(19) DANMARK

(10) **DK/EP 3340642 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***H 04 R 1/10 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2021-09-13**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2021-06-02**

(86) Europæisk ansøgning nr.: **16206674.0**

(86) Europæisk indleveringsdag: **2016-12-23**

(87) Den europæiske ansøgnings publiceringsdag: **2018-06-27**

(84) Designerede stater: **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**

(73) Patenthaver: **GN HEARING A/S, Lautrupbjerg 7, 2750 Ballerup, Danmark**

(72) Opfinder: **ODDERSHEDE, Niels, c/o GN Hearing A/S, Att.: Group IPR, Lautrupbjergvej 7, 2750 Ballerup, Danmark**
RABØL, Ditlev Munk, c/o GN Hearing A/S, Att.: Group IPR, Lautrupbjerg 7, 2750 Ballerup, Danmark

(74) Fuldmægtig i Danmark: **Aera A/S, Niels Hemmingsens Gade 10, 1153 København K, Danmark**

(54) Benævnelse: **HEARING DEVICE WITH SOUND IMPULSE SUPPRESSION AND RELATED METHOD**

(56) Fremdragne publikationer:
EP-A1- 1 450 354
EP-A1- 2 306 754
EP-A1- 2 980 800
US-A1- 2002 097 882
US-A1- 2006 204 025
US-A1- 2011 103 615
US-A1- 2015 124 984

DESCRIPTION

[0001] The present disclosure relates to a hearing device with sound impulse suppression and related method.

BACKGROUND

[0002] Sound impulses with high sound pressure levels may be discomforting, painful or even damaging to users of a hearing device. In particular, hearing aid compressors utilize dynamic sound level compression with time constants that are sufficiently long to reduce distortion of temporal characteristics of speech, which however reduces the ability to compress sound impulses with high energy, in turn increasing the discomfort for a hearing aid user.

[0003] US 2011/0103615 relates to a method of suppressing wind noise in a voice signal. The method determines an upper frequency limit that lies within the frequency spectrum of the voice signal, and for each of a plurality of frequency bands below the upper frequency limit, compares the average power of signal components in a first portion of the signal to the average power of signal components in a second portion of the signal, where the second portion is successive to the first portion. Signal components are identified in at least one of the plurality of frequency bands as containing impulsive wind noise in dependence on the comparison, and the identified signal components are attenuated.

[0004] EP 2 980 800 A1 relates to a method and system for robust noise level estimation comprising calculating an impulsive noise probability of the noise signal, the impulsive noise probability indicating a likelihood that the noise signal involves a short-period impulsive noise. The method also comprises determining a variable smoothing factor for noise level estimation based on the impulsive noise probability and smoothing the noise signal with the variable smoothing factor. The variable smoothing factor is increased as the impulsive noise probability is increased over time, and the variable smoothing factor is decreased as the impulsive noise probability is decreased over time.

[0005] EP 2 306 754 A1 relates to a hearing aid comprising a microphone; a hearing aid processing unit configured to perform hearing aid processing to a signal corresponding to sound collected by the microphone, and produce an output signal; a speaker configured to output sound generated from the output signal to an outside; and a drop detection unit configured to analyze a characteristic of the signal corresponding to the sound collected by the microphone and detect drop of the hearing aid.

SUMMARY

[0006] There is a need for devices and methods overcoming or at least reducing the discomfort resulting from sound impulses.

[0007] Accordingly, a hearing device is disclosed, the hearing device comprising a first microphone for provision of a first microphone input signal; a sound impulse suppression module configured for detecting a sound impulse in the first microphone input signal; a processor for processing the first microphone input signal in a processing set of frequency bands to obtain an electrical output signal; and a receiver for converting the electrical output signal to an audio output signal. The sound impulse suppression module is configured to apply a detection scheme on the first microphone input signal, wherein the detection scheme defines a detection set of frequency bands, wherein the frequency bands of the detection set covers a part of the frequency bands of the processing set, and wherein a sound impulse is detected based on the detection set of frequency bands. The frequency bands of the detection set are arranged within one or more frequency ranges including a first frequency range and a second frequency range, wherein the first frequency range and the second frequency range are separate frequency ranges, and the second frequency range is from 3 kHz to 8 kHz. The sound impulse suppression module is configured to reduce a gain applied to the first microphone input signal by the processor when a sound impulse is detected.

[0008] Further, a method of operating a hearing device is provided, the hearing device comprising a processor configured to process a first microphone input signal from a first microphone in a processing set of frequency bands to obtain an electrical output signal, wherein the method comprises detecting a sound impulse in the microphone input signal; and reducing a gain applied to the first microphone input signal in the processor when a sound impulse is detected, wherein detecting a sound impulse comprises applying a detection scheme on the first microphone input signal, wherein the detection scheme defines a detection set of frequency bands, wherein the detection set of frequency bands covers a part of the frequency bands of processing set, and wherein detecting a sound impulse is based on the detection set of frequency bands. The frequency bands of the detection set are arranged within one or more frequency ranges including a first frequency range and a second frequency range, wherein the first frequency range and the second frequency range are separate frequency ranges, and the second frequency range is from 3 kHz to 8 kHz.

[0009] The present hearing devices and methods provide improved impulse suppression in a hearing device. For example, the present hearing devices can be tailored to suppress specific types of sound impulses. Further, the present disclosure provides a power and processing efficient impulse suppression, which is important considering the limited power and processing resources available in a hearing device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The above and other features and advantages of the present invention will become readily apparent to those skilled in the art by the following detailed description of exemplary embodiments thereof with reference to the attached drawings, in which:

Fig. 1 schematically illustrates an exemplary hearing device,

Fig. 2 is a power spectrum of frequency bands of a detection scheme, and

Fig. 3 is a flowchart of an exemplary method.

DETAILED DESCRIPTION

[0011] Various exemplary embodiments and details are described hereinafter, with reference to the figures when relevant. It should be noted that the figures may or may not be drawn to scale and that elements of similar structures or functions are represented by like reference numerals throughout the figures. It should also be noted that the figures are only intended to facilitate the description of the embodiments. They are not intended as an exhaustive description of the invention or as a limitation on the scope of the invention. In addition, an illustrated embodiment needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular embodiment is not necessarily limited to that embodiment and can be practiced in any other embodiments even if not so illustrated, or if not so explicitly described.

[0012] The hearing device may be a hearing aid, e.g. of the behind-the-ear (BTE) type, in-the-ear (ITE) type, in-the-canal (ITC) type, receiver-in-canal (RIC) type or receiver-in-the-ear (RITE) type. The hearing aid may be a binaural hearing aid.

[0013] The hearing device may be a hearing aid and the processor may be configured to compensate for hearing loss of a user.

[0014] The hearing device may be a headset, a headphone, an earphone, an ear defender, or an earmuff, such as an Ear-Hook, In-Ear, On-Ear, Over-the-Ear, Behind-the-Neck, Helmet, or Headguard.

[0015] The hearing device comprises a first microphone for provision of a first microphone input signal. The hearing device may comprise a second microphone for provision of a second microphone input signal. The hearing device may comprise J microphones for provision of J microphone signals, wherein J is an integer in the range from 1 to 10. In one or more exemplary hearing devices, the number J of microphones is two, three, four, five or more. The hearing device may comprise a third microphone for provision of a third microphone input signal.

[0016] The hearing device comprises a sound impulse suppression module. The sound impulse suppression module is configured for detecting a sound impulse in the first microphone input signal. The sound impulse suppression module is configured for operation in the frequency domain. The sound impulse suppression module comprises an impulse detector configured for operation in the frequency domain, e.g. utilizing a Fourier Transformation, such as the Discrete Fourier Transformation, the Fast Fourier Transformation, etc., for transforming the first microphone input signal into a frequency domain for detecting the sound impulse. The impulse detector may be configured for utilizing a warped frequency transformation, such as the Warped Fourier Transformation, the Warped Discrete Fourier Transformation, the Warped Fast Fourier Transformation, etc., for transforming the first microphone input signal into a warped frequency domain.

[0017] The warped frequency bands may correspond to the Bark frequency scale of the human ear.

[0018] The sound impulse suppression module may be configured for detecting a sound impulse in a second microphone input signal.

[0019] The hearing device comprises a processor for processing the first microphone input signal in a processing set, PFB, of frequency bands FP_i, where i is an index from 1 to L, to obtain an electrical output signal. The processor may be configured to compensate for hearing loss of a user.

[0020] The processor may comprise a filter bank for filtering the first microphone input signal into the frequency bands FP_1, FP_2, ..., FP_L, where the number L of frequency bands in the processing set PFB may be at least 10, such as 15, 17 or 24. In one or more exemplary hearing devices, the number L of frequency bands in the processing set PFB may be 20 or more, such as 64. In one or more exemplary hearing devices, the number L of frequency bands in the processing set PFB may be from 5 to 10.

[0021] Further, the hearing device comprises a receiver for converting the electrical output signal to an audio output signal.

[0022] The sound impulse suppression module is configured to apply a detection scheme, such as a first detection scheme and/or a second detection scheme, on the first microphone input signal.

[0023] A detection scheme defines a detection set DFB of frequency bands FD_j, where j is an index from 1 to M, and a sound impulse is detected based on the detection set of frequency bands.

[0024] The frequency bands of the detection set cover a part of the frequency bands of processing set. Thus, the frequency bands of the processing set cover frequencies that are not covered by the frequency bands of the detection set, and the sound impulse suppression module therefore operates on a reduced frequency range. Therefore, the required processing for impulse detection is reduced compared to a full-fetched sound impulse suppression based on the processing set of frequency bands.

[0025] In one or more exemplary hearing devices, the frequency bands of the detection set may be selected as a proper subset of the frequency bins of a DFT or FFT. In one or more exemplary hearing devices, the number M of frequency bands of the detection set may be less than K, where K is the number of available frequency bins of an FFT employed in the impulse detector/sound impulse suppression module.

[0026] The frequency bands FD_j, j=1, ..., M of the detection set each have center frequencies denoted $fd_{0,j}$ and bandwidths denoted BD_j. The frequency bands FP_i, i=1, ..., L of the detection set each have center frequencies denoted $fp_{0,i}$ and bandwidths denoted BP_i. In one or more hearing devices, the minimum center frequency of center frequencies $fd_{0,j}$, j=1, ..., M is larger than a first center frequency threshold FCTH. The first center frequency threshold FCTH may be larger than 500 Hz, such as larger than 1 kHz, e.g. about 2 kHz.

[0027] In one or more hearing devices, the maximum center frequency of center frequencies $fd_{0,j}$, j=1, ..., M is larger than a second center frequency threshold SCTH. The second center frequency threshold SCTH may be less than 6 kHz, such as less than 1 kHz, e.g. about 2 kHz. The average center frequency of $fd_{0,j}$, j=1, ..., M may be larger than 0.55*BP, such as larger than 0,6*BP, where BP is the bandwidth of the processor, typically about 8-12 kHz. The average center frequency of fdo,j, j=1, ..., M may be less than 0.45*BP, such as less than 0,4*BP, where BP is the bandwidth of the processor, typically about 8-12 kHz. A high average center frequency is indicative of impulse detection in high-frequency bands and a low average center frequency is indicative of impulse detection in low-frequency bands.

[0028] The detection set of frequency bands may be a proper subset of the processing set of frequency bands.

[0029] A frequency band has a lower frequency f_l and an upper frequency f_u. The frequency bands FD_1-FD_M of the detection subset has lower frequencies denoted $f_{l,j}$ and upper frequencies denoted $f_{u,j}$, where j = 1, ..., M.

[0030] The frequency bands of the detection set may have lower frequencies $f_{l,1}$, ..., $f_{l,M}$ above a first frequency threshold. In one or more exemplary hearing devices, the first frequency threshold FFTH may be larger than 1kHz, such as in the range from 1.5 kHz to 5 kHz, e.g. 3 kHz.

[0031] The frequency bands of the detection set may have upper frequencies $f_{u,1}$, ..., $f_{u,M}$ below a second frequency threshold. In one or more exemplary hearing devices, the second frequency threshold SFTH may be less than 6 kHz, such as in the range from 1 kHz to 5 kHz, e.g. 3 kHz.

[0032] The frequency bands of the detection set are arranged within one or more frequency ranges including a first frequency range. The frequency bands of the detection set are arranged within a first frequency range and a second frequency range, wherein the first frequency range and the second frequency range are separate frequency ranges. In one or more exemplary hearing devices, one or more frequency bands of the detection set are arranged within a first frequency range, e.g. from 100 Hz to 1 kHz and one or more frequency bands of the detection set are arranged within a second frequency range, from 3 kHz to 8 kHz.

[0033] In one or more exemplary hearing devices, the frequency bands of the detection set may be selected as a number of the frequency bins of a DFT or FFT. In one or more exemplary hearing devices, the number M of frequency bands of the detection set is less than K, where K is the number of available frequency bins of an FFT employed in the impulse detector/sound impulse suppression module. For an exemplary detection set, M-K>3.

[0034] The detection set DFB of frequency bands applied by the sound impulse suppression module may have less frequency bands than the processing set PFB of frequency bands. Thus, the number of frequency bands in the detection set may be lower than the number of frequency bands in the processing set of frequency bands. Reducing the number of frequency bands in the detection set provides a power efficient and yet reliable detection scheme, e.g. compared to monitoring all frequency bands of the processing set. In one or more exemplary hearing devices, PFB = $\{FP_1, FP_2, ..., FP_L\}$ and DFB = $\{FD_1, FD_2, ..., FD_M\}$, where L is larger than 10, such as 15 or 17. Further, tailoring the frequency bands of the detection set DFB enables the hearing aid designer to ignore sound impulses in one or more frequency bands, e.g. in order to allow/not react on (suppress) sound impulses in one or more frequency bands, where the user actually would like to hear the sound impulses.

[0035] In one or more exemplary hearing devices, the processing set of frequency bands comprises L frequency bands and the detection set of frequency bands comprises M frequency bands, wherein L is larger than M. In one or more exemplary hearing devices, L-M is greater than or equal to 3. M may be 1, 2, 3, 4 or more. In one or more exemplary hearing devices, M is in the range from 5 to 20. In one or more exemplary hearing devices, L-M is greater than or equal to 1 or 2.

[0036] The number M of frequency bands in the detection set may be less than fourteen, such as less than twelve or less than ten. The number L of frequency bands in the processing set may be larger than four, e.g. larger than ten, such as larger than twelve or larger than fourteen.

[0037] The sound impulse suppression module may be configured to determine rise parameter(s) R_j of the first microphone input signal in the frequency band(s) of the detection set. The sound impulse suppression module may be configured to detect a sound impulse based on the rise parameters.

[0038] A rise parameter R_j is indicative of a power increase in the first microphone input signal in a frequency band FD_j.

[0039] For example, where DFB = {FD_1, FD_2, ..., FD_{12}}, the sound impulse suppression module determines twelve rise parameters R_1-R_{12} and detects a sound impulse based on the rise parameters R_1-R_{12}.

[0040] The rise parameters R_j may be based on an instant power estimate and a reference power estimate of the first microphone input signal in the respective frequency bands.

[0041] The rise parameter(s) R_j may be given as:

$$R_j = \frac{P_j}{P\_ref_j},$$

where P_j is an instant power estimate of frequency band FD_j and P_ref_j is a reference power estimate of the first microphone input signal in frequency band FD_j.

[0042] In one or more exemplary hearing devices, the rise parameter R_j may advantageously be implemented in the logarithmic domain, such as the log2 domain. The precision of the log2 is found to be sufficiently accurate, and the remaining part of the impulse detector could improve by having decision and threshold implemented in the logarithmic domain. Thus, rise parameter(s) R_j may be given as:

$$R_j = \log_2 P_j - \log_2 P\_ref_j \quad ,$$

where P_j is an instant power estimate and P_ref_j is a reference power estimate of the first microphone input signal in frequency band FD_j.

[0043] The sound impulse suppression module may be configured to detect a sound impulse based on the number of rise parameters that has reached a respective rise threshold.

[0044] A rise threshold may be a common rise threshold TH for all frequency bands i.e. the same rise threshold may be applied to each of the frequency bands FD_j.

[0045] In one or more exemplary hearing devices, a rise threshold TH_j may be applied for each frequency band FD_j. Rise thresholds TH_j may be different for different frequency bands. For example, a rise threshold TH_7 for FD_7 may be different for the rise threshold TH_{10} for FD_{10}. The rise thresholds TH_j may be defined in the log2 domain.

[0046] In one or more exemplary hearing devices, a rise threshold TH_j may be applied for a plurality of groups of frequency band FD_j. For example, a first rise threshold TH_x may be applied to a first group of frequency bands FD_j, such as for example FD_1 - FD_6, and a second rise threshold TH_y may be applied to a second group of frequency bands FD_j such as for example FD_7-FD_{12}. In one or more exemplary hearing devices, a first rise threshold TH_x may be applied to a first group of frequency bands FD_j, such as for example FD_1 - FD_3 and FD_8 and FD_{10} - FD_{12}, and a second rise threshold TH_y may be applied to a second group of frequency bands FD_j such as for example FD_4 - FD_7 and FD_{11}.

[0047] Thus, the sound impulse suppression module may be configured to determine if rise parameter R_j have reached respective rise threshold TH_j for the frequency bands in the detection set DFB, i.e. if $R_j \geq TH_j$ for FD_j. In one or more exemplary hearing devices, the rise threshold of one frequency band in the detection set is different from the rise threshold of another frequency band in the detection set, e.g. $TH_8 \neq TH_{10}$.

[0048] In one or more exemplary hearing devices, a sound impulse may be detected if the number of rise parameters that has reached a respective rise threshold is larger than a rise number threshold. For example where DFB = $\{FD_1, FD_2, ..., FD_{12}\}$, a sound impulse may be detected if more than RNTH=8 rise parameters out of R_1-R_{12} have reached their respective rise threshold TH_1-TH_{12}, where RNTH is the rise number threshold.

[0049] The detection scheme may define rise thresholds for the frequency bands of the detection set. The detection scheme may define the rise number threshold.

[0050] The sound impulse suppression module may be configured to determine a rise parameter if the instant power estimate of a frequency band in the detection set of frequency bands is greater than the reference power estimate of the frequency band.

[0051] In one or more exemplary hearing devices, the rise parameter is determined if the instant power estimate is greater than the reference power estimate plus a power estimate threshold $PETH_j$.

[0052] The reference power estimate may be a smoothed power estimate based on the instant power estimate and a smoothing parameter. In one or more exemplary hearing devices, the reference power estimate may be base d on power estimates in a reference time period of at least 400 ms, such as at least 1 s.

[0053] The reference power estimate may be calculated as an average over a plurality of previous instant power estimates. The average may be an average over previous instant power estimates over time.

[0054] The instant power estimate P_i may be based on a single input block of samples. The instant power estimate P_i may be based on a number of input blocks of samples, e.g. wherein the number of input blocks is less than 5. An input block has a time length T_{block} given as:

$$T_{block} = N \cdot \frac{1}{f_s},$$

where N is the size of a discrete Fourier Transform DFT or a fast Fourier Transform FFT and

f_S is the sampling frequency. In one or more exemplary hearing devices, T_{block} is in the range from 1-2 ms, e.g. about 1.5 ms. Thus, the number of input block samples used for determining the instant power estimate is kept low to enable detection of sound impulses with very short rise times.

[0055] The hearing device may comprise a broadband power estimator, and the sound impulse suppression module may be configured to detect a sound impulse based on a broadband power estimate from the broadband power estimator, e.g. if the broadband power estimate is larger than a broadband power threshold, BPTH. The detection scheme may define the broadband power threshold, BPTH. The sound impulse suppression module may be configured to apply the detection scheme based on the broadband power estimate. For example, the sound impulse suppression module may be configured to apply a first detection scheme if the broadband power estimate is in a first range, e.g. indicative of low broadband power, and/or the sound impulse suppression module may be configured to apply a second detection scheme different from the first detection scheme if the broadband power estimate is in a second range, e.g. indicative of high broadband power.

[0056] The sound impulse suppression module may be configured to reduce a gain applied to the first microphone input signal (or to a signal based on the first microphone input signal, such as a beamformed signal based on the first microphone input signal) by the processor when a sound impulse is detected. For example, the sound impulse suppression module may be configured to reduce the gain in frequency bands where the rise parameter R_j has reached the rise threshold TH_j for the respective frequency bands. For example, the gain G_{10} applied to the first microphone input signal in FP_{10} may be reduced if $R_{10} \geq TH_{10}$.

[0057] The sound impulse suppression module may be configured to determine one or more gain reductions and transmit the one or more gain reductions to the processor. The sound impulse suppression module may be configured to determine one or more gain reductions based on the rise parameters R_j and/or gain parameters of frequency bands FP_1-FP_L.

[0058] The gain reduction for one frequency band may be different from the gain reduction of another frequency band. For example, the gain reduction GR_{10} for FP_{10} may be different from the gain reduction GR_{12} for FP_{12}. The sound impulse suppression module may be configured to determine a first gain reduction for a first subset of frequency bands, e.g. FP_6-FP_9, in PFB and a second gain reduction for a second subset, e.g. FP_{10}-FP_{17}, of frequency bands in PFB. The sound impulse suppression module may be configured to determine gain reductions GR_1-GR_L for all or some of frequency bands FP_1-FP_L in PFB.

[0059] The hearing device may comprise a sound environment detector for classifying the sound environment into a predetermined set of sound environments. The set of sound environments may comprise a first sound environment, a second sound environment and optionally a third sound environment. The sound impulse suppression module may be configured to apply the detection scheme based on the sound environment. For example, the sound impulse suppression module may be configured to apply a first detection scheme if the sound environment is classified as a first sound environment, and the sound impulse suppression module may be configured to apply a second detection scheme different from the first detection scheme if the sound environment is classified as a second sound environment.

[0060] Further, the present disclosure relates to a method of operating a hearing device comprising a processor configured to process a first microphone input signal from a first microphone in a processing set of frequency bands to obtain an electrical output signal, the hearing device comprising a sound impulse suppression module.

[0061] The method comprises detecting a sound impulse in the microphone input signal, e.g. with an impulse detector of the sound impulse suppression module.

[0062] The method comprises reducing a gain applied to the first microphone input signal in the processor, e.g. with a gain reduction module of the sound impulse suppression module, when a sound impulse is detected,

[0063] In the method, detecting a sound impulse comprises applying a detection scheme on the first microphone input signal, e.g. in the impulse detector, wherein the detection scheme defines a detection set of frequency bands, wherein the detection set of frequency bands covers a part of the frequency bands of the processing set, and wherein detecting a sound impulse is based on the detection set of frequency bands.

[0064] The method may comprise determining rise parameters of the first microphone input signal in the frequency bands of the detection set, wherein a rise parameter is indicative of a power increase in the first microphone input signal in a frequency band, and wherein detecting a sound impulse is based on the rise parameters.

[0065] In the method, detecting a sound impulse may be based on the number of rise parameters that has reached a respective rise threshold.

[0066] In the method, a sound impulse may be detected if the number of rise parameters that has reached a respective rise threshold is larger than a rise number threshold.

[0067] In the method, detecting a sound impulse may be based on a broadband power estimate from a broadband power estimator of the hearing device.

[0068] The method may comprise reducing a gain applied to the first microphone input signal (or to a signal based on the first microphone input signal, such as a beamformed signal based on the first microphone input signal) by the processor when a sound impulse is detected. The method may comprise determining one or more gain reductions and transmitting the one or more gain reductions to the processor. Determining one or more gain reductions may be based on the rise parameters R_i.

[0069] In one or more exemplary methods, the gain reduction GR_i for one frequency band FP_i is different from the gain reduction of another frequency band. For example, the gain reduction GR_{10} for FP_{10} may be different from the gain reduction GR_{12} for FP_{12}. The method may comprise determining a first gain reduction for a first subset of frequency bands in PFB and a second gain reduction for a second subset of frequency bands in PFB.

[0070] In the method, the number of frequency bands in the detection set may be less than fourteen, and the number of frequency bands in the processing set may be larger than fourteen.

[0071] The method may comprise classifying the sound environment into a predetermined set of sound environments, and optionally applying a first detection scheme if the sound environment is classified as a first sound environment. The method may comprise applying a second detection scheme different from the first detection scheme if the sound environment is classified as a second sound environment.

[0072] Table 1 illustrates six exemplary detection schemes DS1-DS6 with associated parameters, where rise thresholds are given in the logarithmic domain. Further, exemplary processing frequency bands PFB associated with the processor are also given.

Table 1: Exemplary detection schemes DS1-DS6.

	DS1	DS2	DS3	DS4	DS5	DS6
DFB	FD_1-FD_{12}	FD_1-FD_{14}	FD_1	FD_1-FD_{12}	FD_1-FD_4	FD_1-FD_5
PFB	FP_1-FP_{17}	FP_1-FP_{17}	FP_1-FP_{17}	FP_1-FP_{17}	FP_1-FP_9	FP_1-FP_{24}
RNTH	8	5	1	10	3	2
	TH_j (j=1-12) =16 dB	TH_j (j=1-14) =16 dB	TH_1=20 dB	TH_j (j=1-7) = 16 dB TH_j (j=8-12) = 9 dB	TH_1 = 2 dB TH_2 = 6 dB TH_j (j=3-4) = 9 dB	TH_1 = 1 dB TH_2 = 2 dB TH_3 = 3 dB TH_4 = 4 dB TH_5 = 5 dB
	$fd_{o,j}$ (j=1-12) > 2 kHz	$fd_{o,j}$ (j=1-14) < 9 kHz	$fd_{o,1}$ > 5 kHz	$fd_{o,j}$ (j=1-12) > 1 kHz		$fd_{o,j}$ (j=1-5) > 6 kHz
FFTH	3 kHz		6 kHz	3 kHz	500 Hz	6 kHz
SFTH		9 kHz			4 kHz	
BPTH	80 dB	80 dB	90 dB	85 dB	75 dB	80 dB

[0073] Fig. 1 shows an exemplary hearing device. The hearing device 2 comprises a first microphone 4 for provision of a first microphone input signal 6; a sound impulse suppression module 8 configured for detecting a sound impulse in the first microphone input signal 6; a processor 10 for processing the first microphone input signal in a processing set of frequency bands with 17 frequency bands to obtain an electrical output signal 12; and a receiver 14 for converting the electrical output signal 12 to an audio output signal. The sound impulse suppression module 8 is configured to apply a detection scheme on the first microphone input signal, e.g. with impulse detector 16, wherein the detection scheme defines a detection set of frequency bands, and wherein a sound impulse is detected in impulse detector 16 based on the detection set of frequency bands. The frequency bands of the detection set covers a part of the frequency bands of the processing set and the number M of frequency bands in the detection set is less than the number L of frequency bands in the processing set. Further, the hearing device comprises a sound environment detector 18 for classifying the sound environment into a predetermined set of sound environments. The resulting sound environment SE of the sound environment classification is transmitted to the sound impulse suppression module 8. The sound impulse suppression module is optionally configured to apply the detection scheme based on the sound environment. For example, the sound impulse suppression module 8 is configured to apply a first detection scheme, e.g. DS1, if the sound environment is classified as a first sound environment, and the sound impulse suppression module 8 is configured to apply a second detection scheme, e.g. DS2, different from the first detection scheme if the sound environment is classified as a second sound environment. The processor feeds broadband power estimate BPE to the sound impulse suppression module.

[0074] The sound impulse suppression module is configured to apply a detection scheme, e.g. DS1, on the first microphone input signal, wherein the detection scheme defines a detection set of frequency bands, wherein the frequency bands of the detection set covers a part of the frequency bands of the processing set, and wherein a sound impulse is detected based on the detection set of frequency bands. In the detection scheme DS1, the frequency bands FD_1-FD_{12} are selected as the 6th to the 17th frequency bins of an FFT with a 32-sample window length and a sampling frequency of in the range from 20-22 kHz. Thus, the frequency bands of the detection set have lower frequencies above a first frequency threshold of 2 kHz. Other sampling frequencies may be applied in the sound impulse suppression module.

[0075] The sound impulse suppression module 8 is configured to determine rise parameters (log domain) of the first microphone input signal in the frequency bands of the detection set, wherein a rise parameter is indicative of a power increase in the first microphone input signal in a frequency band, and wherein the sound impulse suppression module is configured to detect a sound impulse based on the rise parameters. The sound impulse suppression module 8 detects a sound impulse if the number of rise parameters that has reached a respective rise threshold is larger than a rise number threshold of 8. The rise thresholds are optionally defined by the detection scheme, i.e. the rise thresholds may change with change of detection scheme. In detection scheme DS1, the rise thresholds for the respective frequency bands are 16 db. The sound impulse suppression module 8 is configured to reduce a gain applied to the first microphone input signal by the processor when a sound impulse is detected by determining and transmitting gain reduction vector with gain reductions GR_i, i=1, ..., L to the processor 10. The second detection scheme may be DS2, where different rise thresholds THj are applied in DS2.

[0076] Fig. 2 illustrates a power spectrum of frequency bands FD_1-FD_{12} of detection scheme DS1, where FD_1 is the 6^{th} frequency bin of a 32-sample window FFT, FD_2 is the 7^{th} frequency bin, etc. Thus, the detection set is a proper subset of frequency bins 1-17 of the FFT applied in impulse detector 16. The instant power estimates P_1-P_{12} of the frequency bands FD_1-FD_{12} are all above the reference power estimates and P_ref_1-P_ref_{12}. The broadband power estimate is 82 dB, which is larger than BPTH=80 dB of DS1. Further, more than RNTH=8 of the rise parameters R_1-R_{12} have respectively reached TH_1-TH_{12}=16 dB. Therefore, a sound impulse is detected and a gain reduction vector with gain reductions GR_1-GR_{17} is determined and fed to processor, such that the sound impulse is suppressed.

[0077] Fig. 3 is a flowchart of an exemplary method of operating a hearing device comprising a processor configured to process a first microphone input signal from a first microphone in a processing set of frequency bands to obtain an electrical output signal. The method 100 comprises detecting 102 a sound impulse in the microphone input signal; and reducing 104 a gain applied to the first microphone input signal in the processor when a sound impulse is detected. Detecting 102 a sound impulse comprises applying 106 a detection scheme on the first microphone input signal, wherein the detection scheme defines a detection set of frequency bands, wherein the detection set of frequency bands covers a part of the frequency bands of the processing set, and wherein detecting a sound impulse is based on the detection set of frequency bands. The method 100 comprises determining 108 rise parameters of the first microphone input signal in the frequency bands of the detection set, wherein a rise parameter is indicative of a power increase in the first microphone input signal in a frequency band. Detecting 102 a sound impulse is based on the rise parameters and the number of rise parameters that has reached a respective rise threshold, wherein a sound impulse is detected if the number of rise parameters that has reached a respective rise threshold is larger than a rise number threshold. Further, detecting 102 a sound impulse is based on a broadband power estimate from a broadband power estimator of the hearing device.

[0078] Reducing 104 a gain comprises determining 110 one or more gain reductions and transmitting 112 the one or more gain reductions to the processor. Determining one or more gain reductions are based on the rise parameters R_i and/or the broadband power estimate. The method 100 comprises classifying 114 the sound environment into a predetermined set of sound environments, and applying the detection scheme accordingly by applying a first detection scheme if the sound environment is classified as a first sound environment and applying a second detection scheme different from the first detection scheme if the sound environment is classified as a second sound environment.

[0079] Although particular features have been shown and described, it will be understood that they are not intended to limit the claimed invention, and it will be made obvious to those skilled in the art that various changes and modifications may be made without departing from the scope of the claimed invention. The specification and drawings are, accordingly to be regarded in an illustrative rather than restrictive sense.

LIST OF REFERENCES

[0080]

2
: hearing device

4
: first microphone

6
: first microphone input signal

8
: sound impulse suppression module

10
: processor

12
: electrical output signal

14
: receiver

16
: impulse detector

18
: sound environment detector

100
: method of operating a hearing device

102
: detecting a sound impulse in the microphone input signal

104
: reducing a gain

106
: applying a detection scheme on the first microphone input signal

108
: determining rise parameters

110
: determining one or more gain reductions

112
: transmitting the one or more gain reductions to the processor

114
: classifying the sound environment

REFERENCES CITED IN THE DESCRIPTION

Cited references

Patent documents cited in the description

- US20110103615A **[0003]**
- EP2980800A1 **[0004]**
- EP2306754A1 **[0005]**

PATENTKRAV

1. Høreindretning (2), der omfatter:

- en første mikrofon (4) til tilvejebringelse af et første mikrofonindgangssignal (6),

- et lydimpulsundertrykkelsesmodul (8), der er konfigureret til at detektere en lydimpuls i det første mikrofonindgangssignal,

- en processor (10) til behandling af det første mikrofonindgangssignal (6) i et behandlingssæt (PFB) af frekvensbånd med henblik på at opnå et elektrisk udgangssignal (12), og

- en receiver (14) til konvertering af det elektriske udgangssignal til et lydudgangssignal,

hvor lydimpulsundertrykkelsesmodulet (8) er konfigureret til at:

- anvende et detektionssystem på det første mikrofonindgangssignal (6), hvor detektionssystemet definerer et detektionssæt (DFB) af frekvensbånd, hvor detektionssættets (DFB) frekvensbånd dækker en del af behandlingssættets (PFB) frekvensbånd, og hvor der detekteres en lydimpuls baseret på detektionssættet (DFB) af frekvensbånd, hvor detektionssættets (DFB) frekvensbånd er arrangeret inden for et eller flere frekvensområder, der indbefatter et første frekvensområde og et andet frekvensområde, hvor det første frekvensområde og det andet frekvensområde er separate frekvensområder, og det andet frekvensområde er på fra 3 kHz til 8 kHz, og

- reducere en forstærkning, som påføres det første mikrofonindgangssignal af processoren, når der detekteres en lydimpuls.

2. Høreindretning ifølge krav 1, hvor detektionssættets (DFB) frekvensbånd har nedre frekvenser over en første frekvenstærskel.

3. Høreindretning ifølge et hvilket som helst af kravene 1-2, hvor detektionssættets (DFB) frekvensbånd har øvre frekvenser under en første frekvenstærskel.

4. Høreindretning ifølge et hvilket som helst af kravene 1-3, hvor behandlingssættet (PFB) af frekvensbånd omfatter L frekvensbånd, og detektionssættet af frekvensbånd omfatter M frekvensbånd, og hvor L–M er større end eller lig med 3.

5. Høreindretning ifølge et hvilket som helst af kravene 1-4, hvor lydimpulsundertrykkelsesmodulet (8) er konfigureret til at bestemme stigningsparametrene for det første mikrofonindgangssignal i detektionssættets frekvensbånd, hvor en stigningsparameter angiver en effektforøgelse i det første mikrofonindgangssignal (6) i et frekvensbånd, og hvor lydimpulsundertrykkelsesmodulet er konfigureret til at detektere en lydimpuls baseret på stigningsparametrene.

6. Høreindretning ifølge krav 5, hvori lydimpulsundertrykkelsesmodulet (8) er konfigureret til at detektere en lydimpuls baseret på antallet af stigningsparametre, der har nået en respektiv stigningstærskel.

7. Høreindretning ifølge krav 6, hvor der detekteres en lydimpuls, hvis antallet af stigningsparametre, der har nået en respektiv stigningstærskel, er større end en stigningsantaltærskel.

8. Høreindretning ifølge et hvilket som helst af kravene 6-7, hvor detektionssystemet definerer stigningstærskler for detektionssættets frekvensbånd.

9. Høreindretning ifølge et hvilket som helst af kravene 6-8, hvor stigningstærsklen for ét frekvensbånd i detektionssættet er forskellig fra stigningstærsklen for et andet frekvensbånd i detektionssættet.

10. Høreindretning ifølge et hvilket som helst af kravene 5-9, hvor stigningsparametrene er baseret på et øjeblikkeligt effektestimat og et referenceeffektestimat for det første mikrofonindgangssignal i de respektive frekvensbånd.

11. Høreindretning ifølge et hvilket som helst af kravene 1-10, hvor høreindretningen omfatter en bredbåndseffektestimator, og hvor lydimpulsundertrykkelsesmodulet er konfigureret til at detektere en lydimpuls baseret på et bredbåndseffektestimat fra bredbåndseffektestimatoren.

12. Høreindretning ifølge et hvilket som helst af kravene 1-11, hvor høreindretningen omfatter en lydmiljødetektor (18) til klassificering af lydmiljøet i et forudbestemt sæt af lydmiljøer, hvor lydimpulsundertrykkelsesmodulet (8) er konfigureret til at anvende et første detektionssystem (DS1), hvis lydmiljøet klassificeres som et første lydmiljø, og hvor lydimpulsundertrykkelsesmodulet er konfigureret til at anvende et andet detektionssystem (DS2), der er forskelligt fra det første detektionssystem, hvis lydmiljøet klassificeres som et andet lydmiljø.

13. Fremgangsmåde (100) til betjening af en høreindretning, der omfatter en processor, som er konfigureret til at behandle et første mikrofonindgangssignal fra en første mikrofon i et behandlingssæt (PFB) af frekvensbånd med henblik på at opnå et elektrisk udgangssignal, hvilken fremgangsmåde (100) omfatter:

- detektering (102) af en lydimpuls i mikrofonindgangssignalet, og

- reduktion (104) af en forstærkning, der påføres det første mikrofonindgangssignal i processoren, når der detekteres en lydimpuls,

hvor detektering (102) af en lydimpuls omfatter anvendelse (106) af et detektionssystem på det første mikrofonindgangssignal, hvor detektionssystemet definerer et detektionssæt (DFB) af frekvensbånd, hvor detektionssættet af frekvensbånd dækker en del af behandlingssættets frekvensbånd, og hvor detektering af en lydimpuls er baseret på detektionssættet af frekvensbånd, hvor detektionssættets frekvensbånd er arrangeret inden for et eller flere frekvensområder, der indbefatter et første frekvensområde og et andet frekvensområde, hvor det første frekvensområde og det andet frekvensområde er separate frekvensområder, og det andet frekvensområde er på fra 3 kHz til 8 kHz.

DRAWINGS

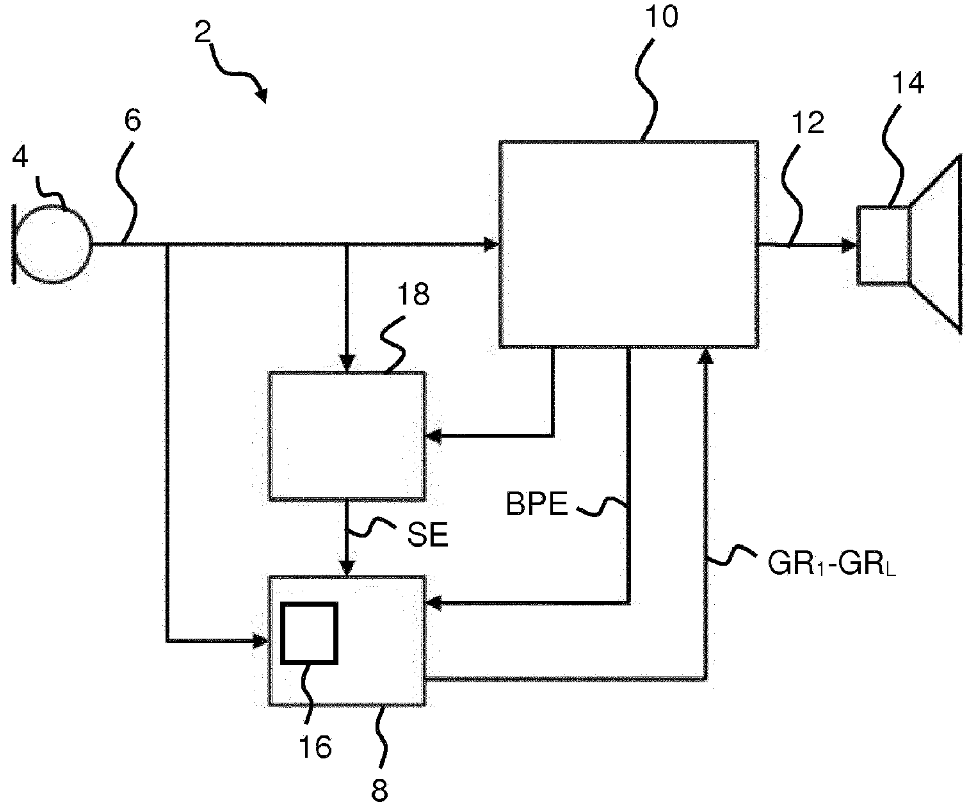

Fig. 1

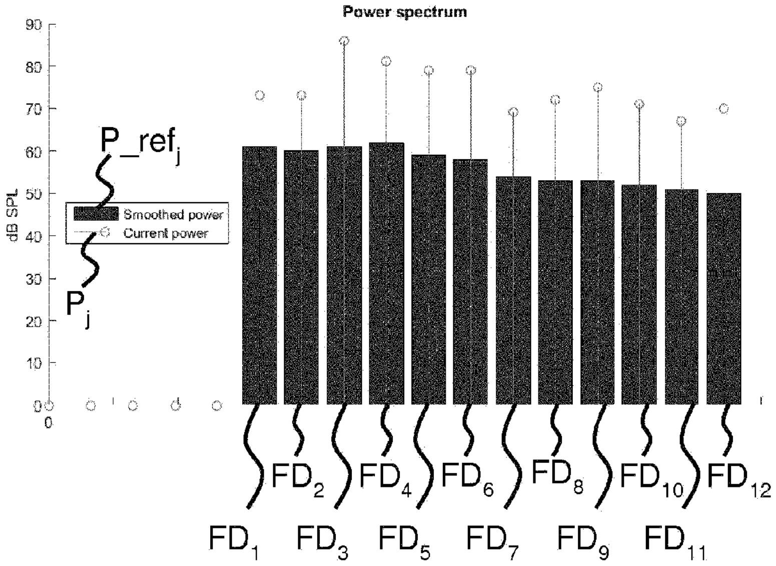
Power spectrum
dB SPL
90
80
70
60
50
40
30
20
10
0
0
P_ref$_j$
P$_j$
Smoothed power
Current power
FD$_1$
FD$_2$
FD$_3$
FD$_4$
FD$_5$
FD$_6$
FD$_7$
FD$_8$
FD$_9$
FD$_{10}$
FD$_{11}$
FD$_{12}$

Fig. 2

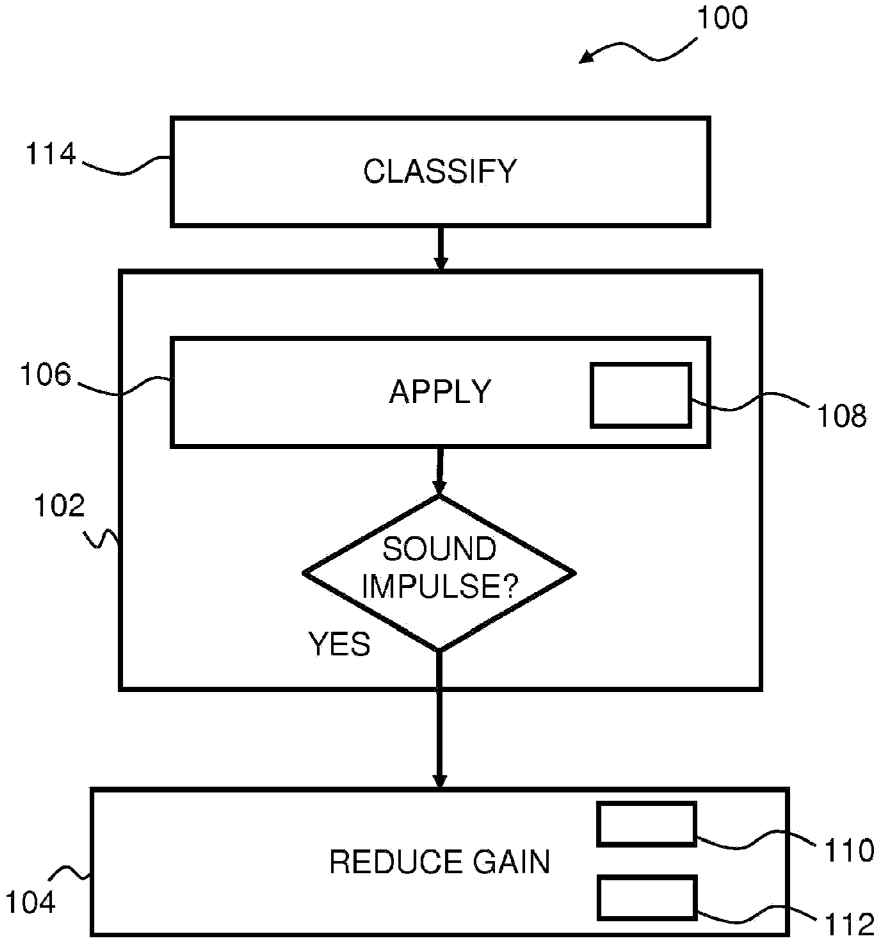
100
114
CLASSIFY
106
APPLY
108
102
SOUND
IMPULSE?
YES
REDUCE GAIN
110
104
112

Fig. 3