiving an acoustic signal from a user's surroundings, generating a corresponding audio signal, possibly modifying the audio signal and providing the possibly modified audio signal as an audible signal to at least one of the user's ears. 'Improving or augmenting the hearing capability of a user' may include compensating for an individual user's specific hearing loss.

[0020] A "hearing device" may further refer to a device such as a hearable, an earphone or a headset adapted to receive an audio signal electronically, possibly modifying the audio signal and providing the possibly modified audio signals as an audible signal to at least one of the user's ears. Such audible signals may be provided in the form of an acoustic signal radiated into the user's outer ear, or an acoustic signal transferred as mechanical vibrations to the user's inner ears through bone structure of the user's head and/or through parts of the middle ear of the user or electric signals transferred directly or indirectly to the cochlear nerve and/or to the auditory cortex of the user.

[0021] In particular, the method according to the first aspect may be performed by at least one hearing aid. The hearing aid device may be any type of hearing aid device including a behind-the-ear (BTE) hearing aid, an in-the-ear (ITE) hearing aid, a completely-in-canal (CIC) hearing aid, an in-the-canal (ITC) hearing aid, a receiver-in-the-ear (RITE) hearing aid. The hearing aid device may comprise a BTE part (adapted for being located behind or at an ear of a user) operationally connected to a loudspeaker (receiver) and a microphone located in an ear canal of the user.

[0022] The hearing device may be adapted to be worn in any known way. This may include i) arranging a unit of the hearing device behind the ear with a tube leading air-borne acoustic signals into the ear canal or with a receiver/loudspeaker arranged close to or in the ear canal and connected by conductive wires (or wirelessly) to the unit behind the ear, such as in a BTE type hearing aid, and/or ii) arranging the hearing device entirely or partly in the pinna and/or in the ear canal of the user such as in an ITE type hearing aid or ITC/CIC type hearing aid, or iii) arranging a unit of the hearing device attached to a fixture implanted into the skull bone such as in a Bone Anchored Hearing Aid or a Cochlear Implant, or iv) arranging a unit of the hearing device as an entirely or partly implanted unit such as in a Bone Anchored Hearing Aid or a Cochlear Implant. The hearing device may be implemented in one single unit (housing) or in a number of units individually connected to each other.

[0023] In general, a hearing device may include i) an input unit such as a microphone for receiving an acoustic signal from a user's surroundings and providing a corresponding input audio signal, and/or ii) a receiving unit for electronically receiving an input audio signal. The hearing device further includes a signal processing unit for processing the input audio signal and an output unit for providing an audible signal to the user in dependence on the processed audio signal.

[0024] The input unit may include multiple input microphones, e.g. for providing direction-dependent audio signal processing. Such directional microphone system is adapted to (relatively) enhance a target acoustic source among a multitude of acoustic sources in the user's environment and/or to attenuate other sources (e.g. noise). In one aspect, the directional system is adapted to detect (such as adaptively detect) from which direction a particular part of the microphone signal originates. This may be achieved by using conventionally known methods. The signal processing unit may include an amplifier that is adapted to apply a frequency dependent gain to the input audio signal. The signal processing unit may further be adapted to provide other relevant functionality such as compression, noise reduction, etc. The output unit may include an output transducer such as a loudspeaker/receiver for providing an air-borne acoustic signal transcutaneously or percutaneously to the skull bone or a vibrator for providing a structure-borne or liquid-borne acoustic signal. In some hearing devices, the output unit may include one or more output electrodes for providing the electric signals such as in a Cochlear Implant.

[0025] According to a second aspect of the present disclosure, a hearing device may be configured to performing a method according to the first aspect. In particular, the hearing device may at least be configured to detect at least one movement and/or acceleration of at least one hearing device; determine at least one tilt, in particular a movement pattern, of the at least one hearing device based on the detected movement and/or acceleration; and/or control and/or regulate operation of the at least one hearing device and/or a connected mobile device based on the determined tilt, in particular the determined movement pattern.

[0026] Alternatively, or additionally, a hearing device may comprise at least one means for performing a method according to the first aspect. In particular, the hearing device may comprise at least one means to detect at least one movement and/or acceleration of at least one hearing device; determine at least one tilt, in particular a movement pattern, of the at least one hearing device based on the detected movement and/or acceleration; and/or control and/or regulate operation of the at least one hearing device and/or a connected mobile device based on the determined tilt, in particular the determined movement pattern.

[0027] According to a third aspect of the present disclosure, a binaural hearing system may comprise a first and a second hearing device. In particular, the hearing binaural system may comprise a first and a second hearing aid. A "binaural hearing system" may refer to a system comprising two hearing devices where the devices are adapted to cooperatively provide audible signals to both of the user's ears.

[0028] The first and the second hearing device may be configured to and/or comprise at least one means for performing a method according to the first aspect. The binaural hearing system may be configured to determine a system tilt, in particular a system movement pattern, based on the detected movement and/or acceleration of the first and second hearing device. During normal operation of the first and second hearing device in the binaural hearing system, both first and second hearing device may be adapted to transmit information on the detected tilt, in particular the detected movement pattern, to the respective other hearing device so that a decision on operation of at least one hearing device and/or a connected mobile device is made depending on a combination of detected tilt in the hearing device and detected tilt information being received (from the other hearing device).

[0029] Finally, according to a fourth aspect of the present disclosure, a hearing system may comprise at least one hearing device and at least one mobile device connected with the hearing device. A "hearing system" may refer to a system comprising one or two hearing devices. The at least one hearing device may be configured to and/or comprise at least one means for performing a method according to the first aspect.

[0030] The binaural hearing system according to the third aspect and/or the hearing system according to the fourth aspect may include at least one mobile device that communicates with the at least one hearing device, the mobile device affecting the operation of the hearing device and/or benefitting from the functioning of the hearing device. A wired or wireless communication link between the at least one hearing device and the mobile device may be established that allows for exchanging information (e.g. control and status signals, possibly audio signals) between the at least one hearing device and the mobile device.

[0031] The at least one hearing device may comprise a wireless interface adapted to communicate with at least one external mobile device. The wireless interface may include one or more antenna and/or inductive coils for communicating at appropriate frequencies, e.g. around 2.4 GHz or lower frequencies for the inductive communication, e.g. around 500 MHz. Having different types of antenna allows for communication at multiple frequencies, e.g. one type for communicating between devices positioned at respective opposite ears and one type for communicating with external devices. The communication may be conducted using protocols such as Bluetooth or proprietary protocols, or even a mix of protocols.

[0032] A mobile device may include at least one of a remote control, a remote microphone, an audio gateway device, a wireless communication device, e.g. a mobile phone, such as a smartphone, or a tablet or another device, e.g. comprising a graphical interface, a public-address system, a car audio system or a music player, or a combination thereof. The audio gateway may be adapted to receive a multitude of audio signals such as from an entertainment device like a TV or a music player, a telephone apparatus like a mobile telephone or a computer, e.g. a PC. The mobile device may further be adapted to, e.g. allow a user to, select and/or combine an appropriate one of the received audio signals, or combination of signals, for transmission to the at least one hearing device. The remote control is adapted to control functionality and/or operation of the at least one hearing device. The function of the remote control may be implemented in a smartphone or other, e.g. portable, electronic device, the smartphone / electronic device possibly running an application (App) that controls functionality of the at least one hearing device.

[0033] It has been found that with the subject-matter according to the different aspects, the user can provide intended feedback to the hearing device. Operation of the hearing device and/or a connected mobile device can be controlled and/or regulated upon this feedback. For example, nodding of the user may be detected and e.g. change operation of the hearing device and/or a connected mobile device.

[0034] In particular, the subject-matter allows for detecting at least one tilt, in particular at least one movement pattern, of the hearing device and utilizing the tilt, in particular the movement pattern, for controlling or regulating hearing device operation. This particularly allows for an optimized signal processing, e.g. a just-right sound amplification. Alternatively, or additionally to e.g. an automatic system of a hearing device for applying a correct amount of noise reduction for a given situation, the subject-matter according to the different aspects of the present disclosure thus allows the user to control and/or regulate the hearing device and/or a connected mobile device by tilting his or her head. Different functionality may be applied for different tilts, e.g. different tilt intervals. Decisions may be smooth functions of the tilt rather than hard decisions.

[0035] Exemplary embodiments of the first, second, third, and/or fourth aspect may have one or more of the properties described below.

[0036] The method may comprise detecting at least one sound signal. In particular, acoustic signals may be detected from the environment. The sound signal may be processed by the hearing device. In particular, the method may comprise determining a sound level and/or signal-to-noise ratio of the sound signal. Preferably, the hearing device may comprise a sound parameter determination unit which is configured to determine a sound level and/or signal-to-noise ratio of the sound signal. The sound parameter unit may also determine if a sound level and/or signal-to-noise ratio of the sound signal is above or below a predetermined threshold value.

[0037] Controlling and/or regulating operation of the hearing device and/or the connected mobile device based on the determined tilt, in particular the determined movement pattern, may be only enabled if the sound level and/or the signal-to-noise ratio of the sound signal is above and/or below a threshold value. Controlling and/or regulating of the hearing device operation and/or the operation of the connected mobile device may thus also be based on the determined sound level and/or signal-to-noise ratio of the sound signal. This particularly allows for controlling and/or regulating hearing device and/or mobile device operation based on head tilts only in e.g. complex sound scenes.

[0038] In particular, the sound level may need to be above a certain threshold and/or the signal-to-noise ratio may need to be below a certain threshold. The tilt based control and/or regulation of the hearing device and/or the connected mobile device may thus be e.g. only enabled in complex sound environments. In particular, in addition to a specific tilt or movement pattern, the sound level may need to be above a certain threshold or the signal to noise ratio should be below a certain threshold.

[0039] Controlling and/or regulating operation of the hearing device may comprise controlling and/or regulating signal processing of the hearing device based on the determined tilt, in particular the determined movement pattern. The hearing device may comprise a processor adapted to apply a signal processing algorithm to an electrical signal provided by an input transducer of the hearing device, such as e.g. at least one microphone, to compensate for a user's specific hearing loss. The hearing device may further comprise a controller configured to control the operation of the processor receiving the electrical signal and the controller being adapted to provide a control signal based on the detected tilt, in particular the detected movement pattern, e.g. changing the state of the processor and/or the wireless interface based on the control signal.

[0040] The processor may be a digital processor specifically intended for signal processing. The processor may physically be part of a lager application specific integrated circuit, ASIC, where e.g. multiple processors are integrated in one component. The controller may be operated in any of a range of modes, e.g. by setting a threshold before changing state for the controlled setting. The controller may utilize multiple thresholds, and/or multiple sensors may be used. Other types of triggers may be implemented.

[0041] In particular, controlling and/or regulating operation of the hearing device may comprise controlling and/or regulating noise reduction of the hearing device based on the determined tilt, in particular the determined movement pattern. For example, weights controlling the directional noise reduction system may be modified. Also, other beam former weights, such as e.g. the weights of an own voice beam former, may be modified. Also, filter coefficient compensating for the microphone location effect (MLE) may be modified depending on the tilt. It may be conceivable, that signal processing, in particular noise reduction, of the hearing device may only be controlled and/or regulated if the at least one tilt, in particular the at least one movement pattern, is above a threshold value.

[0042] For example, the amount of noise reduction may be increased or decreased if the determined tilt is above or below a threshold value. The threshold value may depend on the direction in which the hearing device is moved and/or accelerated. For example, the threshold value may be different for substantially vertical movements, e.g. when the user is looking up or down, than for substantially horizontal movements, e.g. when the user tilts his or her head to the side.

[0043] Controlling and/or regulating noise reduction of the hearing device based on the determined tilt, in particular the determined movement pattern, allows for applying a correct amount of noise reduction for a given situation. The method may particularly allow for intentionally increasing the amount of noise reduction in difficult situations, e.g. by applying a corresponding movement pattern. For example, the amount of noise reduction may be increased if e.g. the user leans his or her head towards a side, or if the user leans his or her head into a special position, e.g. both towards one of the sides and e.g. downwards.

[0044] Less noise reduction based on a given tilt, in particular a given movement pattern, e.g., a tilt upwards or downwards, may as well be an option. In certain situations, directional noise reduction may not be desirable, and rather omnidirectional listening is preferred. Directional noise reduction may then be disabled, if the hearing device detects a corresponding tilt, in particular a corresponding movement pattern.

[0045] The amount of noise reduction may be increased or decreased while the determined tilt is above a first threshold value, in particular a first absolute threshold value, and below a second threshold value, in particular a second absolute threshold value. For example, the amount of noise reduction is reduced while the user's head is tilted to one side and/or up or down, wherein the tilt angle θ is above a first threshold angle and below a second threshold angle.

[0046] The amount of noise reduction may e.g. be increased while $\theta_{side_{min}} < \theta_{side} < \theta_{side_{max}}$ on a single or both hearing devices of a binaural hearing system. Alternatively, the amount of noise reduction may e.g. be increased while $\theta_{updown_{min}} < \theta_{updown} < \theta_{updown_{max}}$ and $\theta_{side_{min}} < \theta_{side} < \theta_{side_{max}}$ on a single or both hearing devices of a binaural hearing system. The amount of noise reduction may also e.g. be decreased while $\theta_{updown_{min}} < \theta_{updown} < \theta_{updown_{max}}$.

[0047] In particular, the amount of noise reduction may be increased or decreased while the determined tilt is above a first absolute threshold value and below a second absolute threshold value. This particularly allows for the same functionality regardless of whether the head is tilted towards the left or right side or up or down. In particular, the amount of noise reduction may e.g. be increased while $|\theta_{side_{min}}| < |\theta_{side}| < |\theta_{side_{max}}|$ on a single or both hearing devices of a binaural hearing system.

[0048] The desired listening direction (i.e., the direction towards which the user prefers to listen) may be altered/adjusted based on the value of θ_{side} and/or on the value of θ_{updown}.

[0049] Controlling and/or regulating noise reduction of the hearing device may comprise controlling and/or regulating beam forming, controlling and/or regulating binaural beam forming, and/or controlling and/or regulating filtering. In particular, controlling and/or regulating noise reduction of the hearing device may comprise enabling and/or disabling a directional and/or an omnidirectional mode, enabling and/or disabling binaural beam forming, and/or controlling and/or regulating post filter attenuation. For example, noise reduction may be controlled in terms of applying a sharper beam former towards a target, applying a more aggressive post filter attenuation, i.e. more noise is attenuated, enabling binaural beamforming which allows a narrower beam compared to local beamforming and/or forcing the preferred listening direction towards a specific direction, such as the front direction.

[0050] Controlling and/or regulating operation of the hearing device may comprise changing a program and/or changing volume of the hearing device. A program and/or volume change of the hearing device may be controlled and/or regulated by intended head movements such as e.g. nodding in a specific pattern.

[0051] Controlling and/or regulating operation of the connected mobile device may comprise answering or rejecting a phone call. For example, a short nod towards a specific direction could be used to answer or reject a phone call. A detected tilt, in particular a detected movement pattern, may e.g. be used to control a wirelessly connected smartphone. Nodding of the head may e.g. be used to accept an incoming phone call, and/or rotation of the head may e.g. be used to reject a phone call.

[0052] A tilt may be determined based on at least one movement and/or acceleration of a first hearing device and at least one movement and/or acceleration of a second hearing device. In particular, a movement pattern may be determined based on at least one movement and/or acceleration of a first hearing device and at least one movement and/or acceleration of a second hearing device. The determination of the tilt, in particular of the movement pattern, may be thus based on a binaural decision, such that both hearing devices detect a tilt towards the same side. This allows for an even more reliable tilt or movement pattern determination, respectively. In particular, even more complex movement patterns may be defined, which consequently may reduce the risk of false tilt determination and thus unintended controlling and/or regulating of the hearing device and/or the connected mobile device.

[0053] For example, a binaural decision may be obtained by combining two local decisions based on local movement pattern inputs. In other words, a binaural decision may be obtained by combining a decision (based on a tilt, in particular a movement pattern) in a first hearing device with a decision (based on a tilt, in particular a movement pattern) in a second hearing device.

[0054] Alternatively, a binaural decision may be obtained based on joint movement pattern inputs. In other words, a binaural decision may be obtained based on joining/combining tilts, in particular movement patterns, of a first hearing device and a second hearing device.

[0055] The hearing device may comprise at least one sensor for detecting at least one movement and/or acceleration of the hearing device. The sensor may provide information about the orientation and/or position of the hearing device and detect if the hearing device user is moving or turning his or her head. The sensor may be any suitable type of sensor capable of detecting movement and/or acceleration and/or orientation and/or position of the hearing device. The sensor may be an integrated part of the hearing device or be attached to the hearing device in any suitable way.

[0056] The sensor used may be a tilt sensor adapted to sense the hearing device being tilted in one, two or three axis and may generate a corresponding tilt sensor signal. Using a tilt sensor allows the user to control and/or regulate the operation of the hearing device and/or a connected mobile device by tilting the hearing device, which may be done inconspicuously.

[0057] It may be beneficial that the sensor is or comprises an accelerometer and/or a gyroscope. The sensor may be or comprise a compass, e.g. a magnetic compass, e.g. a magnetometer. The sensor may be or comprise a positioning system, e.g. a receiver of a satellite positioning system, e.g. a GPS receiver. Hereby, it is possible to use robust and reliable standard components to detect the desired data.

[0058] For example, the sensor may be an accelerometer. An accelerometer is a sensor that detects its own acceleration. This is usually done by determining the inertial force acting on a test mass. In this way, it can be determined, for example, whether an increase or decrease in speed is taking place. An accelerometer may detect if the user is bending his or her head towards left, right, upwards, and/or downwards.

[0059] The accelerometer may be an accelerometer configured to measure linear acceleration in one, two or three directions, whereas the gyroscope may be a gyroscope configured to measure angular velocity in one, two, or three directions. A compass preferably indicates a direction in a horizontal plane at a particular place on the surface of the earth, e.g. in a North, West, South, East framework.

[0060] It may be an advantage that the hearing device contains both an accelerometer and a gyroscope so that both linear and rotational movement of the head of the user or of the hearing device can be determined with high precision and accuracy. In an embodiment, the hearing device (or a device in communication with the hearing device) additionally comprises a positioning system and/or a compass.

[0061] Both accelerometers and gyroscopes are as components designed with specific x, y and z axes relative to their housing. Designing the sensors into hearing devices can be done in ways where the axis/axes of orientations of the sensors directly matches the axis/axes of orientations of the hearing devices, e.g., an axis defined by a 'direction of microphones', when they are placed on a person's ears. In this way, no conversion of the accelerometer data is needed to achieve correct movement data, i.e., moving forward may e.g., correspond directly to the positive direction of the accelerometers x-axis. Alternatively, a fixed transformation of the data can be carried out by use of fixed spatial rotation of the axis, based on previous calculated placement of the sensors in the user situation relative to a characteristic direction of the hearing device, e.g., a direction defined by the housing of the hearing device, e.g., an outer edge of the housing. But to allow user individualization as well as allowing for free orientation of the sensors, it is advantageous to detect the sensors' placement relative to the head of the user by detecting movement data for each hearing device and to compare such data between the hearing devices. A spatial rotation matrix may be determined from the combined data, and this can be used for spatial transformation of the sensors' axis to the user's current head orientation. The transformation should preferably be continuously adapting to the user's head movements.

[0062] The hearing device may comprise a low-pass filter.

[0063] The method may comprise low-pass filtering the tilt estimates. In other words, the determined at least one tilt may be low-pass filtered. Thereby, the settings/parameters (i.e., the controlling and/or regulation of the operation (e.g., signal processing) of the hearing device) which are changed in dependence of the movement pattern(s) change slowly.

[0064] The hearing device may comprise a timing unit.

[0065] The method may comprise determining the amount of time the determined tilt is within a certain distance to a reference head position, by the timing unit. The method may comprise controlling and/or regulating operation (e.g., signal processing) of the hearing device in response to determining a tilt for a certain (predetermined) amount of time. For example, said certain (predetermined) amount of time is at least 1 second, or at least 2 seconds.

[0066] For example, the transition time into the changed settings/parameters (i.e., the amount of time for controlling and/or regulating the operation) and away from the changed settings/parameters may be symmetric, or asymmetric (e.g., the transition time away from the changed settings/parameters back into the 'normal' mode may be faster than the transition time when going into the head-tilt based settings/parameters).

[0067] The disclosure of a method step is to be understood to also disclose the respective means for performing the method step. Likewise, the disclosure of means for performing a method step is to be understood to also disclose the respective method step.

[0068] Further configurations and advantages of the invention will be explained in the following detailed description of some exemplary embodiments of the present invention in conjunction with the drawing.

BRIEF DESCRIPTION OF DRAWINGS

[0069] The aspects of the disclosure may be best understood from the following detailed description taken in conjunction with the accompanying figures. The figures are schematic and simplified for clarity, and they just show details to improve the understanding of the claims, while other details are left out. Throughout, the same reference numerals are used for identical or corresponding parts. The individual features of each aspect may each be combined with any or all features of the other aspects. These and other aspects, features and/or technical effects will be apparent from and elucidated with reference to the illustrations described hereinafter in which:

Fig. 1 schematically illustrates a hearing device mounted at or behind an ear of a user.

Fig. 2 schematically illustrates elements of a hearing device.

Fig. 3a, b schematically illustrates a hearing device user holding his or her head in a first and a second position.

Fig. 4 schematically illustrates examples of how noise reduction may be controlled based on deviation for a specific combination of tilt.

DETAILED DESCRIPTION

[0070] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. Several aspects of the apparatus and methods are described by various blocks, functional units, modules, components, circuits, steps, processes, algorithms, etc. (collectively referred to as "elements"). Depending upon particular application, design constraints or other reasons, these elements may be implemented using electronic hardware, computer program, or any combination thereof.

[0071] The electronic hardware may include microelectronic-mechanical systems (MEMS), integrated circuits (e.g. application specific), microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), gated logic, discrete hardware circuits, printed circuit boards (PCB) (e.g. flexible PCBs), and other suitable hardware configured to perform the various functionality described throughout this disclosure, e.g. sensors, e.g. for sensing and/or registering physical properties of the environment, the device, the user, etc. Computer program shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0072] Fig. 1 schematically illustrates a hearing device 1, in particular a hearing aid 1a. The hearing device 1 is a BTE hearing aid configured to be positioned behind the ear, i.e. between the pinna and the head, of a user 9. The hearing device 1 comprises a sensor 3 adapted to detect at least one movement and/or acceleration of the hearing device 1. The sensor 3 comprises a built-in accelerometer 3a. The arrow denoted g illustrates the gravitational force g. The sensor 3 provides a corresponding sensor signal representing the detected movement and/or acceleration sensed. This will allow the hearing device 1 to determine that it is tilted and/or moved.

[0073] The signal provided by the sensor 3 may be analyzed by a controller 4 as shown in Fig. 2. The analysis includes determining a tilt, in particular a movement pattern, of the hearing device 1 and comparing/matching the tilt and/or movement pattern to one or more predefined tilts/patterns e.g. stored in the hearing device 1. A movement pattern may be a set of standards defined by e.g. the supplier, but may alternatively comprise or be completely defined by the user 9. This could be done during the individualization process of the hearing device, often referred to as the fitting procedure. The tilt or movement pattern that the controller 4 seeks to recognize in the signal from the sensor 3 may be stored in a memory device (not shown) in the hearing device 1. Alternatively, the tilt or movement pattern may be stored in an external device, e.g. a remote server or a mobile phone or the like. Through the wireless interface 8, the tilt or movement pattern may be updated or augmented. The user 9 may be provided with an application for a mobile phone, or other computer device e.g. a tablet, where the user 9 may define the function associated with the pattern.

[0074] A pattern could e.g. be a number of, repeated, tilt motions in a specific direction within a given time frame or with defined intervals, e.g. three tilts within two seconds. In the present context, this will mean that the user 9, while wearing the hearing device 1, may wish to e.g. change the volume / amplification, such as turn the volume up or down, respectively, and may do this by tilting his or her head e.g. three times to the left or right. This movement pattern is then recorded by the sensor 3 and analyzed by the controller 4. Tilting may then be used for controlling operation of the hearing device 1 or a connected mobile device 2. For example, when a decision can be made that a specific movement pattern was executed by the user 9 this is translated to a control signal applied by a processor 5.

[0075] The processor 5 may be connected to an input transducer 6 and perform audio processing, such as frequency specific amplification and/or frequency transpositioning, feedback management, noise reduction, etc. The processor 5 may be embodied by more than one signal physical element each performing one or more functions. The processed signal from the processor 5 is forwarded to an output transducer 7 which may be positioned in a hearing device housing or an in-the-ear part or even be an implanted device implanted in the head of the user 9.

[0076] As shown in Fig. 3a, the tilt may be measured as a deviation from the direction of gravity. The arrow denoted g illustrates the gravitational force. A tilt of the hearing device may be caused by the user 9 bending his or her head towards the left, right, upwards, and/or downwards. The tilt angle θ may be determined as the deviation angle between the direction of gravitational force g and a deviation vector ref_d. In Fig. 3a, the deviation vector ref_d points to the left side when the hearing device is tilted to the right side, here labelled as $ref_{side.}$ The tilt angle θ may then be determined as the angle θ_{side} between the vector g and the deviation vector $ref_{side.}$ When the hearing device user 9 is tilting his or her head down, such as it might be the case when nodding as shown in Fig. 3b, the deviation vector ref_d points to the back, here labelled as ref_{updown}. The tilt angle θ may then be determined as the angle θ_{updown} between the vector g and the deviation vector ref_{updown}.

[0077] Based on the determined tilt, in particular the determined tilt angle θ, controlling operation of the hearing device 1 is performed. Controlling of the hearing device 1 may comprise controlling noise reduction of the hearing device 1. For example, directionality is disabled if the head is tilted, e.g. either to the left, right, downwards, or upwards. The directional system may be disabled gradually as function of angle and the threshold angle may be different depending on whether the instrument is tilted to the left, right, up, or down. Noise reduction may also be increased or decreased based on the determined tilt or movement pattern.

[0078] In Fig. 3a, the user 9 is tilting his or her head to the side. The hearing device 1 is tilted such that the deviation vector ref_{side} differs from the direction of gravity g by the tilt angle θ_{side}. Particularly, the amount of noise reduction may be increased while $\theta_{side_{min}} < \theta_{side} < \theta_{side_{max}}$ on a single or both hearing devices of a binaural hearing system.

[0079] In particular, the amount of noise reduction may be increased or decreased while the determined tilt is above a first absolute threshold value and below a second absolute threshold value. This particularly allows for the same functionality regardless of whether the head is tilted towards the left or right side, or up or down. In particular, the amount of noise reduction may e.g. be increased while $|\theta_{side_{min}}| < |\theta_{side}| < |\theta_{side_{max}}|$ on a single or both hearing devices of a binaural hearing system.

[0080] In Fig. 3b, the user 9 is looking downwards. The hearing device 1 is tilted such that the deviation vector ref_{updown} differs from the direction of gravity g by a tilt angle θ_{updown}. In particular, the tilt angle θ_{updown} may be above a first threshold value and below a second threshold value. The tilt angle may thus cause increasing the amount of noise reduction. In Fig. 3b, the tilt angle is $\theta_{updown_{min}} < \theta_{updown} < \theta_{updown_{max}}$ on a single hearing device (not shown) worn at or behind the right ear of the user 9, which may e.g. cause decrease of the amount of noise reduction.

[0081] Alternatively, the amount of noise reduction may e.g. be increased while $\theta_{updown_{min}} < \theta_{updown} <$

$\theta_{updown_{max}}$ and $\theta_{side_{min}} < \theta_{side} < \theta_{side_{max}}$ on a single or both hearing devices of a binaural hearing system.

[0082] Tilting may also be used for controlling other functionalities of the hearing device 1 or a connected mobile device 2. For example, the user 9 can adjust the volume of the hearing device by the very natural gesture of gently tilting his or her head forward or backwards as if it was a radio knob.

[0083] Controlling and/or regulating of operation of the hearing device 1 and/or a connected mobile device 2 may depend on other modalities as well, e.g. measured sound signals, movements, etc. In particular, controlling and/or regulating of the hearing device operation may depend on detected sound signals, in particular the determined sound level and/or signal-to-noise ratio of a sound signal. Controlling and/or regulating operation of the hearing device and/or the connected mobile device 2 based on a determined tilt, in particular a determined movement pattern, may even be only enabled if the sound level and/or the signal-to-noise ratio of the sound signal is above and/or below a threshold value. Particularly in complex sound environments, the user 9 is thus provided with extra help in terms of e.g. noise reduction.

[0084] A combination of the sensor 3 for detecting the movement and/or acceleration of the hearing device 1 and a capacitive sensor (not shown), where the capacitance changes when e.g. one or more fingers approach the hearing device, could be beneficial in reducing the processing to periods only when the presence or proximity of a finger is detected by the capacitive sensor.

[0085] For a user 9 with two hearing devices, configured in a binaural hearing system, there are further possibilities. The binaural hearing system may comprise a first and a second hearing device as described above. A sensor may be provided in each hearing device. During normal operation of the first and second hearing device in the binaural hearing system, both the first and the second hearing devices are adapted to transmit information from the sensor, e.g. any tilt pattern recognized, or even just the detection of e.g. tilt, to the respective other hearing device so that a decision on turning volume up or down in both hearing devices is made depending on a combination of detected tilt in the hearing device and detected tilt information being received from the other hearing device. This could for instance be a downward tilt of the left hearing device and an upward tilt of the right hearing device, or vice versa. The tilt could be static during the turning up or down of the volume, meaning that the user 9 need not keep tilting the hearing devices up and down, but simply hold them there.

[0086] In a case where the user 9 is wearing two hearing devices, information may be exchanged between the two hearing devices wirelessly. Sensor signals benefit from being exchanged binaurally, increasing the detection probability and allowing more complex movement patterns. Detection of false positives', typically due to head movement, are prevented, or at least alleviated, e.g. by threshold/timeout values and/or comparison with the tilt detected by a sensor sitting on another hearing device as normal head movement will always cause both hearing device to detect the same type of movement.

[0087] A computer program (product) comprising instructions which, when the program is executed by a computer, cause the computer to carry out (steps of) the method described above, in the 'detailed description of embodiments' and in the claims is furthermore provided by the present application.

[0088] In an aspect, the functions may be stored on or encoded as one or more instructions or code on a tangible computer-readable medium. The computer readable medium includes computer storage media adapted to store a computer program comprising program codes, which when run on a processing system causes the data processing system to perform at least some (such as a majority or all) of the steps of the method described above, and in the claims.

[0089] Fig. 4 schematically illustrates examples of how noise reduction may be controlled based on deviation for a specific combination of tilt.

[0090] In other words, Fig. 4 shows different examples of how e.g. the amount of noise reduction (or other hearing aid parameters) may be controlled based on the deviation for a specific combination of tilt (θ'_{Side}, θ'_{Updown}).

[0091] For example, when the head of the user is tilted towards a specific tilt position, the amount of noise reduction is increased. Or alternatively decreased.

[0092] However, other actions depending on the distance/length from a reference position (θ_{Side}, θ_{Updown}) to a specific head tilt position (θ'_{Side}, θ'_{Updown}) may be applied, i.e., depending on how much the user has turned his/her head. For example, the hearing device may be configured to e.g., change volume, change preferred listening direction, etc., with an amount depending on the distance/length of a specific head tilt position (θ'_{Side}, θ'_{Updown}) from a reference position.

[0093] Plot A of Fig. 4 shows the amount of noise reduction as function of the distance to a head tilt position (θ'_{Side}, θ'_{Updown}). As illustrated, the amount of noise reduction may e.g. be based on the magnitude of said distance, i.e.,:

$$\alpha|\theta_{Side}-\theta'_{Side}|+\beta|\theta_{Updown}-\theta'_{Updown}|$$

where different weighting α,β may be applied to the 'side' tilt vs. the 'updown' tilt.

[0094] It is foreseen that other hearing device settings than noise reduction may be adjusted based on a similar distance measure. In other words, operation (e.g., signal processing) of the hearing device may be controlled and/or regulated based on a similar distance measure (i.e., as function of the distance to a head tilt position (θ'_{Side}, θ'_{Updown})).

[0095] Plot B of Fig. 4 shows the amount of noise reduction as function of the squared distance to a head tilt position (θ'_{Side}, θ'_{Updown}). As illustrated, the magnitude-squared of said distance may take the form:

$$\alpha|\theta_{Side}-\theta'_{Side}|^2+\beta|\theta_{Updown}-\theta'_{Updown}|^2$$

[0096] Again, different weighting α,β may be applied to the 'side' tilt vs. the 'updown' tilt. It is foreseen that other hearing device settings than noise reduction may be adjusted based on a similar distance measure.

[0097] Plot C of Fig. 4 shows the amount of noise reduction as function of the absolute distance to a head tilt position (θ'_{Side}, θ'_{Updown}). Thereby, plot C may be independent of whether the user tilts his/her head towards left/right or up/down by applying the absolute value to the tilt angle before the distance measure is determined. As illustrated, said absolute distance may take the form:

$$\alpha||\theta_{Side}|-|\theta'_{Side}||+\beta||\theta_{Updown}|-|\theta'_{Updown}||$$

Again, different weighting α,β may be applied to the 'side' tilt vs. the 'updown' tilt. It is foreseen that other hearing device settings than noise reduction may be adjusted based on a similar distance measure.

[0098] By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media. In addition to being stored on a tangible medium, the computer program can also be transmitted via a transmission medium such as a wired or wireless link or a network, e.g. the Internet, and loaded into a data processing system for being executed at a location different from that of the tangible medium.

[0099] In an aspect, a data processing system comprising a processor adapted to execute the computer program for causing the processor to perform at least some (such as a majority or all) of the steps of the method described above and in the claims, is provided.

[0100] It is intended that the structural features of the devices described above, either in the detailed description and/or in the claims, may be combined with steps of the method, when appropriately substituted by a corresponding process.

[0101] As used, the singular forms "a," "an," and "the" are intended to include the plural forms as well (i.e. to have the meaning "at least one"), unless expressly stated otherwise. It will be further understood that the terms "includes," "comprises," "including," and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will also be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element, but an intervening element may also be present, unless expressly stated otherwise. Furthermore, "connected" or "coupled" as used herein may include wirelessly connected or coupled. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. The steps of any disclosed method are not limited to the exact order stated herein, unless expressly stated otherwise.

[0102] It should be appreciated that reference throughout this specification to "one embodiment" or "an embodiment" or "an aspect" or features included as "may" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the disclosure. Furthermore, the particular features, structures or characteristics may be combined as suitable in one or more embodiments of the disclosure. The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more.

[0103] Accordingly, the scope should be judged in terms of the claims that follow.

Claims

1. A method, in particular performed by at least one hearing device, the method comprising:

   - detecting at least one movement and/or acceleration of at least one hearing device 1;
   - determining at least one tilt, in particular a movement pattern, of the at least one hearing device 1 based on the detected movement and/or acceleration; and
   - controlling and/or regulating operation of the at least one hearing device 1 and/or a connected mobile device 2 based on the determined tilt, in particular the determined movement pattern.

2. Method according to claim 1, wherein the method further comprises:

   - detecting at least one sound signal; and

- determining a sound level and/or signal-to-noise ratio of the sound signal, wherein controlling and/or regulating operation of the hearing device 1 and/or the connected mobile device 2 based on the determined tilt is only enabled if the sound level and/or the signal-to-noise ratio of the sound signal is above and/or below a threshold value.

3. Method according to claim 1 or 2, wherein controlling and/or regulating operation of the hearing device 1 comprises controlling and/or regulating signal processing, in particular controlling and/or regulating noise reduction, of the hearing device 1 based on the determined tilt, in particular the determined movement pattern.

4. Method according to claim 3, wherein the amount of noise reduction is increased or decreased if the determined tilt is above or below a threshold value.

5. Method according to claim 4, wherein the threshold value depends on the direction in which the hearing device 1 is moved and/or accelerated.

6. Method according to any one of claims 3 to 5, wherein the amount of noise reduction is increased or decreased while the determined tilt is above a first threshold value, in particular a first absolute threshold value, and/or below a second threshold value, in particular a second absolute threshold value.

7. Method according to any one of claims 3 to 6, wherein controlling and/or regulating noise reduction of the hearing device 1 comprises controlling and/or regulating beamforming, in particular enabling and/or disabling a directional and/or an omnidirectional mode, controlling and/or regulating binaural beamforming, in particular enabling and/or disabling binaural beamforming, and/or controlling and/or regulating filtering, in particular post filter attenuation.

8. Method according to any one of claims 1 to 7, wherein controlling and/or regulating operation of the hearing device 1 comprises changing a program and/or changing volume of the hearing device 1.

9. Method according to any one of claims 1 to 8, wherein controlling and/or regulating operation of the connected mobile device 2 comprises answering or rejecting a phone call.

10. Method according to any one of claims 1 to 9, wherein the tilt, in particular the movement pattern, is determined based on at least one movement and/or acceleration of a first hearing device and at least one movement and/or acceleration of a second hearing device.

11. Method according to any one of the preceding claims, wherein the tilt is divided into when the hearing device is tilted to the right or left side, θ_{side}, and into when the hearing device is tilted up or down, θ_{updown}.

12. Method according to any one of the preceding claims, wherein the method comprises predefining and storing at least one tilt, in particular at least one movement pattern, of the at least one hearing device, and controlling and/or regulating operation of the at least one hearing device based on the determined tilt, in particular the determined movement pattern.

13. A hearing device 1, in particular a hearing aid, the hearing device 1 being configured to and/or comprising at least one means for performing a method according to one of claims 1 to 12.

14. Hearing device 1 according to claim 13, wherein the hearing device 1 comprises at least one sensor 3 for detecting at least one movement and/or acceleration of the hearing device 1.

15. A binaural hearing system comprising a first and a second hearing device, in particular a first and a second hearing aid, the first and the second hearing device being configured to and/or comprising at least one means for performing a method according to one of claims 1 to 12, wherein the binaural hearing system is configured to determine a system tilt, in particular a system movement pattern, based on the detected movement and/or acceleration of the first and second hearing device.

16. Hearing system comprising:

- at least one hearing device 1, in particular at least one hearing aid, the hearing device 1 being configured to and/or comprising at least one means for performing a method according to one of claims 1 to 12; and
- at least one mobile device 2, in particular a smartphone, connected with the hearing device 1.

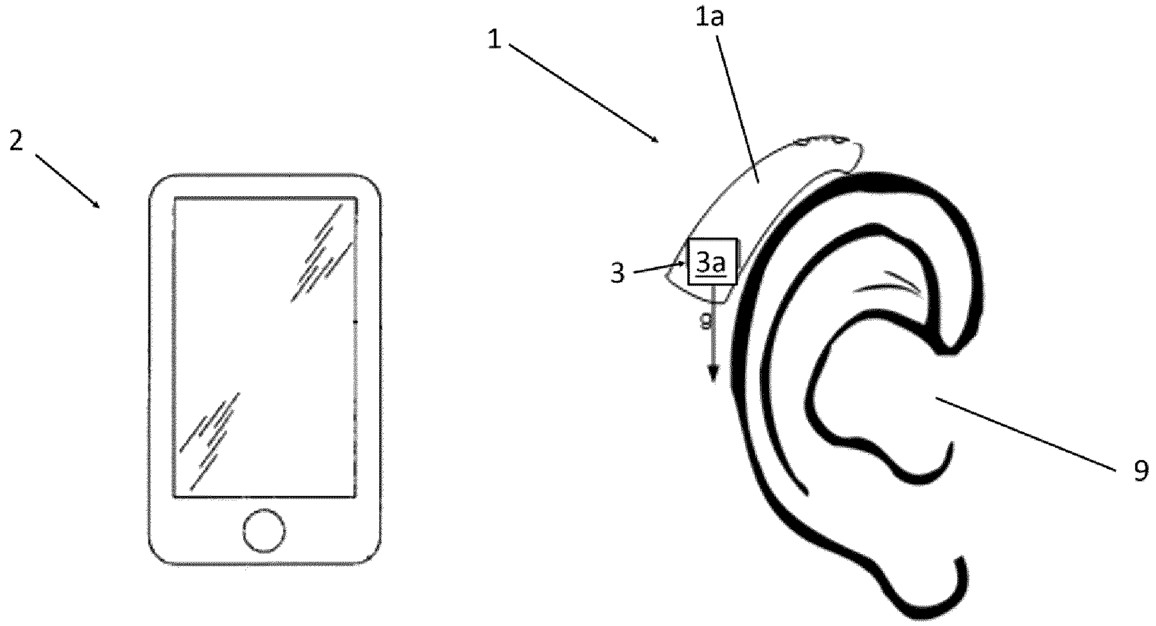

Fig. 1

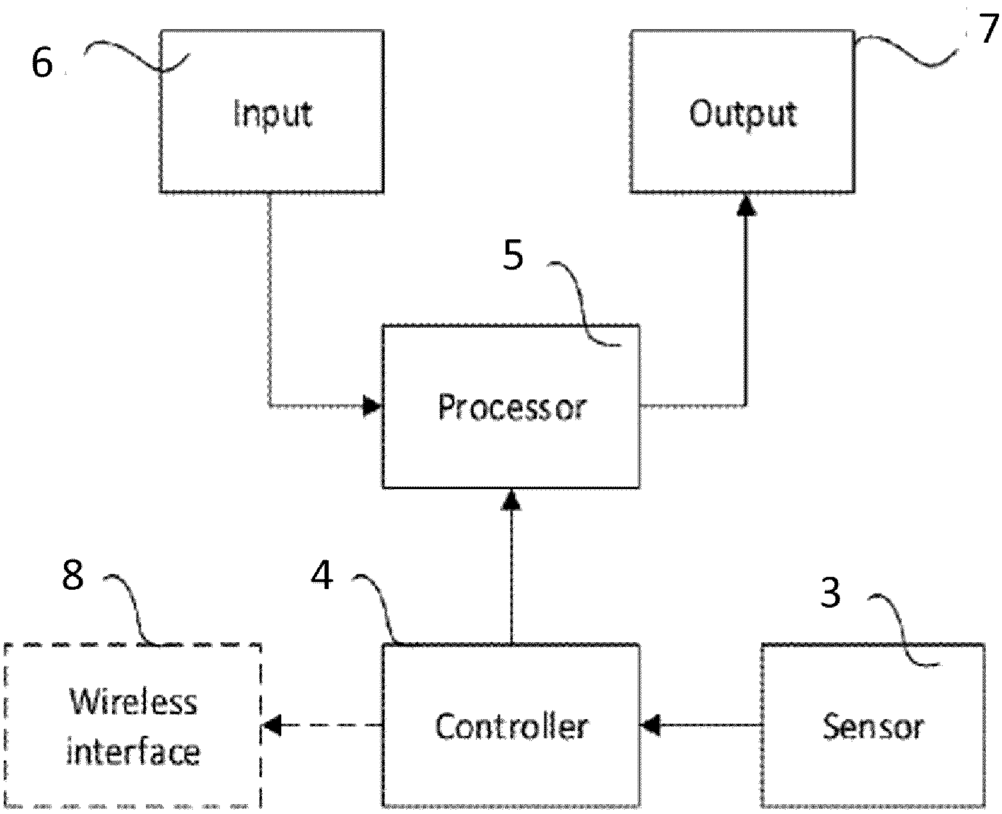
6
Input
7
Output
5
Processor
8
4
3
Wireless
interface
Controller
Sensor

Fig. 2

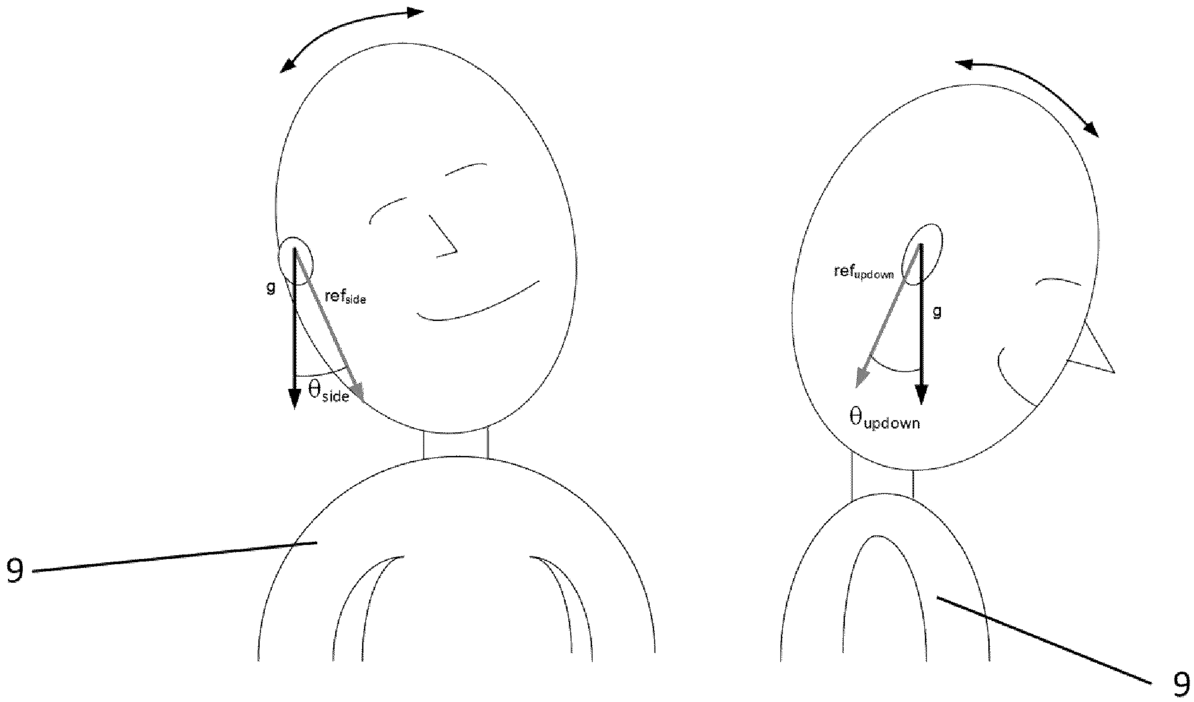

Fig. 3a   Fig. 3b

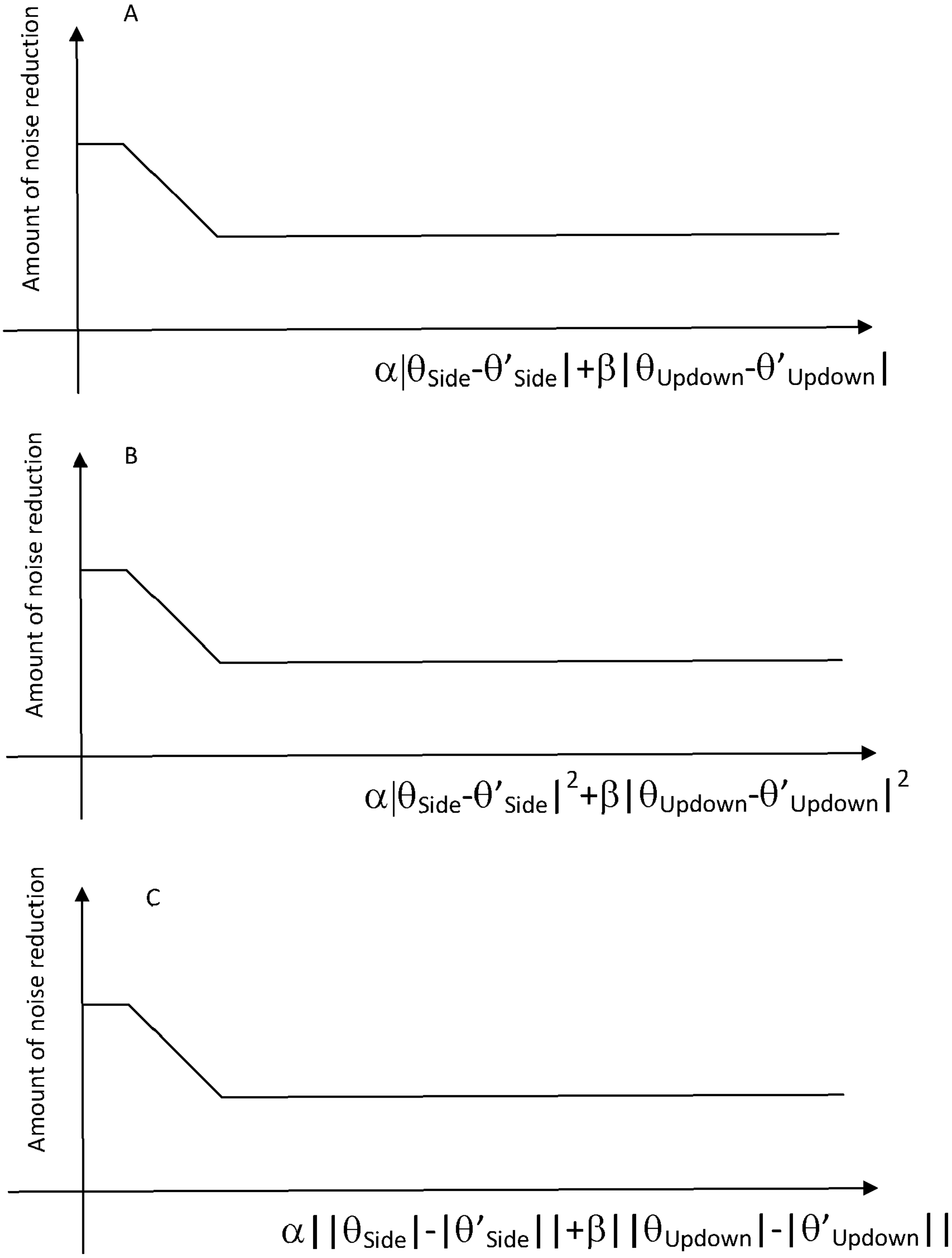
A
Amount of noise reduction
$\alpha|\theta_{Side}-\theta'_{Side}|+\beta|\theta_{Updown}-\theta'_{Updown}|$
B
Amount of noise reduction
$\alpha|\theta_{Side}-\theta'_{Side}|^2+\beta|\theta_{Updown}-\theta'_{Updown}|^2$
C
Amount of noise reduction
$\alpha||\theta_{Side}|-|\theta'_{Side}||+\beta||\theta_{Updown}|-|\theta'_{Updown}||$

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 23 15 0309

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 Y	US 2021/306726 A1 (EL GUINDI NADIM [CH] ET AL) 30 September 2021 (2021-09-30) * paragraph [0003] - paragraph [0005] * * paragraph [0009] * * paragraph [0014] * * paragraph [0034] - paragraph [0046]; figure 1 * * paragraph [0050] - paragraph [0057]; figure 3 * * paragraph [0061] - paragraph [0064]; figure 5 * * paragraph [0065] - paragraph [0069]; figure 6 * * paragraph [0079] - paragraph [0084]; figure 8 * * paragraph [0085] - paragraph [0089]; figure 9 * * paragraph [0098] - paragraph [0100]; figure 12 * -----	1,3-9, 11-14,16 2,10,15	INV. H04R25/00 ADD. H04R1/10
X Y	US 2022/295191 A1 (PEDERSEN MICHAEL SYSKIND [DK] ET AL) 15 September 2022 (2022-09-15) * paragraph [0130] - paragraph [0160] * * paragraph [0215] * * paragraph [0227] * * claims 14-16 * -----	1-3,7, 10,11, 13-16 2,10,15	TECHNICAL FIELDS SEARCHED (IPC) H04R
X	US 2018/253275 A1 (HELWANI KARIM [US] ET AL) 6 September 2018 (2018-09-06) * paragraph [0025] * * paragraph [0028] * * paragraph [0038] * * paragraph [0049] - paragraph [0052]; figure 3 * ----- -/--	1,11,13, 14,16	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	19 June 2023	Guillaume, Mathieu

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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P : intermediate document

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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EUROPEAN SEARCH REPORT

Application Number
EP 23 15 0309

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 Y	US 2015/230036 A1 (PEDERSEN MICHAEL SYSKIND [DK] ET AL) 13 August 2015 (2015-08-13) * paragraph [0001] * * paragraph [0010] - paragraph [0011] * * paragraph [0032] * * paragraph [0172] - paragraph [0179]; figure 4 * * paragraph [0279] - paragraph [0290]; figures 12-13 * -----	1,3,7, 10,11, 13-16 10,15	

TECHNICAL FIELDS SEARCHED (IPC)

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 June 2023	Guillaume, Mathieu

EPO FORM 1503 03.82 (P04C01)

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

page 2 of 2

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 15 0309

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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19-06-2023

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EPO FORM P0459

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