(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 139 638 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.03.2017 Bulletin 2017/10

(21) Application number: **15184032.9**

(22) Date of filing: **07.09.2015**

(51) Int Cl.:
H04R 25/02 *(2006.01)* ***A61B 5/12*** *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

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(54) **HEARING AID FOR INDICATING A PATHOLOGICAL CONDITION**

(57) According to an embodiment, a hearing aid adapted to indicate a pathological condition of a user of the hearing aid when the hearing aid is in use is disclosed. The hearing aid includes an input transducer, a processing unit, an output transducer and a feedback measurement unit. The input transducer is adapted to transform an input sound signal into an electrical input signal. The processing unit adapted to generate an electrical output signal by processing the electrical input signal. The output transducer is adapted to transform the processed electrical output signal to an acoustic output signal and to direct the acoustic output signal towards a tympanic membrane of the user. The feedback measurement unit is adapted to measure an acoustic feedback produced by the tympanic membrane in response to the acoustic output signal. During a time duration, a feedback path logger is adapted to continuously track the measured acoustic feedback and a feedback path modeller is adapted to generate a base pattern across a plurality of frequencies of the tracked acoustic feedback. During a subsequent time duration, the feedback path logger is adapted to continuously track the measured acoustic feedback and the feedback path modeller is adapted to generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback. The hearing aid further includes a comparator and a state classifier. The comparator is adapted to determine a variation between the measured pattern and the base pattern and the state classifier adapted to identify at least one pathological condition corresponding to the determined variation.

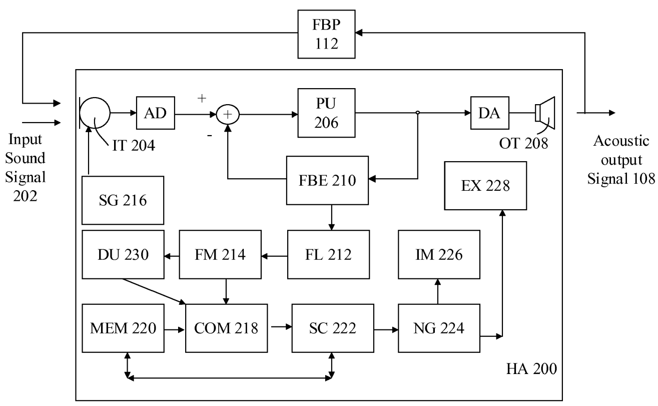

FIG. 2

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Description

FIELD

[0001] The disclosure relates to a device having an ear monitoring functionality. In particular, the disclosure relates to a hearing aid adapted to indicate a pathological condition of a user of the hearing aid based on non-invasive in-situ monitoring of the middle ear status.

BACKGROUND

[0002] The middle ear is a cavity located behind the eardrum (tympanic membrane). For normal operation, the middle ear is maintained at the same pressure as the atmospheric pressure through pressure equalization via the Eustachian tube. However, in some cases such as Eustachian tube dysfunction, the pressure of the middle ear becomes different from that of the atmospheric pressure. Variation in middle ear pressure such as negative pressure or alternating periods of negative, normal and positive pressure may be a risk factor or symptom for middle ear problems. Most middle ear problems result in stiffening of the tympanic membrane due to pathological difference in pressure between the middle ear and the atmospheric pressure. This can interfere with the ability of the middle ear to transfer sounds from the outer ear to the inner ear. When the tympanic membrane is stiffer than normal, it reflects more sounds than it would normally do back to the outer ear. The negative middle ear pressure often is a forerunner to Otitis Media. Although anyone can develop an ear infection, ear infections are much more prevalent among children than in adults. For example, 80% of infants and young children will experience Otitis Media. Of these, many children suffer from Otitis Media for weeks and months before it is detected in a clinic. Otitis Media can cause temporary hearing loss. If left untreated, it can cause permanent hearing loss. A hearing loss itself delays development of language skills, and children who already have a hearing loss are more affected and delayed in their development if an untreated hearing loss is caused by Otitis Media occurs. An early detection of Otitis Media would limit the detrimental effects caused by the hearing loss and limit the associated discomfort and pain. Unfortunately, parents, teachers and other people around the child typically fail to notice the exact condition of the child's middle ear. Therefore, parents would be relieved if they were advised on when to seek medical help for deductive diagnosis of a potential middle ear problem.

[0003] There exists a need for not only identifying condition of the middle ear in a simpler way but also to address the issue of monitoring other pathological conditions. For example, the parts of the inner ear that contribute to hearing and balance are filled with clear and odourless fluid. This fluid is linked through the cochlear aqueduct to the fluid that surrounds and supports the brain. Healthy cochlear fluids are vital to good hearing and balance while healthy cerebral fluids are vital to life. Changes in these fluids may occur. For example, Meniere's disease is caused by changes in cochlear fluids. Conventionally, an analysis of the pressure of the cerebral fluid is used to diagnose brain-related conditions such as cerebral malaria (swelling of the brain due to malaria-filled blood cells blocking cerebral blood supply), meningitis (infection of the outer layers of the brain), and subarachnoid haemorrhage (bleeding around the brain). The traditional approach for measuring cerebral fluid pressure is the lumbar puncture (also called spinal tap) which is invasive and has significant risks. It involves local anaesthesia, insertion of a hollow needle in the spine, and the measurement of the pressure in the spine.

[0004] The deductive and decisive identification of such pathological condition for curative purposes is possible only through a trained medical professional. However, such deductive and decisive identification is dependent upon the potential patient visiting the medical professional for tests and the analysis and such visits are typically infrequent. Therefore, there is a need to provide a preliminary indication of pathological condition such that the user of the hearing aid is alerted to make an appropriately timed visit to the medical professional for diagnosis and treatment.

SUMMARY

[0005] The disclosure relates to indication of a pathological condition based on an in-situ and non-invasive technique. In particular, such indication is implemented using a hearing aid that is in operating position at a hearing aid user. As indicated earlier, a variation in middle ear affects pressure equalization and in effect, affects such as increase the stiffness of the tympanic membrane. This change such as increase in the stiffness of the tympanic membrane affects acoustic feedback detected in response to an input sound signal, which may either include the sound received from the user's auditory environment or a predefined signal with or without the sound received from the auditory environment. Measuring the acoustic feedback determines the middle ear condition and forms the basis for detecting pathological condition using a state classifier. The disclosure further refers to a pending application EP14176716.0 titled "Hearing device with ear monitoring Function", which is incorporated here by reference.

[0006] According to an embodiment, a hearing aid adapted to indicate a pathological condition of a user of the hearing aid when the hearing aid is in use is disclosed. The hearing aid includes a signal generator, an output transducer and a feedback measurement unit. The signal generator is adapted to generate an electrical output signal. The output transducer is adapted to transform the electrical output signal to an acoustic output signal and to direct the acoustic output signal towards a tympanic membrane of the user. The feedback measurement unit adapted to measure an acoustic feedback produced by the tympanic membrane in response to the acoustic output signal. During a time duration, a feedback path logger is adapted to continuously track the measured acoustic feedback and a feedback path modeller is adapted to generate a base pattern across a plurality of frequencies of the tracked acoustic feedback. During a subsequent time duration, the feedback path logger is adapted to continuously track the measured acoustic feedback and the feedback path modeller is adapted to generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback. The hearing aid further includes a comparator and a state classifier. The comparator is adapted to determine a variation between the measured pattern and the base pattern and the state classifier adapted to identify at least one pathological condition corresponding to the determined variation.

[0007] According to an embodiment, a hearing aid adapted to indicate a pathological condition of a user of the hearing aid when the hearing aid is in use is disclosed. The hearing aid includes an input transducer, a processing unit, an output transducer and a feedback measurement unit. The input transducer is adapted to transform an input sound signal into an electrical input signal. The processing unit adapted to generate an electrical output signal by processing the electrical input signal. The output transducer is adapted to transform the processed electrical output signal to an acoustic output signal and to direct the acoustic output signal towards a tympanic membrane of the user. The feedback measurement unit adapted to measure an acoustic feedback produced by the tympanic membrane in response to the acoustic output signal. During a time duration, a feedback path logger is adapted to continuously track the measured acoustic feedback and a feedback path modeller is adapted to generate a base pattern across a plurality of frequencies of the tracked acoustic feedback. During a subsequent time duration, the feedback path logger is adapted to continuously track the measured acoustic feedback and the feedback path modeller is adapted to generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback. The hearing aid further includes a comparator and a state classifier. The comparator is adapted to determine a variation between the measured pattern and the base pattern and the state classifier adapted to identify at least one pathological condition corresponding to the determined variation.

[0008] The term "hearing aid is in use" refers to that the hearing aid is positioned at the user in its operating position. As an illustraive example, the term hearing aid in use is explained by way of a behind the ear aids (BTE) that includes a case, an earmould or dome and a connection between them. In use, the case sits behind the pinna with the connection from the case coming down the front into the ear, where the earmould sits. This includes i) use of the hearing aid during a fitting session, or ii) using the hearing aid during normal operation where the hearing aid is used to amplify sound for the wearer, usually with the aim of making speech from auditory (acoustic) environment more intelligible, and to correct impaired hearing. Thus, the hearing aid provides an in-situ monitoring of the pathological condition of the user. In case where the hearing aid includes a health monitor wearable, the wearable unit is in position at or in the ear in order to be used as monitoring the stiffness of the tympanic membrane in accordance with the disclosure. In this implementation, the hearing aid in use refers to positioning the wearable at or in the ear of the user of the ear as an ear level monitoring unit without an amplification of the input sound signal as is the case in conventional hearing aid. Thus, when the wearable unit is in use, the processing unit is adapted to generate an electrical output signal by processing the electrical input signal. The processing unit may be adapted to process the electrical input signal. This may include processing other than amplifying the electrical input signal. However, the amplification or other processing does not correspond to the hearing impairment of the user.

[0009] The input transducer includes a microphone and may also include a microphone array. The processing, using the processing unit, may include band pass filtering the electrical input signal into a number of frequency bands to obtain a number of band limited signal and amplifying the band limited signal by frequency specific gain factor. The processing unit may be adapted to perform a number of other operations such as compression, noise reduction, microphone array beamsteering, etc. The output transducer typically includes a speaker, usually also referred as receiver. The output transducer may be positioned in a mould that is positioned in the ear, ear canal or bony part of the ear canal. Alternatively, the speaker may be positioned in a BTE casing and the acoustic output signal is delivered to the tympanic membrane via a sound tube that directs the acoustic output signal from the output transducer to the tympanic membrane.

[0010] In one embodiment, the input sound signal includes a sound signal that the input transducer receives from acoustic environment when the hearing aid is in use. In another embodiment, the input sound signal includes a predefined sound signal of predefined characteristics with or without the sound signal that the input transducer receives from acoustic environment when the hearing aid is in use. Thus, in this latter embodiment, the predefined sound signal may be considered as a probe signal that may either be provided independently or in combination with the sound that the input transducer receives from the auditory environment when the hearing aid is in use.

[0011] The hearing aid may include a signal generator that is adapted to generate the predefined sound signal of the predefined characteristics. The predefined characteristics is defined by a specific frequency and specific level. In various embodiments, the specific frequency is selected from a range between 100 Hz to 4 KHz. For example, the predetermined frequency may include a frequency such as 250 Hz, or 500 Hz, or 1000 Hz, or 2000

Hz, or 4000 Hz. Other frequencies within or outside the range is also possible. The predefined frequency may be implemented as a frequency sweep. In an embodiment, the predefined sound signal may include one or more of a broad band noise, narrow band noise and clicks. In one embodiment, the specific level when amplified or unamplified is below the perceivable level of the user. In another embodiment, the specific level when amplified or unamplified is above the perceivable level of the user. In these embodiments, the "perceivable level" is defined by the predefined sound signal having a characteristic signal pressure level such that in unamplified or amplified form, the signal pressure level or amplified signal pressure level is such that the user starts perceiving the predefined sound signal as sound. Thus, an unamplified predefined sound signal is related to frequency specific hearing threshold of the user whereas the amplified predefined sound signal is related to 0 dB SPL (20 micropascal sound pressure). In the previous embodiment of below perceivable level, the predefined sound signal may be used to obtain feedback measurement for identification of pathological conditions without distorting the signal of interest, such as speech signals during normal operation of the hearing aid. In order to obtain feedback measurement for generating the base pattern and the measured pattern, a predefined frequency specific amplification to the feedback signal may be applied before performing feedback measurement. In the latter embodiment of the above perceivable level, the feedback measurement is relatively more reliable.

[0012] In either embodiments of level being above or below perceivable level, the processing unit may be adapted to process the sound signal received from the auditory environment such that the deterioration in sound quality or negative affect in speech intelligibility because of the predefined sound signal is minimized. Similarly, in either embodiments of level being above or below perceivable level, the feedback measurement unit may be adapted to separate out the feedback corresponding only to the predefined sound signal only.

[0013] Thus, in one embodiment, the isolated feedback measurement relating to the predefined sound signal alone may be used to generate the base pattern and measured pattern. In another embodiment, the base pattern and the measured pattern are generated in accordance to the feedback measurement corresponding only to the sound signal received at the input transducer from the auditory environment. In yet another embodiment, the base pattern and the measured pattern are generated in accordance to the feedback measurement corresponding to a combination of the sound signal received at the input transducer from the auditory environment and the predefined sound signal.

[0014] Acoustic feedback problems typically occur when the output loudspeaker signal of an audio system is partly returned to the input microphone via an acoustic coupling through the air. Thus, the sounds leaked from the vent or seal between the ear mould and the ear canal may cause the feedback. When in-situ gain of the hearing aid is sufficiently high, or when a larger than optimal size vent is used, the output of the hearing aid generated within the ear canal may exceed the attenuation offered by the ear mould/ shell. The disclosed hearing aid is adapted to measure the acoustic feedback.

[0015] In one embodiment, the feedback measurement unit includes a feedback estimator adapted to estimate the acoustic feedback. Such estimation is based on conventionally known feedback estimation algorithms such as in known feedback cancellation techniques using adaptive filters, where an estimation the acoustic feedback path is made to create a signal to cancel the feedback signal. Other estimation techniques are available in Guo Meng, Analysis, Design, and Evaluation of Acoustic Feedback Cancellation Systems for Hearing Aids, Aalborg University (2013); A. Spriet et al., Adaptive feedback cancellation in hearing aids, Journal of the Franklin Institute 343 (2006) 545-573; etc.

[0016] In another embodiment, the feedback measurement unit includes a measurement microphone and a level estimator. The measurement microphone is housed in an ear mould of the hearing aid and the ear mould is adapted to be placed within the ear canal of the user. The measurement microphone is adapted to receive the sound reflected from the tympanic membrane in response to the input sound signal and to transform the reflected sound to a reflected electrical sound signal. The level estimator is adapted to estimate the level from the reflected electrical sound signal. The level estimator may rely on peak or average amplitude, on the root mean square level of the signal, or on some statistical property of the signal. For example, in one aspect, the level is based on magnitude or magnitude squared of the respective reflected electrical signal. The determination may be based on a short term basis, such as a level based on a short time interval, such as for example the last 5 ms to 40 ms or such as the last 10 ms. The level may then be converted to a domain such as a logarithmic domain or any other domain. The skilled person would find it reasonable to implement the comparator for determining level difference using a number of conventionally known techniques.

[0017] The term "continuously tracking" refers to recording data whenever the feedback measurement unit produces feedback measurements. The functioning of the feedback measurement unit such as feedback estimator is generally pre-configured such as during a fitting session.

[0018] In an embodiment, for each frequency or sampled frequencies across the plurality of frequencies, the base pattern comprises average or weighted average of feedback values as available through continuous tracking at different measurement points during the time duration. Also, for the specific frequency or sampled frequencies across the plurality of frequencies, the measured pattern comprises average or weighted average of feedback values at different measurement points during the subsequent time duration. The "sampled frequencies" refer to discretely chosen frequencies within a plurality range comprising the plurality of frequencies.

[0019] In an embodiment, the different measurement points are defined as measurement separated by essentially the same time period. This implementation may include a time counter in order to identify distinct measurement points. Additionally or alternatively, the different measurement points are defined as environment classified measurement points such that auditory environment specific measurements are obtained. This implementation may include an environment classifier that is adapted to classify the auditory environment such as loud, medium, soft, etc. in accordance with the sound received at the input transducer of the hearing aid. Once an environment for which the measurement is to be obtained is detected, the measurements are made. Furthermore, the different measurement points are defined as activity classified measurement points such that the activity specific measurement points are obtained. This implementation may include an activity classifier that is adapted to classify a user's activity such as sleeping, running, etc. in accordance with the detection signals received from sensors available at the hearing aid or external sensors. These sensors may include Electroencephalography sensors, heart rate monitors, etc. Measurements over the time duration such as a week or a month or more than a month to generate base pattern, and subsequent time duration such as a week or a month or more than a month would account for daily variation in middle ear measurements originating from variability of the hearing aid positioning especially that of mould in the ear canal, growth of the child's ear canal, variations in temperature, activity level, sweat, jaw movement and ear wax build up.

[0020] In an embodiment, a receiver of transmitter-receiver unit comprising within the heairng aid receives an instruction signal for defining a start point and end point of the time duration and the subsequent time duration. Alternatively, the start point and end point of the time duration and the subsequent time duration may be predefined at a fitting session. In yet another embodiment, the hearing aid is programmed to adaptively define the start point and end point for the time duration and the subsequent time duration based on predefined rule such as based on environment classification rule i.e. when the a specific identified environment repeats more than x number of times like user already been exposed to loud environment 10 times. Other rules for defining the time duration and subsequent time duration specific to a user would be apparent to the skilled person.

[0021] In different disclosed embodiments, the subsequent time duration follows the time duration. Also, the base pattern is the primary pattern - one or more measure patterns generated based on feedback measurements as obtained from one or more subsequent time durations are compared against the base pattern. In some embodiments, if no pathological condition based on variation between the measured pattern and the base pattern is detected, then the modeller may update the base pattern (available in the memory) by incorporating the data points of the measured pattern (available from the memory or logger) into the base pattern for creating an updated base pattern. The updated base pattern may then be used as a base pattern for comparison with measured patterns from other subsequent time durations. The figure in later sections does not show a communication channel between the modeller and the memory. However, the modeller may be communicatively connected to the memory.

[0022] The base pattern and the measured pattern represents a feedback level curve at each or at sampled frequencies across the plurality of frequencies. Additionally or alternatively, the base pattern and the measure pattern represent a feedback level curve for a specific frequency at different measurement points during the time duration and subsequent time duration respectively. The base pattern and the measured pattern may also be represented as mathematical functions, i.e. base function and measured function.

[0023] In an embodiment, the hearing aid includes a derivative unit adapted to determine a first order and/ or higher order derivative of the base pattern and/ or the measured pattern. The derivative may include time based derivative or frequency based derivative. The derivative unit may include derivative techniques that are well-known in the art like Laplace derivative operator. In an embodiment, the functioning of the derivative unit may be included in the comparator.

[0024] According to an embodiment, the comparator is adapted to determine the variation between the base pattern and the measured pattern. Such determination may include a number of implementations. For example, it may be suitable that variation relating to particular frequency may be preferentially "weighted" compared to other frequencies to provide improved statistical analysis. In this manner, important frequency values or ranges can be afforded more weight.

[0025] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between the measured pattern comprising feedback values at the measurement points during the subsequent time duration and the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference, at at least one frequency across the plurality of frequencies, between the measured pattern comprising feedback value for each frequency across the plurality of frequencies and the base pattern comprising feedback value for each frequency across the plurality of frequencies.

[0026] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between a time derivative value of a first order and/ or higher order derivative of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a time derivative of a first order and/ or higher order derivative of the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference, at at least one frequency across the plurality of frequencies, between a frequency derivate value of a first order and/ or higher order derivative of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a frequency derivative value of a first order and/ or higher order derivative of the base pattern comprising feedback value for each frequency across the plurality of frequencies.

[0027] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between a parameter of a feature of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a comparable parameter of a comparable feature of the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference between a parameter of a feature of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a comparable parameter of a comparable feature of the base pattern comprising feedback value for each frequency across the plurality of frequencies. In these embodiments, the parameter may include width, height, depth, slope, etc. and the feature may include peak, valley, crater, etc. as represented in the pattern. The skilled person would appreciate that other parameters and features may also be included.

[0028] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between a parameter of a feature of first order and/ or higher order time derivative of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a comparable parameter of a comparable feature of first order and/ or higher order time derivative of the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference between a parameter of a feature of a first order and/ or higher order frequency derivative of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a comparable parameter of a comparable feature of a first order and/ or higher order frequency derivative of the base pattern comprising feedback value for each frequency across the plurality of frequencies. In these embodiments, the parameter may include width, height, depth, slope, etc. and the feature may include peak, valley, crater, etc. as represented in the patterns. The skilled person would appreciate that other parameters and features may also be included.

[0029] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between shape and/ or size of the measured pattern/ a section of the measured pattern and shape and/ or size of the base pattern/ corresponding section of the base pattern. The measured pattern comprising feedback values at the measurement points during the subsequent time duration and the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference between shape and/ or size of the measured pattern/ a section of the measured pattern and shape and/ or size of the base pattern/ corresponding section of the base pattern. The measured pattern comprising feedback value for each frequency across the plurality of frequencies and the base pattern comprising feedback value for each frequency across the plurality of frequencies.

[0030] In one embodiment, determining the variation includes evaluating difference, for a specific frequency, between shape and/ or size of a first order and/ or higher order derivative of the measured pattern/ a section of the measured pattern and shape and/ or size of a first order and/ or the higher order derivative of the base pattern/ corresponding section of the base pattern. The measured pattern comprising feedback values at the measurement points during the subsequent time duration and the base pattern comprising feedback values at the measurement points during the time duration. In another embodiment, determining the variation includes evaluating difference between shape and/ or size of a first order and/ or higher order derivative of the measured pattern/ a section of the measured pattern and shape and/ or size of a first order and/ or higher order derivative of the base pattern/ corresponding section of the base pattern. The measured pattern comprising feedback value for each frequency across the plurality of frequencies and the base pattern comprising feedback value for each frequency across the plurality of frequencies.

[0031] In the preceding embodiments, the patterns may be generated using known curve fitting techniques, and the patterns may be compared for variations using conventional statistical analysis techniques.

[0032] The hearing aid according to any of the preceding claims, wherein the comparator is adapted to categorize the determined variation in a variation type in accordance to the determination of the variation between the measured pattern and the base pattern. The variation type may include categorization based on a predefined dictionary of vibration types.

[0033] In an embodiment, the hearing aid includes a memory. The memory is adapted to store a plurality of predefined variations and/ or a plurality predefined variation types. The memory further stores associations of each of the stored plurality of predefined variations and/ or stored plurality predefined variation types with one or more possible pathological condition.

[0034] The memory is adapted to store the base pattern and/ or first order and/ or higher order derivative of the base pattern as generated after the time duration. The comparator is adapted to access the memory to retrieve the base pattern for determining the variation between the measured pattern and the base pattern.

[0035] The pathological conditions that may be screened for, identified or monitored may include one or more conditions like Otitis Media, meningitis, subarachnoid hemorrhage, cerebral malaria, attention-deficit Disorder, dyslexia, Parkinson's Disease, Heart Disease, Alzheimer's Disease, Juvenile Diabetes, Autism, etc., indication for loss of hearing or loss of hearing of certain frequencies.

[0036] The state classifier may be adapted to access information stored in the memory and to identify the pathological condition by comparing the determined variation with pathological condition associated with the stored predefined variation and/ or predefined variation type that represents the determined variation/ determined variation type. The predefined variation and/ or predefined variation type thus defines a variation / variation type that is linked to at least one pathological condition. This may be implemented via a search module that is adapted to search a look up table stored in the memory. Many way of implementing are known for associating or indexing the variation/ variation type with the pathological condition and searching the pathological condition in accordance to the measured variation and variation type.

[0037] In order to indicate the identified pathological condition, the hearing aid may further include a notification generator adapted to generate and transmit an indicator signal, corresponding to the identified pathological condition, to an indicator module for producing a perceivable effect. The perceivable effect may be selected from a group consisting of a visual signal at the hearing aid device/ remote device like a smartphone, a vibration of the hearing aid device/ remote device like the smartphone, an audio signal using the receiver of the hearing aid device/ speaker of a remote device like a smartphone, text signal at the remote device like smartphone.

[0038] The notification generator may be adapted to produce the indicator signal and thus perceivable effect at the indicator module that is a function of the magnitude or type of variation or identified pathological condition. For example, for a hearing aid having an LED for status indication, if the pathological condition is a generally considered less dangerous, then the indicator produces an ORANGE LED light whereas for a pathological condition that is considered dangerous, the indicator produces a RED LED light. It may also be envisaged that the notification generator may also be adapted to generate a positive indicator signal representative of non detection of any pathological condition-such as a GREEN LED light.

[0039] In an embodiment, the details of the indicator signal is stored in the memory and/ or cloud server via transmission of the details from the hearing aid to the cloud server. Such details may include one or more of determined variation / variation type, identified pathological conditions, time stamp of the identification of the pathological condition, environment class or activity class corresponding to the time stamp. The time stamp defines time as an identifier of when an event occurred.

[0040] In an embodiment, the hearing aid may be adapted to track the measured feedback measurements during the time duration and the subsequent time duration respectively. The measured feedback may then be transmitted form the hearing aid to the external electronics such as a smartphone and/ or automatically uploaded to user's profile in a cloud server. The smartphone and/ or a cloud service may include features that offer functioning of the following features disclosed above such as functionalities of the data modeller, comparator, state classifier, memory, and notification generator, in order to indicate the pathological conditions. Thus, the skilled person would envisage implementing these features externally to the hearing aid. In a specific implementation, the user's doctor or medical service provider is also alerted when any pathological condition is identified.

[0041] In one embodiment, the processing unit is adapted to adjust at least one parameter, such as gain, of the hearing device based on the determined variation between the measured pattern and the base pattern.

[0042] According to another embodiment, a method for indicating a pathological condition of a user of the hearing aid when the hearing aid is in use is disclosed. The method includes measuring an acoustic feedback, using an acoustic feedback measurement unit, produced by a tympanic membrane of the user in response to an acoustic output signal directed towards a tympanic membrane of the user. This method further includes i) continuously tracking, during a time duration, the measured acoustic feedback and generating a base pattern across a plurality of frequencies of the tracked acoustic feedback; and ii) continuously tracking, during a subsequent time duration, the measured acoustic feedback and generating a measured pattern across the plurality of frequencies of the tracked acoustic feedback. Lastly, a pathological condition is determined in accordance with a variation between the measured pattern and the base pattern.

[0043] In one embodiment, the base pattern and the measured pattern is transmitted from the hearing aid to an external electronic device. The external electronic device being adapted to determine a variation between the measured pattern and the base pattern; and to identify a pathological condition corresponding to the determined variation. Additionally or alternatively, a comparator comprised within the hearing aid, is used to determine a variation between the measured pattern and the base pattern; and identifying, using a state classifier comprised within the hearing aid, a pathological condition corresponding to the determined variation.

[0044] The external electronic device and/ or the state classifier may be adapted to identify the pathological condition by comparing the determined variation with pathological condition associated with the stored predefined variation and/ or predefined variation type that represents the determined variation/ determined variation type.

BRIEF DESCRIPTION OF DRAWINGS

[0045] 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:

Figure 1 illustrates a hearing aid in position according to an embodiment of the disclosure;
Figure 2 illustrates a hearing aid for indicating a pathological condition according to an embodiment of the disclosure;
Figure 3 illustrates a base pattern and a measured pattern according to an embodiment of the disclosure; and
Figure 4 illustrates a method for indicating a pathological condition according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0046] 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 practised 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.

[0047] The electronic hardware may include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. 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.

[0048] The disclosed hearing aid is typically adapted to improve or augment the hearing capability of a user by receiving an input sound 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. The "hearing aid" may further refer to a device such as 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.

[0049] The hearing aid is adapted to be worn in any known way. This may include 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 such as in a Behind-the-Ear 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 a In-the-Ear type hearing aid or In-the-Canal/ Completely-in-Canal type hearing aid. In these conventional hearing aid, the hearing aid is also adapted to amplify the incoming sound signal in order to address hearing impairment of the user of the hearing aid. In another embodiment, hearing aid includes an ear level monitoring unit that is arranged entirely or partly in the pinna and/ or in the ear canal of the user such that feedback measurements as disclosed herein are made but without the need of conventional hearing aid processing such as amplification of incoming sound signal to address hearing impairment of the user of the ear level monitoring unit.

[0050] In an embodiment, the disclosed hearing aid may be positioned bilaterally at two ears as part of a "binaural hearing system". The hearing aids are adapted to cooperatively provide audible signals to both of the user's ears. In this case, a further comparison between the left ear variation and right ear variation may be performed in order to categorise as similar indication or different indication.

[0051] The binaural hearing system may further include auxiliary device(s) that communicates with at least one hearing aids, the auxiliary device affecting the operation of the hearing aids and/or benefitting from the functioning of the hearing aids. A wired or wireless communication link between the at least one hearing aid and the auxiliary device is established that allows for exchanging information (e.g. control and status signals, possibly audio signals) between the at least one hearing aid and the auxiliary device. Such auxiliary devices may include at least one of remote controls, remote microphones, audio gateway devices, mobile phones, public-address systems, car audio systems or music players or a combination thereof. The audio gateway is 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, a PC. The audio gateway is further adapted 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 aid. The remote control is adapted to control functionality and operation of the at least one hearing devices. The function of the remote control may be implemented in a SmartPhone or other electronic device, the SmartPhone/ electronic device possibly running an application that controls functionality of the at least one hearing device.

[0052] Figure 1 illustrates a hearing aid in position according to an embodiment of the disclosure. The figure shows a behind-the-ear type hearing aid where an output transducer is positioned in the ear or ear canal. The behind-the-ear housing 102 is positioned behind the ear 114 and includes components like input transducer, processing unit, etc. An ear mould 104 includes the output transducer and may also include a measurement microphone at 106. The input transducer and the output transducer are communicatively connected using a connecting wire 116. Although the illustration shows a behind-the-ear type hearing aid but other conventionally known hearing aid types are within the scope of this disclosure.

[0053] The hearing aid directs an acoustic output signal 108 towards a tympanic membrane 120 of the user. A part of the acoustic output signal 108 gets reflected as a reflected sound 112. The level of the reflected sound is a function of the stiffness of the tympanic membrane 120. Such stiffness is dependent on the pressure equalization capabilities of the middle ear 110. It is apparent that the feedback will increase with an increase in the stiffness of the tympanic membrane provided other conditions affecting the feedback such as vent specification, positioning of the mould, sealing of the mould with the canal, etc. are same across different feedback measurements. The ear mould may further include at least a vent 118, specification of which is based on obtaining a balance between occlusion and feedback problems. In this implementation, the measurement microphone 106 is adapted to capture the sound reflected from the tympanic membrane and feedback can then be measured from electrical signal corresponding to the reflected sound received at the measurement microphone 106. However, the feedback measurement may also be obtained using a feedback estimator.

[0054] Figure 2 illustrates a hearing aid for indicating a pathological condition according to an embodiment of the disclosure. The embodiment is disclosed in relation to a typical hearing aid that is adapted to address hearing impairment of the user. However, the skilled person would appreciate that the disclosure is useable for health monitoring wearable that are adapted to be positioned at or in ear, the wearable are not adapted to amplify sound signal as would be the case with conventional hearing aids. Other processing may preferably be included in the wearable devices such as noise reduction especially when the input sound signal includes sound from user's auditory environment.

[0055] The disclosed hearing aid 200 is adapted to be located in or at the ear of the user. The hearing aid includes an input transducer 204 adapted to convert an input sound signal 202 into an electrical input signal. In the illustration, the sound received from the user's auditory environment is indicated as the input sound signal 202. However, in other implementations, a signal generator 216 is adapted to provide a predefined sound signal of predefined characteristics. In this implementation, the input sound signal includes the predefined sound signal with or without the sound signal that the input transducer receives from acoustic environment when the hearing aid is in use. The electrical signal is typically converted to a digital signal using an analog-to-digital converter AD. A forward signal path is defined between the input transducer 204 and output transducer 208, and comprising a processing unit 206.The electrical signal is processed in a processing unit 206, which is adapted to generate an electrical output signal by processing the electrical input signal such as band-pass filtering, amplification, noise reduction, etc.. The processed electrical signal is typically coverted to an analog signal using a digital-to-analog conveter DA. An output transducer 208 is adapted to transform the processed electrical output signal to an acoustic output signal 108 and to direct the acoustic output signal towards a tympanic membrane (refer 120, Fig. 1) of the user. During the operation of the hearing aid, a part of the delivered acoustic output signal 108 is fed back into the input transducer 204, as shown as the feedback path 112, because of acoustic coupling between the output transducer and input transducer.

[0056] In an embodiment, the hearing aid includes a feedback estimator 210 for determining feedback along the feedback path 112 from the output transducer 208 to the input transducer 204. The feedback estimator may include an adaptive filter, which includes a variable filter part and an algorithm part. The variable filter part is controlled by a prediction error algorithm, e.g. an LMS (Least Means Squared) algorithm, in the algorithm part in order to predict the part of the microphone signal that is caused by feedback from the loudspeaker of the hearing aid. The prediction error algorithm uses a reference signal to find the setting of the adaptive filter that minimizes the prediction error when the reference signal is applied to the adaptive filter. Many known techniques are also useable to estimate feedback. A few such techniques, incorporated here by reference, are available in US2015063614, US2015043764, US2014146977, US2014146977, US2013188796, US2013070936. The feedback estimator 210 may be part of the a feedback cancellation system further comprises a sum unit ('+') operatively coupled to the input transducer and the output of the feedback estimator, and wherein the feedback path estimate is subtracted from the electric input signal from the input transducer. In an alternative embodiment, the feedback measurement may be obtained by a combination of a measurement microphone that is adapted to receive the signal reflected from the tympanic membrane in response to the input sound signal and a level detector adapted to detect level of the reflected signal.

[0057] The hearing aid may further include a feedback path logger 212 and a feedback path modeller 214. The logger 212 is adapted to continuously track the measured acoustic feedback and the modeller 214 is adapted to generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback. During a time duration, the feedback path modeller is adapted to generate a base pattern based on the measured feedback and during a subsequent time duration, the feedback path modeller is adapted to generate a measured pattern based on the measured feedback. The modeller may be generated using known curve fitting techniques.

[0058] The hearing aid may further include a derivative unit 230. The derivative unit is adapted to determine first order and/ or higher order derivative of the base pattern and measured pattern. The derivative may include time based derivative or frequency based derivative. The derivative unit may include derivative techniques that are well-known in the art like Laplace derivative operator.

[0059] The hearing aid may further include a comparator 218 that is adapted to determine a variation between the measured pattern and the base pattern. The comparator may be based on statistical analysis algorithms that are suitable for comparing patterns (curves). The comparator may be further adapted to categorize the determined variation in a variation type in accordance to the determination of the variation between the measured pattern and the base pattern.

[0060] The hearing aid may further include a memory 220 that is adapted to store, among other information, at least one of i) a plurality of predefined variations and/ or a plurality predefined variation types, ii) associations of each of the stored plurality of predefined variations and/ or stored plurality predefined variation types with one or more possible pathological condition; iii) the base pattern as generated and/ or first order and/ or higher order derivative of the base pattern after the time duration; and iv) an identified pathological conditions with a time stamp. The memory is in bi-directional communication with a state classifier 222.

[0061] The hearing aid may further include a state classifier 222 adapted to identify a pathological condition corresponding to the determined variation. The state classifier is adapted to i) receive the variation and/ or variation type from the comparator and ii) access information stored in the memory and to identify the pathological condition by comparing the determined variation with pathological condition associated with the stored predefined variation and/ or predefined variation type that represents the determined variation/ determined variation type.

[0062] The hearing aid may further include a notification generator 224 adapted to generate and transmit an indicator signal, corresponding to the identified pathological condition, to an indicator module 226 for producing a perceivable effect. The perceivable effect thus allows to produce an alarm to notify the user or others like parents, medical professional, etc.

[0063] The hearing aid may further include a communication exchange module 228 comprising a transmitter-receiver unit to communicate with auxiliary devices. In one embodiment, the notification signal is transmitted to an auxiliary device such as a smartphone to produce the alarm. In another embodiment, the identified pathological condition is transmitted to a cloud server for storing the identified pathological condition. In yet another embodiment, the receiver receives an instruction signal for defining a start and end of time duration and subsequent time duration.

[0064] In an embodiment, the hearing aid may be adapted to track the measured feedback measurements during the time duration and the subsequent time duration respectively. The measured feedback may then be transmitted using the exchange module 225 form the hearing aid to the external electronics such as a smartphone and/ or automatically uploaded to user's profile in a cloud server. The smartphone and/ or a cloud service may include features that offer functioning of the following features disclosed above such as functionalities of the data modeller, comparator, state classifier, memory, and notification generator, in order to indicate the pathological conditions. Thus, the skilled person would envisage implementing these features externally to the hearing aid. In a specific implementation, the user's doctor or medical service provider is also alerted when any pathological condition is identified.

[0065] The hearing aid may further include a manually operable user interface such as a push button PB, allowing a user to control a function of the hearing aid, e.g. its processing or a volume setting.

[0066] Figure 3 illustrates comprising a base pattern and a measured pattern according to an embodiment of the disclosure. The graph 300 illustrates a base pattern 304 showing how feedback across a plurality of frequencies (frequency range) varies during a time duration. The frequency specific feedback (example 306) is average or weighted average of feedback for that specific frequency (f2) during the time duration. The graph 300 also illustrates a measured pattern 302 showing how feedback across the plurality of frequencies (frequency range) varies during a subsequent time duration. The frequency specific feedback (example 312) is average or weighted average of feedback for that specific frequency (f1) during the subsequent time duration. The comparator (refer 218, Fig. 2) is adapted to determine variation between the illustrated measured pattern and the base pattern.

[0067] The comparator may be adapted to compare a parameter of a feature such as height of a feedback peak as shown by 306 for the base pattern and 312 for the measured pattern. Based on the comparison, the comparator may determine the frequencies at which same heighted feedback peaks occurred, i.e. f2 and f1 respectively. Additionally or alternatively, the comparator may compare the feedbacks at a specified frequency. For example, change in feedback at 314 for the base pattern to 308 for the measured pattern at frequency f3 and from

316 of the base pattern to 310 of the measured pattern at frequency f4. Other comparison in order to determine variation between the base pattern and the measured pattern may also be performed such as comparing rate of change of feedback in the measured pattern (slope 310-308) with that of in the base pattern (slope 316-314) for frequency range f3-f4.

[0068] Figure 4 illustrates a method 400 for indicating a pathological condition according to an embodiment of the disclosure. The pathological condition is indicated for a user of the hearing aid when the hearing aid is in use. At 402, an acoustic feedback is measured using an acoustic feedback measurement unit, produced by a tympanic membrane of the user in response to an acoustic output signal directed towards a tympanic membrane of the user. During a time duration at 404, the measured acoustic feedback is tracked and a base pattern across a plurality of frequencies of the tracked acoustic feedback is generated. During a subsequent time duration at 406, the measured acoustic feedback is tracked and a measured pattern across the plurality of frequencies of the tracked acoustic feedback is generated. At 408, variation between the measured pattern and the base pattern is determined and lastly at 410, a pathological condition is determined in accordance with a variation between the measured pattern and the base pattern.

[0069] 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, instructions etc. 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. 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 device for being executed at a location different from that of the tangible medium.

[0070] According to an embodiment, a computer readable medium is disclosed. The computer readable medium is adapted to include instructions which when executed by a device such as hearing aid and/ or external electronic device adapts the device to

i) measure an acoustic feedback using an acoustic feedback measurement unit, produced by a tympanic membrane of the user in response to an acoustic output signal directed towards a tympanic membrane of the user;

ii) continuously track the measured acoustic feedback during a time duration and generate a base pattern across a plurality of frequencies of the tracked acoustic feedback.

iii) continuously track the measured acoustic feedback during a subsequent time duration, and generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback; and

iv) determine variation between the measured pattern and the base pattern and identify a pathological condition in accordance with a variation between the measured pattern and the base pattern.

[0071] 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.

[0072] 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 elements 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 is not limited to the exact order stated herein, unless expressly stated otherwise.

[0073] 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.

[0074] The claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein 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.

[0075] Accordingly, the scope should be judged in terms of the claims that follow.

Claims

1. A hearing aid adapted to indicate a pathological condition of a user of the hearing aid when the hearing aid is in use, the hearing aid comprising:

    an input transducer adapted to transform an input sound signal into an electrical input signal;
    a processing unit adapted to generate an electrical output signal by processing the electrical input signal;
    an output transducer adapted to transform the processed electrical output signal to an acoustic output signal and to direct the acoustic output signal towards a tympanic membrane of the user;
    a feedback measurement unit adapted to measure an acoustic feedback produced by the tympanic membrane in response to the acoustic output signal;
    during a time duration,

        a feedback path logger is adapted to continuously track the measured acoustic feedback and a feedback path modeller is adapted to generate a base pattern across a plurality of frequencies of the tracked acoustic feedback;

    during a subsequent time duration,

        the feedback path logger is adapted to continuously track the measured acoustic feedback and the feedback path modeller is adapted to generate a measured pattern across the plurality of frequencies of the tracked acoustic feedback;

    a comparator adapted to determine a variation between the measured pattern and the base pattern; and
    a state classifier adapted to identify at least one pathological condition corresponding to the determined variation.

2. The hearing aid according to any of the preceding claims, wherein the input sound signal comprises
a sound signal that the input transducer receives from acoustic environment when the hearing aid is in use; or
a predefined sound signal of predefined characteristics with or without the sound signal that the input transducer receives from acoustic environment when the hearing aid is in use.

3. The hearing aid according to claim 2, further comprising a signal generator adapted to generate the predefined sound signal of the predefined characteristics, the predefined characteristics comprises a specific frequency and a specific level wherein
the predefined characteristics comprises a specific frequency and a specific level which when amplified or unamplified is below the perceivable level of the user; or the predefined characteristics comprises a specific frequency and a specific level which when amplified or unamplified is above the perceivable level of the user.

4. The hearing aid according to any of the preceding claims, wherein the feedback measurement unit comprises
a feedback estimator adapted to estimate the acoustic feedback; and/ or
a measurement microphone housed in an ear mould of the hearing aid wherein the ear mould being adapted to be placed within the ear canal of the user and the measurement microphone is adapted to receive the sound reflected from the tympanic membrane in response to the input sound signal and to transform the reflected sound to a reflected electrical sound signal, and a level estimator adapted to estimate the level from the reflected electrical sound signal.

5. The hearing aid according to any of the preceding claims, wherein for a specific frequency or sampled frequencies across the plurality of frequencies
the base pattern comprises average or weighted average of feedback values at different measurement points during the time duration; and
the measured pattern comprises average or weighted average of feedback values at different measurement points during the subsequent time duration.

6. The hearing aid according to any of the preceding claims, further comprising a derivative unit adapted to determine a first order and/ or higher order derivative of the base pattern and/ or the measured pattern.

7. The hearing aid according to any of the preceding claims, wherein the determining the variation between the base pattern and the measured pattern comprises
evaluating difference, for a specific frequency, between the measured pattern comprising feedback values at the measurement points during the subsequent time duration and the base pattern comprising feedback values at the measurement points during the time duration; and/ or
evaluating difference, at at least one frequency across the plurality of frequencies, between the measured pattern comprising feedback value for each frequency across the plurality of frequencies

and the base pattern comprising feedback value for each frequency across the plurality of frequencies; and/ or

evaluating difference, for a specific frequency, between a time derivative value of a first order and/ or higher order derivative of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a time derivative of a first order and/ or higher order derivative of the base pattern comprising feedback values at the measurement points during the time duration; and/ or

evaluating difference, at at least one frequency across the plurality of frequencies, between a frequency derivate value of a first order and/ or higher order derivative of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a frequency derivative value of a first order and/ or higher order derivative of the base pattern comprising feedback value for each frequency across the plurality of frequencies; and/ or

evaluating difference, for a specific frequency, between a parameter of a feature of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a comparable parameter of a comparable feature of the base pattern comprising feedback values at the measurement points during the time duration; and/ or

evaluating difference between a parameter of a feature of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a comparable parameter of a comparable feature of the base pattern comprising feedback value for each frequency across the plurality of frequencies.

evaluating difference, for a specific frequency, between a parameter of a feature of first order and/ or higher order time derivative of the measured pattern comprising feedback values at the measurement points during the subsequent time duration and a comparable parameter of a comparable feature of first order and/ or higher order time derivative of the base pattern comprising feedback values at the measurement points during the time duration; and/ or

evaluating difference between a parameter of a feature of a first order and/ or higher order frequency derivative of the measured pattern comprising feedback value for each frequency across the plurality of frequencies and a comparable parameter of a comparable feature of a first order and/ or higher order frequency derivative of the base pattern comprising feedback value for each frequency across the plurality of frequencies; and/ or

evaluating difference, for a specific frequency, between shape and/ or size of the measured pattern/ a section of the measured pattern across the subsequent time duration and shape and/ or size of the base pattern/ corresponding section of the base pattern across the time duration and/ or

evaluating difference between shape and/ or size of the measured pattern/ a section of the measured pattern across the plurality of frequencies and shape and/ or size of the base pattern/ corresponding section of the base pattern across the plurality of frequencies; and/ or.

evaluating difference, for a specific frequency, between shape and/ or size of a first order and/ or higher order derivative of the measured pattern/ a section of the measured pattern across the subsequent time duration and shape and/ or size of a first order and/ or the higher order derivative of the base pattern/ corresponding section of the base pattern across the time duration, and/ or

evaluating difference between shape and/ or size of a first order and/ or higher order derivative of the measured pattern/ a section of the measured pattern across the plurality of frequencies and shape and/ or size of a first order and/ or higher order derivative of the base pattern/ corresponding section of the base pattern across the plurality of frequencies.

8. The hearing aid according to any of the preceding claims, wherein the comparator is adapted to categorize the determined variation in a variation type in accordance to the determination of the variation between the measured pattern and the base pattern.

9. The hearing aid according to any of the preceding claims, further comprising a memory adapted to store at least one or more of

a plurality of predefined variations and/ or a plurality predefined variation types;

associations of each of the stored plurality of predefined variations and/ or stored plurality predefined variation types with one or more possible pathological condition;

the base pattern as generated and/ or first order and/ or higher order derviative of the base pattern after the time duration; and

an identified pathological conditions with a time stamp.

10. The hearing aid according to any of the preceding claims, wherein the state classifier is adapted to access information stored in the memory and to identify the pathological condition by comparing the determined variation with pathological condition associated with the stored predefined variation and/ or predefined variation type that represents the determined variation/ determined variation type.

11. The hearing aid according to any of the preceding claims, further comprising a notification generator adapted to generate and transmit an indicator signal, corresponding to the identified pathological condition, to an indicator module for producing a perceivable effect, the perceivable effect selected from a group consisting of a visual signal at the hearing aid device/ remote device like a smartphone, a vibration of the hearing aid device/ remote device like the smartphone, an audio signal using the receiver of the hearing aid device/ speaker of a remote device like a smartphone, text signal at the remote device like smartphone.

12. The hearing aid according to any of the preceding claims, wherein in the processing unit is adapted to adjust at least one parameter, such as gain, of the hearing device based on the determined variation between the measured pattern and the base pattern.

13. A method for indicating a pathological condition of a user of the hearing aid when the hearing aid is in use, the method comprising:

measuring an acoustic feedback, using an acoustic feedback measurement unit, produced by a tympanic membrane of the user in response to an acoustic output signal directed towards a tympanic membrane of the user;
continuously tracking, during a time duration, the measured acoustic feedback and generating a base pattern across a plurality of frequencies of the tracked acoustic feedback;
continuously tracking, during a subsequent time duration, the measured acoustic feedback and generating a measured pattern across the plurality of frequencies of the tracked acoustic feedback; and
determining a pathological condition in accordance with a variation between the measured pattern and the base pattern.

14. The method according to claim 13, further comprising
transmitting, from the hearing aid, the base pattern and the measured pattern to an external electronic device, the external electronic device being adapted to determine a variation between the measured pattern and the base pattern; and to identify a pathological condition corresponding to the determined variation; and/ or
determining, using a comparator comprised within the hearing aid, a variation between the measured pattern and the base pattern; and identifying, using a state classifier comprised within the hearing aid, a pathological condition corresponding to the determined variation;

15. The method according to any of the preceding claims 13-14, wherein the electronic device and/ or the state classifier is adapted to identify the pathological condition by comparing the determined variation with pathological condition associated with the stored predefined variation and/ or predefined variation type that represents the determined variation/ determined variation type.

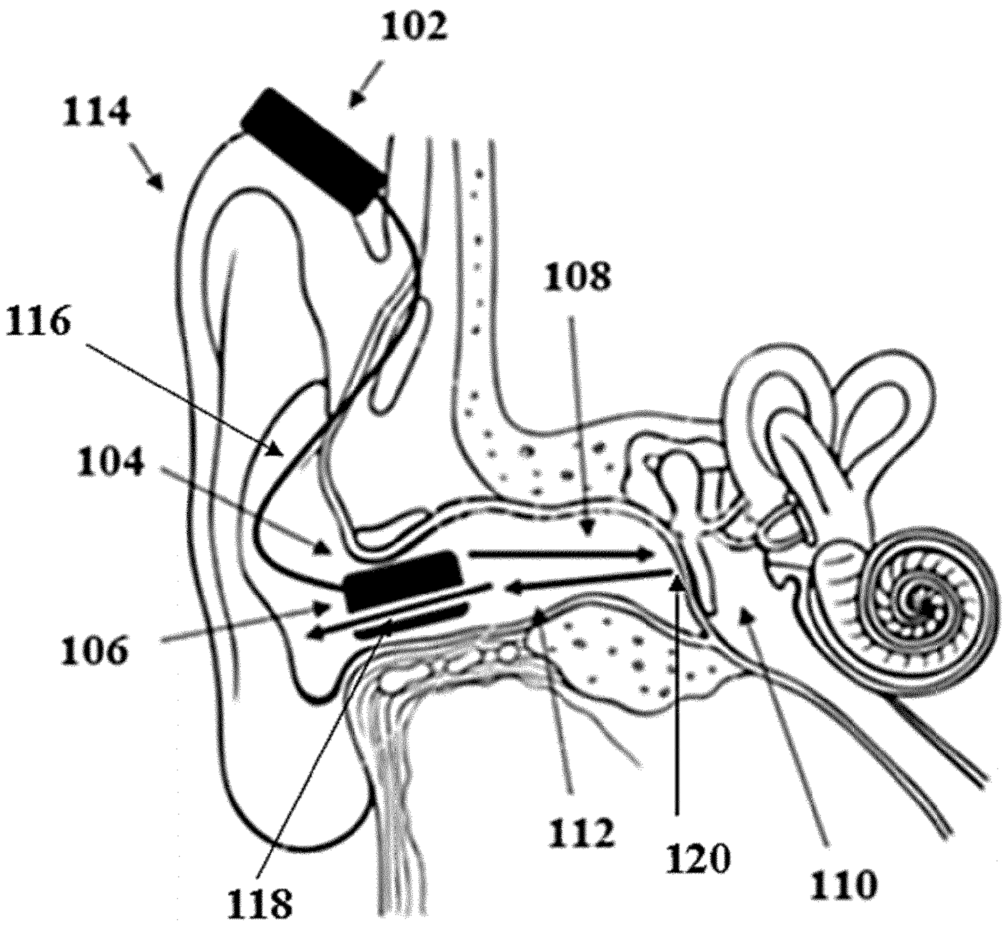

FIG. 1

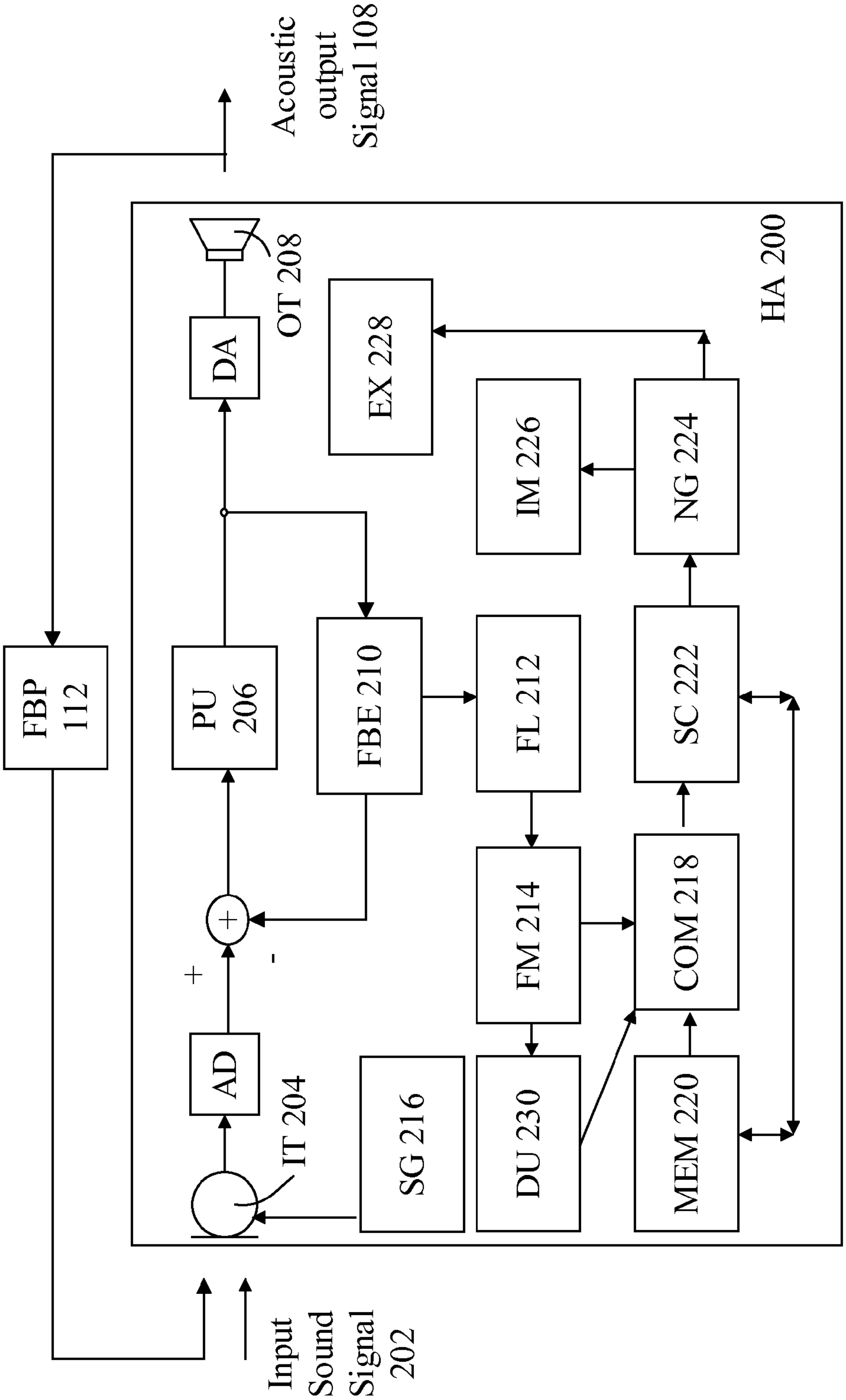
Acoustic output Signal 108
FBP 112
PU 206
DA
OT 208
HA 200
EX 228
IM 226
NG 224
FBE 210
FL 212
SC 222
+
-
AD
IT 204
SG 216
FM 214
COM 218
DU 230
MEM 220
Input Sound Signal 202

FIG. 2

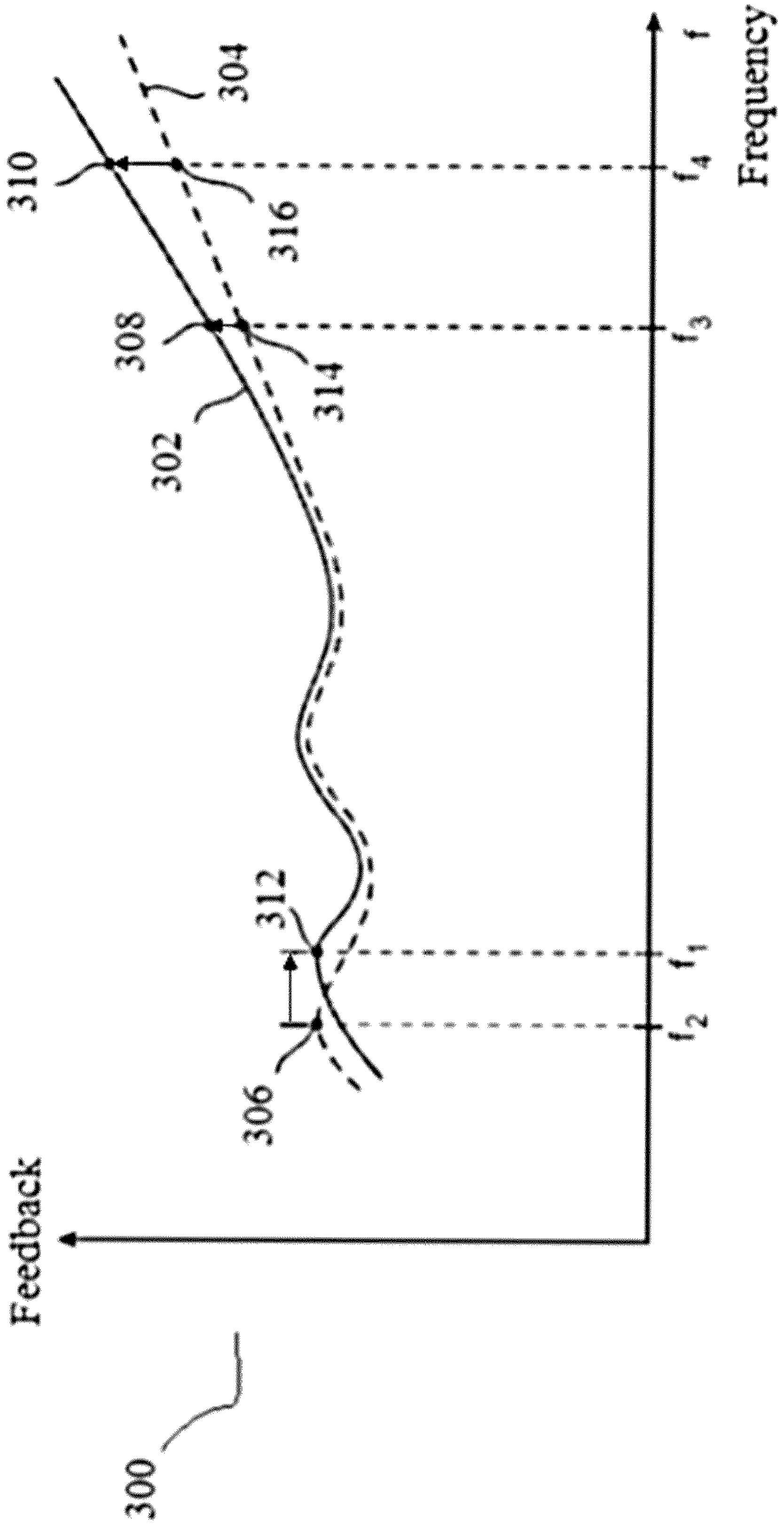
300
Feedback
Frequency
f
f_1
f_2
f_3
f_4
302
304
306
308
310
312
314
316

FIG. 3

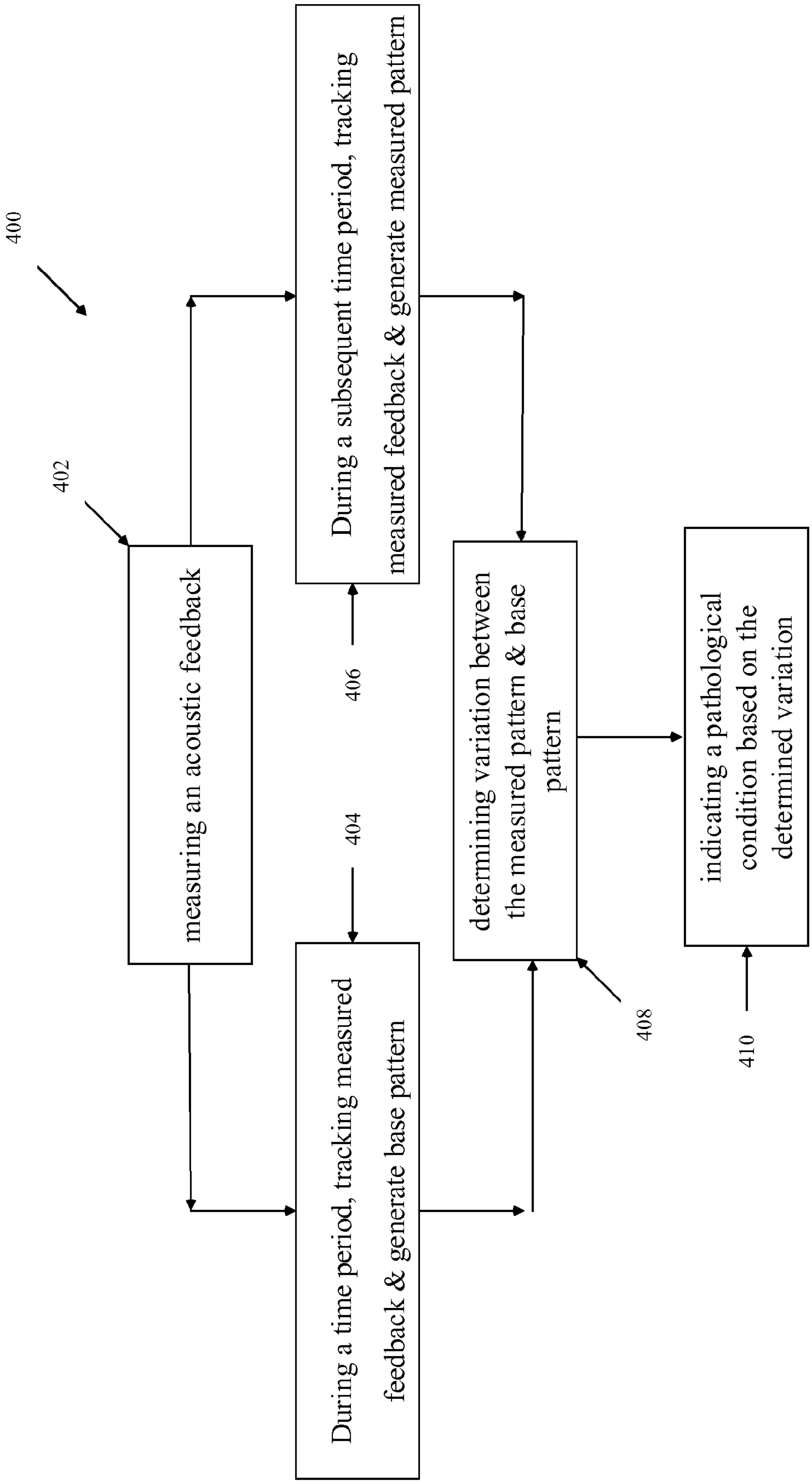
400
402
measuring an acoustic feedback
404
During a time period, tracking measured feedback & generate base pattern
406
During a subsequent time period, tracking measured feedback & generate measured pattern
408
determining variation between the measured pattern & base pattern
410
indicating a pathological condition based on the determined variation

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 4032

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 A	WO 2009/023633 A1 (PERSONICS HOLDINGS INC [US]; GOLDSTEIN STEVEN WAYNE [US]; USHER JOHN [] 19 February 2009 (2009-02-19) * paragraphs [0029], [0036], [0037], [0058], [0064], [0067], [0068], [0072], [0073]; figures 1,2,7 * -----	1-12 13-15	INV. H04R25/02 A61B5/12
A	WO 2012/082721 A2 (UNIV ILLINOIS [US]; PORGES STEPHEN W [US]; LEWIS GREGORY F [US]) 21 June 2012 (2012-06-21) * paragraphs [0032], [0083] - paragraph [0087] * -----	1-15	
A	WO 2013/102867 A1 (CONSIGLIO NAZIONALE RICERCHE [IT]) 11 July 2013 (2013-07-11) * the whole document * * -----	1-15	
A	MARGOLIS ROBERT H ET AL: "Wideband reflectance tympanometry in normal adults", THE JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA, AMERICAN INSTITUTE OF PHYSICS FOR THE ACOUSTICAL SOCIETY OF AMERICA, NEW YORK, NY, US, vol. 106, no. 1, 1 July 1999 (1999-07-01), pages 265-280, XP012001058, ISSN: 0001-4966, DOI: 10.1121/1.427055 * the whole document * * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) A61B H04R

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	29 January 2016	Pigniez, Thierry

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 18 4032

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The members are as contained in the European Patent Office EDP file on
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29-01-2016

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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