

(19)



(11)

EP 2 806 660 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
16.11.2016 Bulletin 2016/46

(51) Int Cl.:
H04R 25/00 ^(2006.01) *H04R 25/02* ^(2006.01)

(21) Application number: **13168718.8**

(22) Date of filing: **22.05.2013**

(54) **A hearing aid with improved localization**

Hörgerät mit verbesserter Ortung

Prothèse auditive avec localisation améliorée

(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**

(43) Date of publication of application:
26.11.2014 Bulletin 2014/48

(73) Proprietor: **GN ReSound A/S
2750 Ballerup (DK)**

(72) Inventor: **Gran, Karl-Fredrik Johan
SE-216 11 Limhamn (SE)**

(74) Representative: **Guardian
IP Consulting I/S
Diplomvej, Building 381
2800 Kgs. Lyngby (DK)**

(56) References cited:
**US-A1- 2009 067 651 US-A1- 2009 202 091
US-A1- 2010 092 016 US-A1- 2012 308 057**

EP 2 806 660 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

FIELD OF TECHNOLOGY

- 5 **[0001]** A new hearing aid is provided with improved localization of sound sources with relation to the wearer of the hearing aid.

BACKGROUND

- 10 **[0002]** Hearing aid users have been reported to have poorer ability to localize sound sources when wearing their hearing aids than without their hearing aids. This represents a serious problem for the mild-to-moderate hearing impaired population.

- 15 **[0003]** Furthermore, hearing aids typically reproduce sound in such a way that the user perceives sound sources to be localized inside the head. The sound is said to be internalized rather than being externalized. A common complaint for hearing aid users when referring to the "hearing speech in noise problem" is that it is very hard to follow anything that is being said even though the signal to noise ratio (SNR) should be sufficient to provide the required speech intelligibility. A significant contributor to this fact is that the hearing aid reproduces an internalized sound field. This adds to the cognitive loading of the hearing aid user and may result in listening fatigue and ultimately that the user removes the hearing aid(s).

- 20 **[0004]** Thus, there is a need for a new hearing aid with improved localization of sound sources, i.e. the new hearing aid preserves information of the directions and distances of respective sound sources in the sound environment with relation to the orientation of the head of the wearer of the hearing aid.

[0005] Human beings detect and localize sound sources in three-dimensional space by means of the human binaural sound localization capability.

- 25 **[0006]** The input to the hearing consists of two signals, namely the sound pressures at each of the eardrums, in the following termed the binaural sound signals. Thus, if sound pressures at the eardrums that would have been generated by a given spatial sound field are accurately reproduced at the eardrums, the human auditory system will not be able to distinguish the reproduced sound from the actual sound generated by the spatial sound field itself.

- 30 **[0007]** It is not fully known how the human auditory system extracts information about distance and direction to a sound source, but it is known that the human auditory system uses a number of cues in this determination. Among the cues are spectral cues, reverberation cues, interaural time differences (ITD), interaural phase differences (IPD) and interaural level differences (ILD).

- 35 **[0008]** The transmission of a sound wave from a sound source positioned at a given direction and distance in relation to the left and right ears of the listener is described in terms of two transfer functions, one for the left ear and one for the right ear, that include any linear transformation, such as coloration, interaural time differences and interaural spectral differences. Such a set of two transfer functions, one for the left ear and one for the right ear, is called a Head-Related Transfer Function (HRTF). Each transfer function of the HRTF is defined as the ratio between a sound pressure p generated by a plane wave at a specific point in or close to the appertaining ear canal (p_L in the left ear canal and p_R in the right ear canal) in relation to a reference. The reference traditionally chosen is the sound pressure p_i that would have been generated by a plane wave at a position right in the middle of the head with the listener absent.

- 40 **[0009]** The HRTF contains all information relating to the sound transmission to the ears of the listener, including diffraction around the head, reflections from shoulders, reflections in the ear canal, etc., and therefore, the HRTF varies from individual to individual.

[0010] In the following, one of the transfer functions of the HRTF will also be termed the HRTF for convenience.

- 45 **[0011]** The hearing aid related transfer function is defined similar to a HRTF, namely as the ratio between a sound pressure p generated by the hearing aid at a specific point in the appertaining ear canal in response to a plane wave and a reference. The reference traditionally chosen is the sound pressure p_i that would have been generated by a plane wave at a position right in the middle of the head with the listener absent.

- 50 **[0012]** The HRTF changes with direction and distance of the sound source in relation to the ears of the listener. It is possible to measure the HRTF for any direction and distance and simulate the HRTF, e.g. electronically, e.g. by filters. If such filters are inserted in the signal path between a playback unit, such as a tape recorder, and headphones used by a listener, the listener will achieve the perception that the sounds generated by the headphones originate from a sound source positioned at the distance and in the direction as defined by the transfer functions of the filters simulating the HRTF in question, because of the true reproduction of the sound pressures in the ears.

- 55 **[0013]** Binaural processing by the brain, when interpreting the spatially encoded information, results in several positive effects, namely better signal-to-noise ratio (SNR); direction of arrival (DOA) estimation; depth/distance perception and synergy between the visual and auditory systems.

[0014] The complex shape of the ear is a major contributor to the individual spatial-spectral cues (ITD, ILD and spectral

cues) of a listener. Devices which pick up sound behind the ear will, hence, be at a disadvantage in reproducing the HRTF since much of the spectral detail will be lost or heavily distorted.

[0015] This is exemplified in Figs. 1 and 2 where the angular frequency spectrum of an open ear, i.e. non-occluded, measurement is shown in Fig. 1 for comparison with Fig. 2 showing the corresponding measurement on the front microphone on a behind the ear device (BTE) using the same ear. The open ear spectrum shown in Fig. 1 is rich in detail whereas the BTE result shown in Fig. 2 is much more blurred and much of the spectral detail is lost.

[0016] Patent application US 2010/092016 A1 discloses a hearing aid with microphones separately disposed in the entrance of the ear canal and at the rear of the pinna, wherein the difference in frequency characteristic due to a difference in transfer function is corrected.

[0017] Patent application US 2004/136541 A1 discloses a method to adjust a hearing aid device having a microphone system that is disposed outside of the auditory canal of the user. A correction function is applied to the signal received by the microphone, such that it at least approximately converts that signal into a signal that corresponds to the signal received in the auditory canal.

SUMMARY

[0018] It is desirable to position one or more microphones of the hearing aid at position(s) with relation to a user wearing the hearing aid in which spatial cues of sounds arriving at the user is preserved. It is for example advantageous to position a microphone in the outer ear of the user in front of the pinna, i.e. opposite behind the pinna where microphones of a conventional BTE hearing aid are positioned; for example at the entrance to the ear canal; or, inside the ear canal, in order to preserve spatial cues of sounds arriving at the ear to a much larger extent than what is possible with a microphone positioned behind the pinna. A position below the triangular fossa has also proven advantageous with relation to preservation of spatial cues.

[0019] Positioning of a microphone at the entrance to the ear canal or inside the ear canal leads to the problem that the microphone is located close to the sound emitting device of the hearing aid, whereby the risk of feedback generation is increased, which in turn limits the maximum stable gain which can be prescribed with the hearing aid.

[0020] The standard way of solving this problem is to completely seal off the ear canal using a custom mould. This, however, introduces the occlusion effect as well as comfort issues with respect to moisture and heat.

[0021] For comparison, the maximum stable gain of a BTE hearing aid with front and rear microphones positioned behind the ear, and an In-The-Ear (ITE) hearing aid with an open fitted microphone positioned in the ear canal is shown in Fig. 3. It can be seen that the ITE hearing aid has much lower maximum stable gain (MSG) than the front and rear BTE microphones for nearly all frequencies.

[0022] In the new hearing aid, output signals of an arbitrary configuration of microphones and possibly other types of input sound transducers, such as transducers for implantable hearing aids, telecoils, receivers of digital audio datastreams, etc, undergo signal processing in such a way that spatial cues are preserved and conveyed to the user of the hearing aid. The microphone and possible other transducer output signals are filtered with filters that are configured to preserve spatial cues.

[0023] The new hearing aid provides improved localization to the user by providing, in addition to conventionally positioned microphones as in a BTE hearing aid, at least one ITE microphone intended to be positioned in the outer ear of the user in front of the pinna, i.e. not behind the pinna like the microphone(s) conventionally accommodated in a BTE hearing aid housing, e.g. at the entrance to the ear canal or immediately below the triangular fossa; or, inside the ear canal, when in use, in order to receive sound arriving at the ear of the user and containing the desired spatial information relating to localization of sound sources in the sound environment.

[0024] The circuitry of the new hearing aid combines an audio sound signal of the at least one ITE microphone residing in front of the pinna with audio sound signals of other sound input transducer(s) in such a way that spatial cues are preserved.

[0025] Thus, a hearing aid is provided, comprising
a BTE hearing aid housing configured to be worn behind the pinna of a user and accommodating

at least one BTE sound input transducer, such as an omni-directional microphone, a directional microphone, a transducer for an implantable hearing aid, a telecoil, a receiver of a digital audio datastream, etc., configured for conversion of acoustic sound into a BTE audio sound signal,

an ITE microphone housing configured to be positioned in the outer ear of the user and accommodating

at least one ITE microphone configured for conversion of acoustic sound into an ITE audio sound signal,

a signal detector configured for

determination of ITE signal magnitudes of the ITE audio sound signal at a plurality of frequencies, and
determination of BTE signal magnitudes of the BTE audio sound signal at the plurality of frequencies,

a gain processor for determination of gain values at respective frequencies of the plurality of frequencies based on the determined respective ITE signal magnitudes and BTE signal magnitudes, a multiplier configured for multiplying the BTE audio sound signal with the determined gain values at the respective frequencies, characterised by a signal combiner configured for outputting a weighted sum of the ITE audio sound signal and the gain modified BTE audio sound signal to

a processor configured to generate a hearing loss compensated output signal based on the weighted sum.

[0026] Preferably, the hearing aid also comprises an output transducer for conversion of the hearing loss compensated output signal to an auditory output signal, such as an acoustic output signal, an implanted transducer signal, etc, that can be received by the human auditory system.

[0027] The ITE audio sound signal may be formed as a weighted sum of the output signals of each microphone of the at least one ITE microphone. Other forms of signal processing may be included in the formation of the ITE audio sound signal.

[0028] Likewise, the BTE audio sound signal may be formed as a weighted sum of the output signals of each sound input transducer of the at least one BTE sound input transducer. Other forms of signal processing may be included in the formation of the BTE audio sound signal.

[0029] Preferably, one microphone of the at least one BTE sound input transducer is located proximate a top part of the BTE hearing aid housing so that sound arriving from the frontal looking direction of the user of the hearing aid has an unobstructed propagation path towards the input of the microphone, when the BTE hearing aid housing is mounted in its intended operating position behind the pinna of the user. Possible other microphones of the at least one BTE sound input transducer are located proximate the one microphone so that the one or more microphones of the at least one BTE sound input transducer are accommodated in the upper part of the BTE hearing aid housing residing above a horizontal, tangential plane to the upper circumference of the entrance to the ear canal of the user, when the BTE hearing aid housing is mounted in its intended operating position behind the pinna of the user.

[0030] The hearing aid may further comprise

a sound signal transmission member for transmission of a sound signal from a sound output in the BTE hearing aid housing at a first end of the sound signal transmission member to the ear canal of the user at a second end of the sound signal transmission member,

an earpiece configured to be inserted in the ear canal of the user for fastening and retaining the sound signal transmission member in its intended position in the ear canal of the user.

[0031] Throughout the present disclosure, the "ITE audio sound signal" may be used to identify any analogue or digital signal forming part of the signal path from the combined output of the at least one ITE microphone to an input of the processor, including pre-processed ITE audio sound signals.

[0032] Likewise, the "BTE audio sound signal" may be used to identify any analogue or digital signal forming part of the signal path from the combined output of the at least one BTE sound input transducer to an input of the processor, including pre-processed BTE audio sound signals.

[0033] In use, the at least one ITE microphone is positioned so that the ITE audio sound signal generated in response to the incoming sound has a transfer function that constitutes a good approximation to the HRTFs of the user. For example, the at least one ITE microphone may be constituted by a single microphone positioned at the entrance to the ear canal. The hearing aid circuitry conveys the directional information contained in the ITE audio sound signal to the resulting hearing loss compensated output signal of the processor so that the hearing loss compensated output signal of the processor also attains a transfer function that constitutes a good approximation to the HRTFs of the user whereby improved localization is provided to the user.

[0034] BTE (behind-the-ear) hearings aids are well-known in the art. A BTE hearing aid has a BTE housing that is shaped to be worn behind the pinna of the user. The BTE housing accommodates components for hearing loss compensation. A sound signal transmission member, i.e. a sound tube or an electrical conductor, transmits a signal representing the hearing loss compensated sound from the BTE housing into the ear canal of the user.

[0035] In order to position the sound signal transmission member securely and comfortably at the entrance to the ear canal of the user, an earpiece, shell, or earmould may be provided for insertion into the ear canal of the user constituting an open solution. In an open solution, the earpiece, shell, or earmould does not obstruct the ear canal when it is positioned in its intended operational position in the ear canal. Rather, there will be a passageway through the earpiece, shell, or earmould or, between a part of the ear canal wall and a part of the earpiece, shell, or earmould, so that sound waves may escape from behind the earpiece, shell, or earmould between the ear drum and the earpiece, shell, or earmould through the passageway to the surroundings of the user. In this way, the occlusion effect is substantially eliminated.

[0036] Typically, the earpiece, shell, or earmould is individually custom manufactured or manufactured in a number of standard sizes to fit the user's ear to sufficiently secure the sound signal transmission member in its intended position

in the ear canal and prevent the earpiece from falling out of the ear, e.g., when the user moves the jaw.

[0037] The output transducer may be a receiver positioned in the BTE hearing aid housing. In this event, the sound signal transmission member comprises a sound tube for propagation of acoustic sound signals from the receiver positioned in the BTE hearing aid housing and through the sound tube to an earpiece positioned and retained in the ear canal of the user and having an output port for transmission of the acoustic sound signal to the eardrum in the ear canal.

[0038] The output transducer may be a receiver positioned in the earpiece. In this event, the sound signal transmission member comprises electrical conductors for propagation of hearing loss compensated audio sound signals from the hearing aid circuitry in the BTE hearing aid housing through the conductors to a receiver positioned in the earpiece for emission of sound through an output port of the earpiece.

[0039] Further, a method is provided of preserving spatial cues in an audio sound signal to be converted into an auditory output signal, such as an acoustic output signal, an implanted transducer signal, etc, that can be received by the human auditory system, comprising the steps of

converting acoustic sound into a first audio sound signal,
mounting at least one microphone at an ear of a user for conversion of acoustic sound into a second audio sound signal in a position at the ear of the user in which spatial cues of the acoustic sound is preserved in the second acoustic sound signal,

determining first signal magnitudes of the first audio sound signal at a plurality of frequencies,
determining second signal magnitudes of the second audio sound signal at the plurality of frequencies,
determining gain values at respective frequencies of the plurality of frequencies based on the determined first signal magnitudes and second signal magnitudes, and multiplying the first audio sound signal with the determined gain values at the respective frequencies,

characterised by the steps of

forming a weighted sum of the multiplied first audio sound signal and the second audio sound signal, and
performing hearing loss compensation based on the weighted sum.

[0040] The method may also be a method of suppressing feedback in a hearing aid with the at least one microphone with an operational position at an ear of a user, comprising the further steps of mounting a BTE hearing aid housing accommodating at least one BTE sound input transducer in its operational position behind the pinna of the user, converting acoustic sound into the first audio sound signal utilizing the at least one BTE sound input transducer.

[0041] The weighted sum of the multiplied first audio sound signal and the second audio sound signal forms this method, e.g. a compromise between preservation of spatial cues and suppression of possible feedback. The weight of the audio signal containing spatial cues, e.g. as obtained by a microphone positioned at the entrance to the ear canal of the user, may be set to zero, whereby only the audio sound signal from the at least one BTE sound input transducer is amplified as a result of hearing loss compensation while the audio signal containing spatial cues is not included in the hearing loss compensation processing, whereby risk of feedback is reduced and a large maximum stable gain can be provided due to the relatively large distance between from the output transducer of the hearing aid and the at least one BTE sound input transducer. In this way, the audio sound signal containing spatial cues may operate as monitor signal imparting the desired spatial information of the current sound environment to the audio signal output by the at least one BTE sound input transducer.

[0042] Signal magnitudes at the plurality of frequencies may be determined as absolute values of the Fourier transformed signal, or as rms-values, absolute values, amplitude values, etc., of the signal, appropriately bandpass filtered and averaged, etc.

[0043] For example, in a hearing aid with one or more microphones, typically two microphones, positioned in a BTE hearing aid housing as is well-known in the art of hearing aids, the audio sound signal(s) output by the individual microphone(s) are combined into the BTE audio sound signal that is processed in accordance with the new method so that spatial cues are preserved.

[0044] This is obtained by modifying the BTE audio sound signal in accordance with an ITE sound signal obtained from one or more microphones, typically one microphone, positioned in location(s) relative to the user of the hearing aid, wherein spatial cues of sound arriving at those locations are preserved, e.g. at the entrance to the ear canal, inside the ear canal, immediately below the triangular fossa, etc.

[0045] According to the new method, the BTE audio sound signal is processed so that differences in signal magnitudes between the BTE audio sound signal and the ITE audio sound signal are reduced. The processing may be performed in a selected frequency range, or in a plurality of selected frequency ranges, or in the entire frequency range in which the hearing aid circuitry is capable of operating.

[0046] For example, in the selected frequency range(s), spectrum analysis is performed whereby the absolute value $B(f)$ as a function of frequency of the BTE audio sound signal and the absolute value $A(f)$ as a function of frequency of the ITE audio sound signal are determined. Then, multiplier gain values $G(f)$ as a function of frequency are determined $G(f) = A(f)/B(f)$, and the multiplier with the determined gain values $G(f)$ is inserted in the signal path of the BTE audio sound signal.

[0047] In general, determined gain values at the plurality of frequencies may be converted to corresponding filter coefficients of a linear phase filter inserted into the signal path of the BTE audio sound signal; or, the gain values may be applied directly to the BTE audio sound signal in the frequency domain.

[0048] In general, determined gain values may be compared to the respective maximum stable gain values at each of the plurality of frequencies, and gain values that are larger than the respective maximum stable gain values may be substituted by the respective maximum stable gain value, possibly minus a margin, to avoid risk of feedback.

[0049] It has been shown that the output signal of the multiplier, in the following denoted the gain modified BTE audio sound signal, has preserved spatial cues due to signal magnitude similarities with the ITE audio sound signal.

[0050] Subsequently, the gain modified BTE audio sound signal is input to a processor for hearing loss compensation.

[0051] In one example of the new hearing aid, only the BTE audio sound signal is amplified as a result of hearing loss compensation while the ITE audio sound signal is not included in the hearing loss compensation processing, whereby possible feedback from the output transducer to the at least one ITE microphone is reduced and a large maximum stable gain can be provided.

[0052] The at least one ITE microphone may operate as monitor microphone(s) for generation of an ITE audio sound signal with the desired spatial information of the current sound environment.

[0053] The new hearing aid may further have an adaptive feedback suppressor for feedback suppression and having an input connected to an output of the processor for reception of the hearing loss compensated output signal, at least one output modelling the feedback path from an output of the hearing aid to the respective at least one ITE microphone and at least one BTE sound input transducer and connected to

at least one subtractor for subtraction of the respective at least one output of the adaptive feedback suppressor from the respective output of at least one ITE microphone and the at least one BTE sound transducer and outputting the respective difference signal as the respective ITE audio sound signal and BTE audio sound signal.

[0054] The hearing aid may further comprise a feedback monitor connected to the adaptive feedback suppressor and configured to monitor the state of feedback and having an output providing an indication of the state of feedback.

[0055] The gain processor may have an input that is connected to the output of the feedback monitor and may be configured to modify, in response to the output signal of the feedback monitor, the calculated gain values as a function of frequency in such a way that risk of feedback is reduced, e.g. by lowering the determined gain values at selected frequencies with risk of feedback.

[0056] Feedback may be taken into account by monitoring feedback stability status and modifying gain value determination in response to the feedback stability status. When no feedback is detected, the gain processor operates to reduce differences in signal magnitudes of the BTE and ITE audio sound signals as explained above.

[0057] In the event that the feedback stability status changes towards instability, the determination of gain values in the gain processor may be modified in order to avoid feedback, e.g. the determined gain value may be lowered in one or more frequency ranges with risk of feedback.

[0058] When feedback stability status reverts to a stable condition, gain value determination based solely on the ITE and BTE audio sound signals may be resumed. The reduced gain values may be changed gradually towards the determined gain values with no risk of feedback.

[0059] The ITE microphone housing accommodating at least one ITE microphone may be combined with, or be constituted by, the earpiece so that the at least one microphone is positioned proximate the entrance to the ear canal when the earpiece is fastened in its intended position in the ear canal.

[0060] The ITE microphone housing may be connected to the BTE hearing aid housing with an arm, possibly a flexible arm that is intended to be positioned inside the pinna, e.g. around the circumference of the conchae abutting the antihelix and at least partly covered by the antihelix for retaining its position inside the outer ear of the user. The arm may be pre-formed during manufacture, preferably into an arched shape with a curvature slightly larger than the curvature of the antihelix, for easy fitting of the arm into its intended position in the pinna. In one example, the arm has a length and a shape that facilitate positioning of the at least one ITE microphone in an operating position immediately below the triangular fossa.

[0061] The processor may be accommodated in the BTE hearing aid housing, or in the ear piece, or part of the processor may be accommodated in the BTE hearing aid housing and part of the processor may be accommodated in the ear piece. There is a one-way or two-way communication link between circuitry of the BTE hearing aid housing and circuitry of the earpiece. The link may be wired or wireless.

[0062] Likewise, there is a one-way or two-way communication link between circuitry of the BTE hearing aid housing and the microphone housing. The link may be wired or wireless.

[0063] The hearing aid circuitry operates to perform hearing loss compensation while maintaining spatial information of the sound environment for optimum spatial performance of the hearing aid and while at the same time providing as large maximum stable gain as possible.

[0064] The ITE audio sound signal output by the earpiece may be a combination of several pre-processed ITE microphone signals, or the output signal of a single ITE microphone of the at least one ITE microphone. The short time

spectrum for a given time instance of the ITE audio sound signal of the earpiece is denoted $S^{IEC}(f, t)$ (IEC = In the Ear Component).

[0065] One or more output signals of the at least one BTE sound input transducers are provided. The spectra of these signals are denoted $S_1^{BTEC}(f, t)$, and $S_2^{BTEC}(f, t)$, etc (BTEC = Behind The Ear Component). The output signals may be pre-processed. Preprocessing may include, without excluding any form of processing; adaptive and/or static feedback suppression, adaptive or fixed beamforming and pre-filtering.

[0066] The multiplier may be configured to adaptively modify the BTE audio sound signal to correspond to the ITE audio sound signal as closely as possible.

[0067] The hearing aid may comprise a signal combiner configured for combination of the ITE audio sound signal with the gain modified BTE audio sound signal and having an output connected to the processor input for hearing loss compensation. The signal combiner may output a weighted sum of the ITE and BTE audio sound signals. In selected frequency bands with no risk of feedback, the signal combiner may pass the ITE audio sound signal (ITE weight = 1 and BTE weight = 0), i.e. the ITE audio sound signal may constitute the input signal, or the main part of the input signal, supplied to the processor input. In frequency bands with risk of feedback, the signal combiner may pass the BTE audio sound signal (ITE weight = 0 and BTE weight = 1), i.e. the BTE audio sound signal may constitute the input signal, or the main part of the input signal, supplied to the processor input, while a weighted sum of the BTE and ITE audio sound signals may constitute the main part of the input signal supplied to the processor input in complementary frequency band(s).

[0068] In this way, the at least one ITE microphone may be used as the sole input source to the processor in a frequency band wherein the required gain for hearing loss compensation can be applied to the ITE audio sound signal without feedback. Outside this frequency band, the BTE audio sound signal is applied to the processor for provision of the required gain. In yet other frequency bands, the signal combiner may supply a weighted sum of the BTE audio sound signal and the ITE audio sound signal to the processor, the weighted sum forming a compromise between preservation of spatial cues and suppression of possible feedback.

[0069] The combination of the signals could e.g. be based on different types of band pass filtering.

[0070] The hearing aid may be a multi-channel hearing aid in which signals to be processed are divided into a plurality of frequency channels, and wherein signals are processed individually in each of the frequency channels. The adaptive feedback suppression circuitry may also be divided into the plurality of frequency channels; or, the adaptive feedback suppression circuitry may still operate in the entire frequency range; or, may be divided into other frequency channels, typically fewer frequency channels, than the other circuitry is divided into.

[0071] The processor may be configured for processing the ITE and BTE audio sound signals in such a way that the hearing loss compensated output signal substantially preserves spatial cues in a selected frequency band.

[0072] The selected frequency band may comprise one or more of the frequency channels, or all of the frequency channels. The selected frequency band may be fragmented, i.e. the selected frequency band need not comprise consecutive frequency channels.

[0073] The plurality of frequency channels may include warped frequency channels, for example all of the frequency channels may be warped frequency channels.

[0074] Outside the selected frequency band, the at least one ITE microphone may be connected conventionally as an input source to the processor of the hearing aid and may cooperate with the hearing aid circuitry in a well-known way.

[0075] In this way, the at least one ITE microphone supplies the input to the hearing aid at frequencies where the hearing aid is capable of supplying the desired gain with this configuration. In frequency band(s), wherein the hearing aid cannot supply the desired gain with this configuration, the microphones of BTE hearing aid housing are included in the signal processing as disclosed above. In this way, the gain can be increased while simultaneously conveying the spatial information about the sound environment provided by the at least one ITE microphone to the user.

[0076] Signal processing in the new hearing aid may be performed by dedicated hardware or may be performed in a signal processor, or performed in a combination of dedicated hardware and one or more signal processors.

[0077] As used herein, the terms "processor", "signal processor", "controller", "system", etc., are intended to refer to CPU-related entities, either hardware, a combination of hardware and software, software, or software in execution.

[0078] For example, a "processor", "signal processor", "controller", "system", etc., may be, but is not limited to being, a process running on a processor, a processor, an object, an executable file, a thread of execution, and/or a program.

[0079] By way of illustration, the terms "processor", "signal processor", "controller", "system", etc., designate both an application running on a processor and a hardware processor. One or more "processors", "signal processors", "controllers", "systems" and the like, or any combination hereof, may reside within a process and/or thread of execution, and one or more "processors", "signal processors", "controllers", "systems", etc., or any combination hereof, may be localized on one hardware processor, possibly in combination with other hardware circuitry, and/or distributed between two or more hardware processors, possibly in combination with other hardware circuitry.

BRIEF DESCRIPTION OF THE DRAWINGS

[0080] In the following, preferred embodiments of the invention is explained in more detail with reference to the drawing, wherein

- Fig. 1 shows a plot of the angular frequency spectrum of an open ear,
- Fig. 2 shows a plot of the angular frequency spectrum of a BTE front microphone worn at the same ear,
- Fig. 3 shows plots of maximum stable gain of a BTE front and rear microphones and an open fitted ITE microphone positioned in the ear canal,
- Fig. 4 schematically illustrates an exemplary new hearing aid,
- Fig. 5 schematically illustrates another exemplary new hearing aid,
- Fig. 6 shows in perspective a new hearing aid with an ITE-microphone in the outer ear of a user,
- Fig. 7 shows a schematic block diagram of an exemplary new hearing aid with improved localization,
- Fig. 8 shows a schematic block diagram of the hearing aid of Fig. 7 with added monitoring of feedback suppression, and
- Fig. 9 shows a schematic block diagram of the hearing aid of Fig. 8 with added adaptiveness of the signal combiner.

DETAILED DESCRIPTION OF THE DRAWINGS

[0081] The new method and hearing aid will now be described more fully hereinafter with reference to the accompanying drawings, in which various examples of the new method and hearing aid are illustrated. The new method and hearing aid according to the appended claims may, however, be embodied in different forms and should not be construed as limited to the examples set forth herein. Rather, these examples are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the appended claims to those skilled in the art.

[0082] It should be noted that the accompanying drawings are schematic and simplified for clarity, and they merely show details which are essential to the understanding of the new method and hearing aid, while other details have been left out.

[0083] Like reference numerals refer to like elements throughout. Like elements will, thus, not be described in detail with respect to the description of each figure.

[0084] Fig. 4 schematically illustrates a BTE hearing aid 10 comprising a BTE hearing aid housing 12 (not shown - outer walls have been removed to make internal parts visible) to be worn behind the pinna 100 of a user. The BTE housing 12 accommodates at least one BTE sound input transducer 14, 16 with a front microphone 14 and a rear microphone 16 for conversion of a sound signal into a microphone audio sound signal, optional pre-filters (not shown) for filtering the respective microphone audio sound signals, A/D converters (not shown) for conversion of the respective microphone audio sound signals into respective digital microphone audio sound signals that are input to a processor 18 configured to generate a hearing loss compensated output signal based on the input digital audio sound signals.

[0085] The hearing loss compensated output signal is transmitted through electrical wires contained in a sound signal transmission member 20 to a receiver 22 for conversion of the hearing loss compensated output signal to an acoustic output signal for transmission towards the eardrum of a user and contained in an earpiece 24 that is shaped (not shown) to be comfortably positioned in the ear canal of a user for fastening and retaining the sound signal transmission member in its intended position in the ear canal of the user as is well-known in the art of BTE hearing aids.

[0086] The earpiece 24 also holds one ITE microphone 26 that is positioned at the entrance to the ear canal when the earpiece is positioned in its intended position in the ear canal of the user. The ITE microphone 26 is connected to an A/D converter (not shown) and optional to a pre-filter (not shown) in the BTE housing 12, with interconnecting electrical wires (not visible) contained in the sound transmission member 20.

[0087] The BTE hearing aid 10 is powered by battery 28.

[0088] Various functions of the processor 18 are disclosed above and in more detail below.

[0089] Fig. 5 schematically illustrates another BTE hearing aid 10 similar to the hearing aid shown in Fig. 1, except for the fact that in Fig. 5, the receiver 22 is positioned in the hearing aid housing 12 and not in the earpiece 24, so that acoustic sound output by the receiver 22 is transmitted through the sound tube 20 and towards the eardrum of the user when the earpiece 24 is positioned in its intended position in the ear canal of the user.

[0090] The positioning of the ITE microphone 26 proximate the entrance to the ear canal of the user when the BTE hearing aids 10 of Figs. 4 and 5 are used is believed to lead to a good reproduction of the HRTFs of the user.

[0091] Fig. 6 shows a new hearing aid 10 in its operating position with the BTE housing 12 behind the ear, i.e. behind the pinna 100, of the user. The illustrated new hearing aid 10 is similar to the hearing aids shown in Figs. 4 and 5 except for the fact that the ITE microphone 26 is positioned in the outer ear of the user outside the ear canal at the free end of an arm 30. The arm 30 is flexible and intended to be positioned inside the pinna 100, e.g. around the circumference of the conchae 102 behind the tragus 104 and antitragus 106 and abutting the antihelix 108 and at least partly covered by the antihelix for retaining its position inside the outer ear of the user. The arm may be pre-formed during manufacture, preferably into an arched shape with a curvature slightly larger than the curvature of the antihelix 104, for easy fitting of the arm 30 into its intended position in the pinna. The arm 30 contains electrical wires (not visible) for interconnection of the ITE microphone 26 with other parts of the BTE hearing aid circuitry.

[0092] In one example, the arm 30 has a length and a shape that facilitate positioning of the ITE microphone 26 in an operating position below the triangular fossa.

[0093] Fig. 7 is a block diagram illustrating one exemplary signal processing in the new hearing aid 10. The illustrated hearing aid 10 has a front microphone 14 and a rear microphone 16 accommodated in the BTE hearing aid housing 12 configured to be worn behind the pinna of the user and for conversion of sound signals arriving at the microphones 14, 16 into respective audio sound signals 33, 35. Further, the illustrated hearing aid 10 has an ITE microphone 26 accommodated in an earpiece (not shown) to be positioned in the outer ear of the user, for conversion of sound signals arriving at the microphone 26 into ITE audio sound signal 31.

[0094] The microphone audio sound signals 31, 33, 35 are digitized and pre-processed, such as pre-filtered, in respective pre-processors 32, 34, 36.

[0095] The pre-processed audio sound signals 38, 40 of the front and rear microphones 14, 16 are combined with, e.g. added to, each other in BTE signal combiner 50, and the combined signal 56, i.e. the BTE audio sound signal 56, is input to multiplier 46 for multiplication with gain values that are determined so that the signal magnitudes of the gain modified BTE audio sound signal 48 is identical to, or substantially identical to, the signal magnitudes of the ITE audio sound signal 60, whereby spatial cues in the ITE audio sound signal 60 are preserved.

[0096] The signal detector 42 performs a spectral analysis of the ITE audio sound signal 60, and the signal magnitude detector 64 determines signal magnitudes of the ITE audio sound signal 60 at a plurality of frequencies.

[0097] Likewise, the signal detector 44 performs a spectral analysis of the BTE audio sound signal 56, and the signal magnitude detector 66 determines signal magnitudes of the BTE audio sound signal 56 at the plurality of frequencies.

[0098] The gain processor 58 calculates gain values at respective frequencies of the plurality of frequencies based on the determined ITE audio sound signal magnitudes and BTE audio sound signal magnitudes, and outputs the determined gain values to the multiplier 46 that is connected for multiplying the BTE audio sound signal 56 with the determined gain values at the respective frequencies.

[0099] The ITE microphone 26 is positioned in a location relative to the user of the hearing aid 10, wherein spatial cues of sound arriving at the location are preserved, e.g. at the entrance to the ear canal, inside the ear canal, immediately below the triangular fossa, etc.

[0100] The BTE audio sound signal 56 is processed so that differences in signal magnitudes between the BTE audio sound signal 56 and the ITE audio sound signal 60 are reduced. The processing may be performed in a selected frequency range, or in a plurality of selected frequency ranges, or in the entire frequency range in which the hearing aid circuitry is capable of operating.

[0101] The determined gain values at the plurality of frequencies may be converted to corresponding filter coefficients of a linear phase filter inserted into the signal path of the BTE audio sound signal 56; or, the gain values may be applied directly to the BTE audio sound signal 56 in the frequency domain.

[0102] The determined gain values may further be compared to the corresponding maximum stable gain at the respective frequencies and for gain values that are larger than the respective maximum stable gains, the gain values may be substituted with the respective maximum stable gains, possibly minus a margin, to avoid risk of feedback.

[0103] It has been shown that the output signal 48 of the multiplier 46 has preserved spatial cues due to signal magnitude similarities with the ITE audio sound signal 60.

[0104] The gain modified BTE audio sound signal 48 may be input to the processor 18 for hearing loss compensation so that the ITE audio sound signal 60 does not form a direct part of the input to the processor 18, whereby risk of feedback is minimized.

[0105] However, in the hearing aid 10 illustrated in Fig. 7, the hearing aid 10 further comprises a signal combiner 62 configured for combination of the ITE audio sound signal 60 with the gain modified BTE audio sound signal 48 and providing a combined output signal 52 connected to an input of the processor 18 for hearing loss compensation. The signal combiner 62 may output a weighted sum of the ITE and BTE audio sound signals 60, 48.

[0106] The signal combiner may process the ITE audio sound signal 60 and BTE audio sound signal 56 differently in different frequency bands. For example, in selected frequency bands with no risk of feedback, the signal combiner 62

may pass the ITE audio sound signal 60 to the input of the processor 18, i.e. the ITE audio sound signal 60 may constitute the input signal 52, or the main part of the input signal 52, supplied to the input of the processor 18 and may cooperate with the processor 18 of the hearing aid 10 in a well-known way for hearing loss compensation. In this way, the ITE microphone 26 may be used as the sole input source to the processor 18 in a frequency band wherein the required gain for hearing loss compensation can be applied to the output signal 60 of the ITE microphone 26 without feedback.

[0107] In frequency bands with risk of feedback, the signal combiner 62 may pass the gain modified BTE audio sound signal 48 to the input of the processor 18, i.e. the BTE audio sound signal 48 may constitute the input signal, or the main part of the input signal, supplied to the input of the processor 18 for provision of the required gain with minimum risk of feedback and preservation of spatial cues, at least to some extent, due to the multiplication of the BTE audio sound signal 56 in the multiplier 62.

[0108] In other frequency bands, the signal combiner 62 may supply a weighted sum of the BTE audio sound signal 48 and the ITE audio sound signal 60 to the processor 18, the weighted sum forming a compromise between preservation of spatial cues and suppression of possible feedback.

[0109] The combination of the signals 48, 60 could e.g. be based on different types of band pass filtering.

[0110] The output signal 52 of the signal combiner 62 is input to processor 18 for hearing loss compensation, e.g. in a compressor. The hearing loss compensated signal 54 is output to the receiver 22 that converts the signal 54 to an acoustic output signal for transmission towards the ear drum of the user.

[0111] The ITE microphone 26 operates as monitor microphone for generation of an audio sound signal 60 with the desired spatial information of the current sound environment due to its positioning in the outer ear of the user.

[0112] The new hearing aid circuitry shown in Fig. 7 may operate in the entire frequency range of the hearing aid 10.

[0113] In order to suppress feedback, the illustrated new hearing aid 10 also has adaptive feedback suppression circuitry, including an adaptive feedback filter 70 with an input 72 connected to the output of the hearing aid processor 18 and with individual outputs 74, 76-1, 76-2, each of which is connected to a respective subtractor 78, 80-1, 80-2 for subtraction of each output 74, 76-1, 76-2 from a respective microphone output 31, 33, 35 to provide a respective feedback compensated signal 82, 84-1, 84-2 as is well-known in the art. Each feedback compensated signal 82, 84-1, 84-2 is fed to the corresponding pre-processor 32, 34, 36, and also to the adaptive feedback filter 70 for control of the adaption of the adaptive feedback filter 70. The adaptive feedback filter outputs 74, 76-1, 76-2 provide signals that constitute approximations of corresponding feedback signals travelling from the output transducer 22 to the respective microphone 14, 16, 26 as is well-known in the art.

[0114] The hearing aid 10 shown in Fig. 7 may be a multi-channel hearing aid in which microphone audio sound signals 31, 33, 35 to be processed are divided into a plurality of frequency channels, and wherein signals are processed individually in each of the frequency channels, possibly apart from the adaptive feedback suppression circuitry 70, 72, 74, 76-1, 76-2, 78, 80-1, 80-2, 82, 84-1, 84-2, 86 that may still operate in the entire frequency range; or, may be divided into other frequency channels, typically fewer frequency channels than the remaining illustrated circuitry.

[0115] For a multi-channel hearing aid 10, Fig. 7 may illustrate the circuitry and signal processing in a single frequency channel, as mentioned above possibly apart from the adaptive feedback suppression circuitry that may be divided into different frequency channels.

[0116] The circuitry and signal processing may be duplicated in a plurality of the frequency channels, e.g. in all of the frequency channels.

[0117] For example, the signal processing illustrated in Fig. 7 may be performed in a selected frequency band, e.g. selected during fitting of the hearing aid to a specific user at a dispenser's office.

[0118] The selected frequency band may comprise one or more of the frequency channels, or all of the frequency channels. The selected frequency band may be fragmented, i.e. the selected frequency band need not comprise consecutive frequency channels.

[0119] The plurality of frequency channels may include warped frequency channels, for example all of the frequency channels may be warped frequency channels.

[0120] Outside the selected frequency band, the ITE microphone 26 may be connected conventionally as an input source to the processor 18 of the hearing aid 10 and may cooperate with the processor 18 of the hearing aid 10 in a well-known way.

[0121] In this way, the ITE microphone 26 supplies the input to the hearing aid at frequencies where the hearing aid is capable of supplying the desired gain with this configuration. In the selected frequency band, wherein the hearing aid cannot supply the desired gain with this configuration, the microphones 14, 16 of BTE hearing aid housing are included in the signal processing as disclosed above. In this way, the gain can be increased while the spatial information of the sound environment as provided by the ITE microphone is simultaneously maintained.

[0122] An arbitrary number N of ITE microphones may substitute the ITE microphone 26, and a combination of output signals from the N ITE microphones may be combined in a ITE signal combiner to form the ITE audio sound signal 60, e.g. as a weighted sum. The weights may be frequency dependent.

[0123] Likewise, an arbitrary number M of BTE microphones may substitute the BTE microphones 14, 16, and a

combination of output signals from the M BTE microphones may be combined in a BTE signal combiner to form the BTE audio sound signal 56, e.g. as a weighted sum. The weights may be frequency dependent.

[0124] Fig. 8 is a block diagram illustrating the same hearing aid 10 as in Fig. 7 and operating in the same way, except for the fact that a feedback monitor 86 has been added that is configured for monitoring the state of the adaptive feedback filter 70, e.g. in order to detect emerging feedback. The feedback monitor 86 provides a feedback monitor signal 88 accordingly. The gain processor 58 receives the monitor signal 88 and modifies its gain value calculation in response to the value of the monitor signal 88, i.e. in response to the state of feedback.

[0125] When no emerging feedback is detected, the gain value calculation is performed as explained above.

[0126] In the event that state of feedback changes towards instability, e.g. emerging feedback is detected, the determined gain value may be lowered to reduce risk of feedback, e.g. in the entire frequency range in which the hearing aid circuitry is capable of operating, or, in a selected frequency band in which the feedback is otherwise expected to emerge.

[0127] When feedback stability status reverts to a stable condition, gain value calculation as explained above, is resumed.

[0128] The lowered gain values may be changed gradually towards the gain values determined by the gain processor 58 without risk of feedback.

[0129] For example, the gain values may be changed gradually according to:

$$w = (1 - \beta) * gain_{reduced} + \beta * gain_{not\ reduced}$$

wherein $gain_{reduced}$ is the lowered gain value of the multiplier, $gain_{not\ reduced}$ is the gain value as determined by the gain processor 58 with no risk of feedback.

β may be a function (between 0 and 1) of state of feedback. If β is 0, feedback problem is very severe and low gain values are used to ensure stability. If β is 1, feedback is not a problem at all and the gain processor operates as explained above.

[0130] An example of calculation of β is given by

$$\beta = \min \left(\frac{\|\hat{H}_{FB} - \bar{H}_{FB}\|_2^2}{\|\bar{H}_{FB}\|_2^2}, 1 \right)$$

where $\hat{H}_{FB}$ is the estimated feedback path response, e.g. from the output transducer 22 to the ITE audio sound signal 60 as modeled by adaptive feedback suppressor 70, and $\bar{H}_{FB}$ is a stable feedback path response, e.g. determined during start-up of the hearing aid.

[0131] The hearing aid 10 shown in Fig. 9 is similar to the hearing aid 10 shown in Fig. 8 and operates in the same way, apart from the fact that, in Fig. 9, the signal combiner 62 is adaptive in response to the state of feedback as output by the feedback monitor 86. For example, the ITE audio sound signal 60 of the at least one ITE microphone 26 may be used as the sole input source to the processor 18 in one or more frequency bands in which no feedback is currently present or emerging, whereas in one or more frequency bands in which feedback is present or evolving, the BTE audio sound signal 56 of the at least one BTE sound input transducer 14, 16 is applied to the signal processor 18 for provision of the required gain without feedback.

[0132] The signal combiner 62 may adaptively connect the ITE audio sound signal 60 of the at least one ITE microphone 26 as the sole input source to the processor 18 in one or more frequency channels in which no feedback instability is currently detected by the feedback monitor 86, and the BTE audio sound signal 56 of the at least one BTE sound input transducer 14, 16 in frequency channels with current risk of feedback as detected by the feedback monitor 86.

Claims

1. A BTE hearing aid comprising
a BTE hearing aid housing to be worn behind the pinna of a user and accommodating

at least one BTE sound input transducer configured for conversion of acoustic sound into a BTE audio sound signal,

an ITE microphone housing configured to be positioned in the outer ear of the user and accommodating

at least one ITE microphone configured for conversion of acoustic sound into an ITE audio sound signal,

a signal detector configured for

determination of ITE signal magnitudes of the ITE audio sound signal at a plurality of frequencies, and
determination of BTE signal magnitudes of the BTE audio sound signal at the plurality of frequencies,

a gain processor for determining gain values at respective frequencies of the plurality of frequencies based on the
determined ITE signal magnitudes and BTE signal magnitudes,

a multiplier configured for multiplying the BTE audio sound signal with the gain values at the respective frequencies,
characterized by

a signal combiner configured for outputting a weighted sum of the ITE audio sound signal and the gain modified
BTE audio sound signal to

a processor configured to generate a hearing loss compensated output signal based on the weighted sum.

2. A hearing aid according to claim 1, comprising

an adaptive feedback suppressor for feedback suppression and having

an input connected for reception of a hearing loss compensated output signal, at least one output, each of which
is modelling the feedback path from an output of the hearing aid to one of the at least one ITE microphone and
at least one BTE sound input transducer and connected to

at least one subtractor for subtraction of the at least one output of the adaptive feedback suppressor from the output
of the one of the at least one ITE microphone and the at least one BTE sound transducer and outputting the respective
difference signal as the respective one of the ITE audio sound signal and BTE audio sound signal.

3. A hearing aid according to claim 2, comprising

a feedback monitor connected to the adaptive feedback suppressor and configured to monitor the state of feedback
and having an output providing an indication of the state of feedback, and wherein
the gain processor further has an input that is connected to the feedback monitor, and wherein the gain processor
is configured for determination of the gain value at each of the plurality of frequencies based on the determined ITE
signal magnitudes and BTE signal magnitudes and a state of feedback.

4. A hearing aid according to claim 3, wherein the signal combiner further has an input that is connected to the feedback
monitor, and wherein the signal combiner is configured for combination of the ITE audio sound signal with the BTE
audio sound signal in response to the state of feedback.

5. A hearing aid according to any of the preceding claims, wherein the gain processor is configured for limiting the
gain value so that the resulting gain of the hearing aid is kept below the maximum stable gain at the plurality of
frequencies.

6. A hearing aid according to any of the preceding claims, wherein the ITE and BTE audio sound signals are divided
into a plurality of frequency channels, and wherein the signal detector is configured for individually processing the
audio sound signals in selected frequency channels each of which comprises a respective one of the plurality of
frequencies.

7. A hearing aid according to claim 6, wherein the signal combiner is configured for forming individual weighted sums
of the ITE audio sound signal and the gain modified BTE audio sound signal in at least some of the frequency channels.

8. A hearing aid according to claim 6 or 7, wherein the at least one BTE sound input transducer is disconnected in a
selected frequency channel of the plurality of frequency channels so that hearing loss compensation is based solely
on the ITE audio sound signal in the selected frequency channel.

9. A method of preserving spatial cues in an audio sound signal to be converted into acoustic sound, comprising the
steps of
converting acoustic sound into a first audio sound signal,

mounting at least one microphone at an ear of a user for conversion of acoustic sound into a second audio sound signal in a position at the ear of the user in which spatial cues of the acoustic sound is preserved in the second audio sound signal,

converting acoustic sound into the second audio sound signal utilizing the at least one microphone,

determining first signal magnitudes of the first audio sound signal at a plurality of frequencies,

determining second signal magnitudes of the second audio sound signal at the plurality of frequencies,

determining gain values at respective frequencies of the plurality of frequencies based on the determined first signal magnitudes and second signal magnitudes,

multiplying the first audio sound signal with the determined gain values at the respective frequencies,

characterized by the steps of

forming a weighted sum of the multiplied first audio sound signal and the second audio sound signal, and

performing hearing loss compensation based on the weighted sum.

10. A method according to claim 9, comprising the steps of

mounting a BTE hearing aid housing accommodating at least one BTE sound input transducer in its operational position behind the pinna of the user,

converting acoustic sound into the first audio sound signal utilizing the at least one BTE sound input transducer.

Patentansprüche

1. BTE-Hörhilfe umfassend

ein BTE-Hörhilfengehäuse, das hinter der Ohrmuschel eines Benutzers zu tragen ist und mindestens einen BTE-Schalleingabewandler aufnimmt, der zur Wandlung von akustischem Schall in ein BTE-Audio-Schallsignal ausgebildet ist,

ein ITE-Mikrofongehäuse, das ausgebildet ist, um in dem äußeren Ohr des Benutzers positioniert zu werden, und mindestens ein ITE-Mikrofon, das zur Wandlung von akustischem Schall in ein ITE-Audio-Schallsignal ausgebildet ist, aufnimmt,

einen Signaldetektor, der ausgebildet ist, um

ITE-Signalstärken des ITE-Audio-Schallsignals mit mehreren Frequenzen zu bestimmen, und

BTE-Signalstärken des BTE-Audio-Schallsignals mit den mehreren Frequenzen zu bestimmen,

einen Verstärkungsprozessor zum Bestimmen von Verstärkungswerten bei jeweiligen Frequenzen der mehreren Frequenzen basierend auf den bestimmten ITE-Signalstärken und BTE-Signalstärken,

einen Multiplizierer, der ausgebildet ist, um das BTE-Audio-Schallsignal mit den Verstärkungswerten bei den jeweiligen Frequenzen zu multiplizieren, **gekennzeichnet durch**

einen Signalkombinierer, der ausgebildet ist, um eine gewichtete Summe des ITE-Audio-Schallsignals und des bezüglich der Verstärkung veränderten BTE-Audio-Schallsignals zu einem Prozessor auszugeben, der ausgebildet ist, um ein bezüglich des Hörverlusts kompensiertes Ausgangssignal zu erzeugen basierend auf der gewichteten Summe.

2. Hörhilfe nach Anspruch 1, umfassend

einen anpassungsfähigen Rückkopplungsunterdrücker zur Rückkopplungsunterdrückung, und der einen Eingang, der zum Empfang eines bezüglich des Hörverlusts kompensierten Ausgangssignals verbunden ist, mindestens einen Ausgang, von welchen jeder die Rückkopplungsstrecke von einem Ausgang der Hörhilfe zu einem des mindestens einen ITE-Mikrofons und mindestens einen BTE-Schalleingangswandlers modelliert und mit mindestens einem Subtrahierer zur Subtraktion der mindestens einen Ausgabe des anpassungsfähigen Rückkopplungsunterdrückers von der Ausgabe des einen des mindestens einen ITE-Mikrofons und des mindestens einen BTE-Schallwandlers und Ausgabe des jeweiligen Differenzsignals als jeweiliges des ITE-Audio-Schallsignals und BTE-Audio-Schallsignals verbunden ist, aufweist.

3. Hörhilfe nach Anspruch 2 umfassend

einen Rückkopplungsmonitor, der mit dem anpassungsfähigen Rückkopplungsunterdrücker verbunden ist und ausgebildet ist, um den Zustand der Rückkopplung zu überwachen, und der einen Ausgang aufweist, der eine Angabe bezüglich des Zustands der Rückkopplung bereitstellt, und wobei der Verstärkungsprozessor ferner einen Eingang aufweist, der mit dem Rückkopplungsmonitor verbunden ist, und wobei der Verstärkungsprozessor ausgebildet ist, um den Verstärkungswert an jeder der mehreren Frequenzen basierend auf den bestimmten ITE-Signalstärken und BTE-Signalstärken und einem Zustand der Rückkopplung zu bestimmen.

4. Hörhilfe nach Anspruch 3, wobei der Signalkombinierer ferner einen Eingang aufweist, der mit dem Rückkopplungsmonitor verbunden ist, und wobei der Signalkombinierer ausgebildet ist, um das ITE-Audio-Schallsignal mit dem BTE-Audio-Schallsignal in Reaktion auf den Zustand der Rückkopplung zu kombinieren.

5. Hörhilfe nach einem der vorherigen Ansprüche, wobei der Verstärkungsprozessor ausgebildet ist, um den Verstärkungswert derart zu beschränken, dass die resultierende Verstärkung der Hörhilfe unter der maximalen stabilen Verstärkung bei den mehreren Frequenzen gehalten wird.

6. Hörhilfe nach einem der vorherigen Ansprüche, wobei die ITE- und BTE-Audio-Schallsignale in mehrere Frequenzkanäle unterteilt sind, und wobei der Signaldetektor ausgebildet ist, um die Audio-Schallsignale individuell in ausgewählten Frequenzkanälen zu verarbeiten, von welchen jeder eine jeweilige der mehreren Frequenzen umfasst.

7. Hörhilfe nach Anspruch 6, wobei der Signalkombinierer ausgebildet ist, um individuelle gewichtete Summen des ITE-Audio-Schallsignals und des bezüglich der Stärke veränderten BTE-Audio-Schallsignals in mindestens einigen der Frequenzkanäle zu bilden.

8. Hörhilfe nach Anspruch 6 oder 7, wobei der mindestens eine BTE-Schalleingangswandler in einem ausgewählten Frequenzkanal der mehreren Frequenzkanäle derart getrennt ist, dass die Hörverlustkompensierung alleine auf dem ITE-Audio-Schallsignal in dem ausgewählten Frequenzkanal basiert.

9. Verfahren zum Aufrechterhalten räumlicher Hinweise in einem Audio-Schallsignal, das in akustischen Schall zu wandeln ist, umfassend folgende Schritte:

Wandeln von akustischem Schall in ein erstes Audio-Schallsignal,
Anbringen mindestens eines Mikrofons an einem Ohr eines Benutzers zur Wandlung von akustischem Schall in ein zweites Audio-Schallsignal in einer Position an dem Ohr des Benutzers, in welcher räumliche Hinweise des akustischen Schalls in dem zweiten Audio-Schallsignal aufrechterhalten werden,
Wandeln von akustischem Schall in das zweite Audio-Schallsignal unter Verwendung des mindestens einen Mikrofons,
Bestimmen erster Signalstärken des ersten Audio-Schallsignals bei mehreren Frequenzen,
Bestimmen zweiter Signalstärken des zweiten Audio-Schallsignals bei den mehreren Frequenzen,
Bestimmen von Verstärkungswerten bei jeweiligen Frequenzen der mehreren Frequenzen basierend auf den bestimmten ersten Signalstärken und zweiten Signalstärken,
Multiplizieren des ersten Audio-Schallsignals mit den bestimmten Verstärkungswerten bei den jeweiligen Frequenzen,
gekennzeichnet durch folgende Schritte:

Bilden einer gewichteten Summe des multiplizierten ersten Audio-Schallsignals und des zweiten Audio-Schallsignals, und
Durchführen einer Hörverlustkompensierung basierend auf der gewichteten Summe.

10. Verfahren nach Anspruch 9, umfassend folgende Schritte:

Anbringen eines BTE-Hörhilfengehäuses, das mindestens einen BTE-Schalleingangswandler aufnimmt, in seiner Betriebsposition hinter der Ohrmuschel des Benutzers,
Wandeln von akustischem Schall in das erste Audio-Schallsignal unter Verwendung des mindestens einen BTE-Schalleingangswandlers.

Revendications

1. Prothèse auditive à contour d'oreille (BTE) comprenant un boîtier pour prothèse auditive BTE à porter derrière le pavillon d'un utilisateur et contenant
au moins un transducteur d'entrée sonore BTE configuré pour la conversion d'un son acoustique en un signal sonore audio BTE,
un boîtier de microphone intraauriculaire (ITE) configuré pour être positionné dans l'oreille externe de l'utilisateur et contenant
au moins un microphone ITE configuré pour la convertir un son acoustique en un signal sonore audio ITE,

un détecteur de signal configuré pour
la détermination d'amplitudes de signal ITE du signal sonore audio ITE à une pluralité de fréquences, et
la détermination d'amplitudes de signal BTE du signal sonore audio BTE à la pluralité de fréquences,
un processeur de gain pour la détermination de valeurs de gain à des fréquences respectives de la pluralité de
5 fréquences sur la base des amplitudes de signal ITE déterminées et des amplitudes de signal BTE,
un multiplicateur configuré pour la multiplication du signal sonore audio BTE avec les valeurs de gain aux fréquences
respectives,

caractérisé par

un combineur de signal configuré pour émettre une somme pondérée du signal sonore audio ITE et du signal
10 sonore audio BTE modifié en gain à un processeur configuré pour générer un signal de sortie compensé en perte
d'audition sur la base de la somme pondérée.

2. Prothèse auditive selon la revendication 1, comprenant
un supprimeur de retour adaptatif pour la suppression du retour et ayant une entrée connectée pour la réception
15 d'un signal de sortie compensé en perte d'audition,
au moins une sortie, dont chacune modélise le chemin de retour d'une sortie de la prothèse auditive à un des au
moins un microphones ITE et au moins un transducteur d'entrée de son BTE et connectée à
au moins un soustracteur pour soustraction de l'au moins une sortie du supprimeur de retour adaptatif de la sortie
de l'un des au moins un microphones ITE et de l'au moins un transducteur de son BTE et l'émission du signal de
20 différence respectif comme le signal respectif du signal sonore audio ITE et du signal sonore audio BTE.
3. Prothèse auditive selon la revendication 2, comprenant
un contrôleur de retour connecté au supprimeur de retour adaptatif et configuré pour contrôler l'état du retour et
ayant une sortie fournissant une indication de l'état de retour, et dans laquelle
25 le processeur de gain a en outre une entrée qui est connectée au contrôleur de retour, et dans laquelle le processeur
de gain est configuré pour la détermination de la valeur de gain à chacune de la pluralité de fréquences sur la base
des amplitudes de signal ITE et des amplitudes de signal BTE déterminées et d'un état de retour.
4. Prothèse auditive selon la revendication 3, dans laquelle le combineur de signal a en outre une entrée qui est
30 connectée au contrôleur de retour, et dans laquelle le combineur de signal est configuré pour la combinaison du
signal sonore audio ITE et du signal sonore audio BTE en réponse à l'état de retour.
5. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle le processeur de gain est
configuré pour la limitation de la valeur de gain de sorte que le gain résultant de la prothèse auditive soit maintenu
35 en dessous du gain maximum stable à la pluralité de fréquences.
6. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle les signaux sonores audio
ITE et BTE sont divisés en une pluralité de canaux de fréquence, et dans laquelle le détecteur de signal est configuré
pour traiter individuellement les signaux sonores audio dans des canaux de fréquence sélectionnés dont chacun
40 comprend une respective parmi la pluralité de fréquences.
7. Prothèse auditive selon la revendication 6, dans laquelle le combineur de signal est configuré pour former des
sommes pondérées individuelles du signal sonore audio ITE et du signal sonore audio BTE modifié en gain dans
au moins certains des canaux de fréquence.
45
8. Prothèse auditive selon la revendication 6 ou 7, dans laquelle l'au moins un transducteur d'entrée sonore BTE est
déconnecté dans un canal de fréquence sélectionné de la pluralité de canaux de fréquence de sorte que la com-
pensation de perte d'audition soit basée uniquement sur le signal sonore audio ITE dans le canal de fréquence
sélectionné.
50
9. Procédé de préservation de repères spatiaux dans un signal sonore audio à convertir en son acoustique, comprenant
les étapes consistant à convertir le son acoustique en un premier signal sonore audio,
monter au moins un microphone sur une oreille d'un utilisateur pour la conversion d'un son acoustique en un second
signal sonore audio dans une position sur l'oreille de l'utilisateur dans laquelle des repères spatiaux du son acoustique
55 sont préservés dans le second signal sonore audio,
convertir le son acoustique en le second signal sonore audio en utilisant l'au moins un microphone,
déterminer des premières amplitudes de signal du premier signal sonore audio à une pluralité de fréquences,
déterminer des secondes amplitudes de signal du second signal sonore audio à la pluralité de fréquences,

déterminer des valeurs de gain à des fréquences respectives de la pluralité de fréquences sur la base des premières amplitudes de signal et des secondes amplitudes de signal déterminées,
multiplier le premier signal sonore audio par les valeurs de gain déterminées aux fréquences respectives,
caractérisé par les étapes consistant à
former une somme pondérée du premier signal sonore audio et du second signal sonore audio multipliés et
réaliser une compensation de perte d'audition sur la base de la somme pondérée.

10. Procédé selon la revendication 9, comprenant les étapes consistant à
monter un boîtier de prothèse auditive BTE recevant au moins un transducteur d'entrée sonore BTE dans sa position
opérationnelle derrière le pavillon de l'utilisateur,
convertir un son acoustique en le premier signal sonore audio en utilisant l'au moins un transducteur d'entrée sonore BTE.

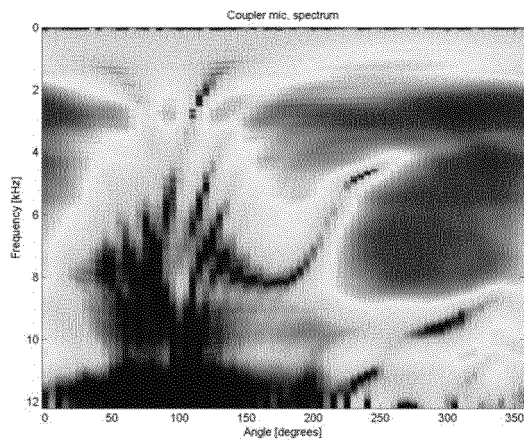


Fig. 1

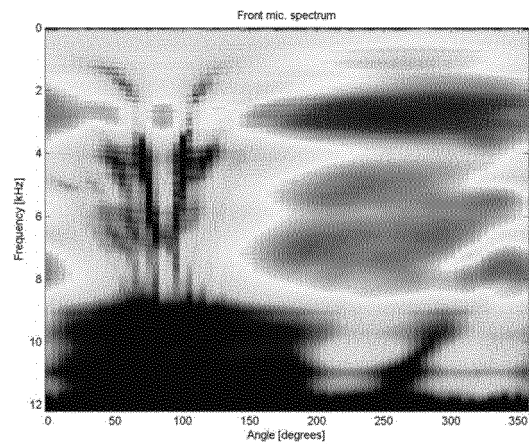


Fig. 2

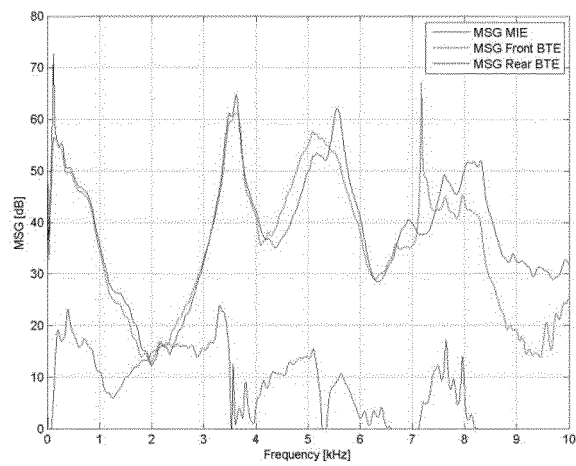


Fig. 3

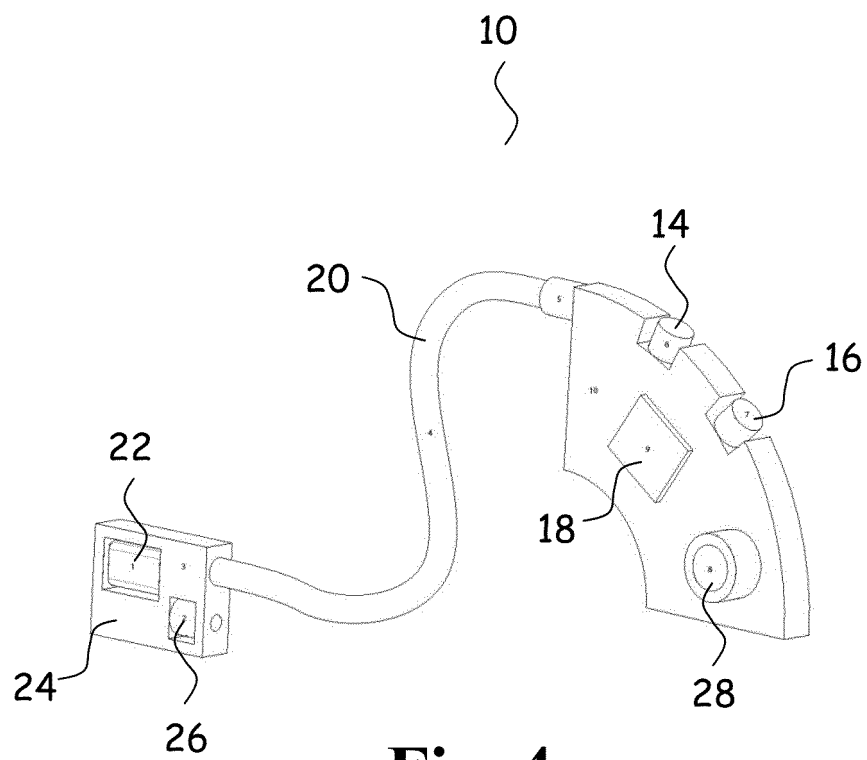


Fig. 4

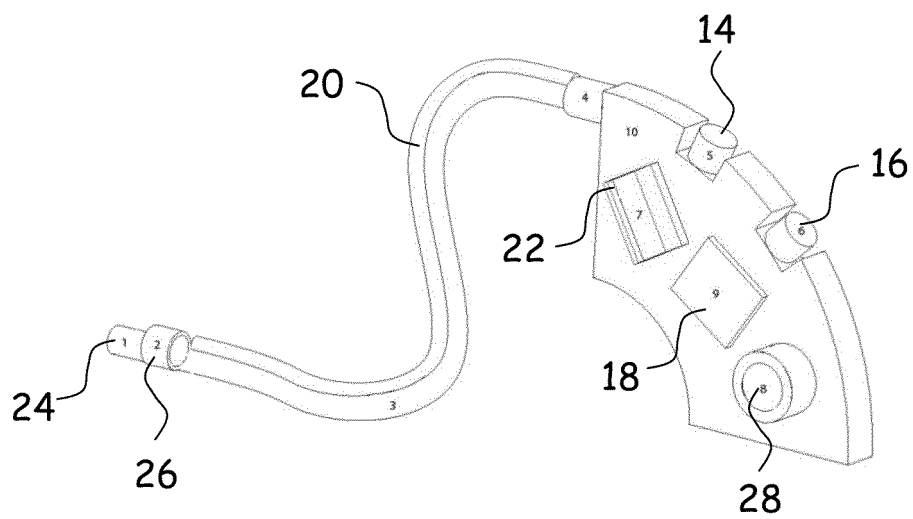


Fig. 5

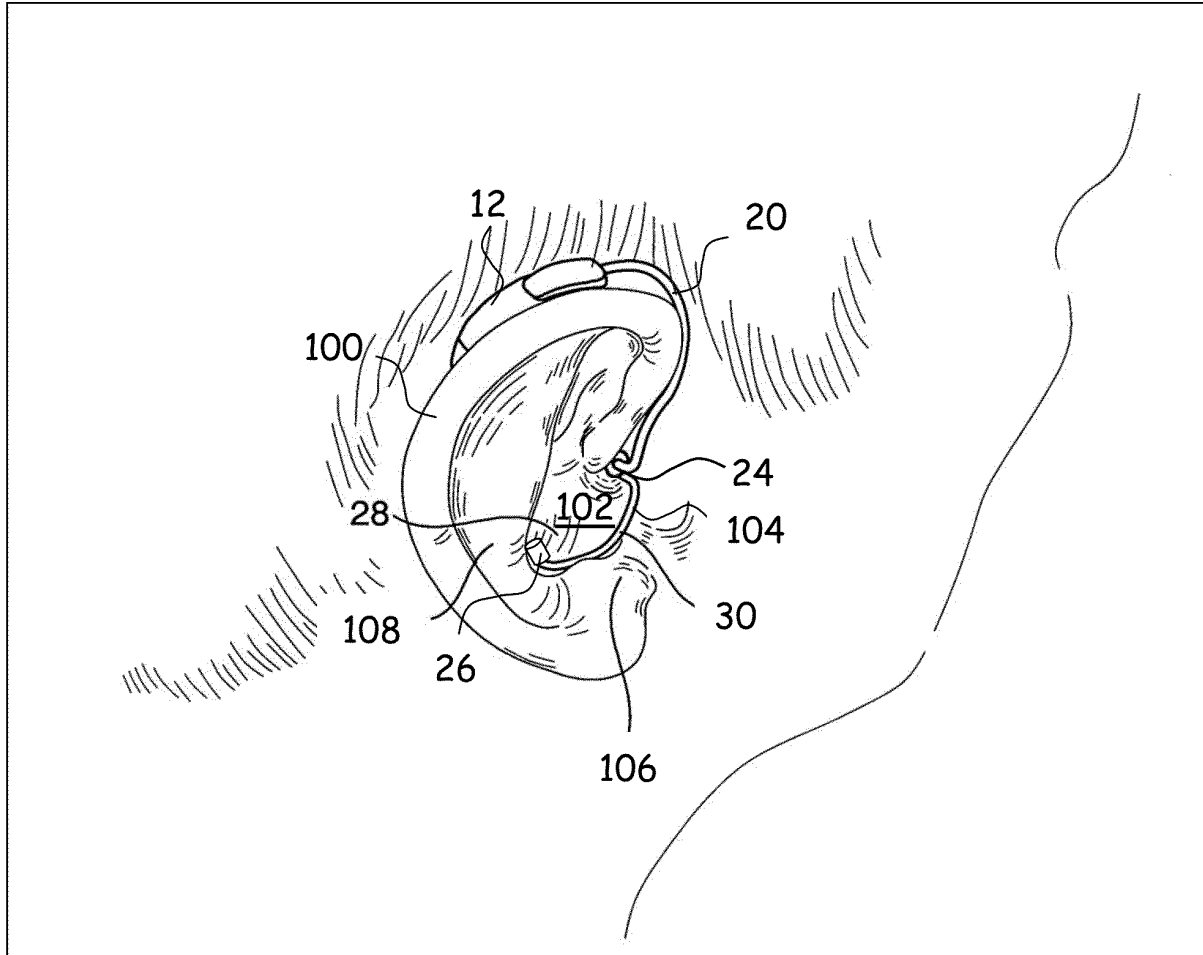


Fig. 6

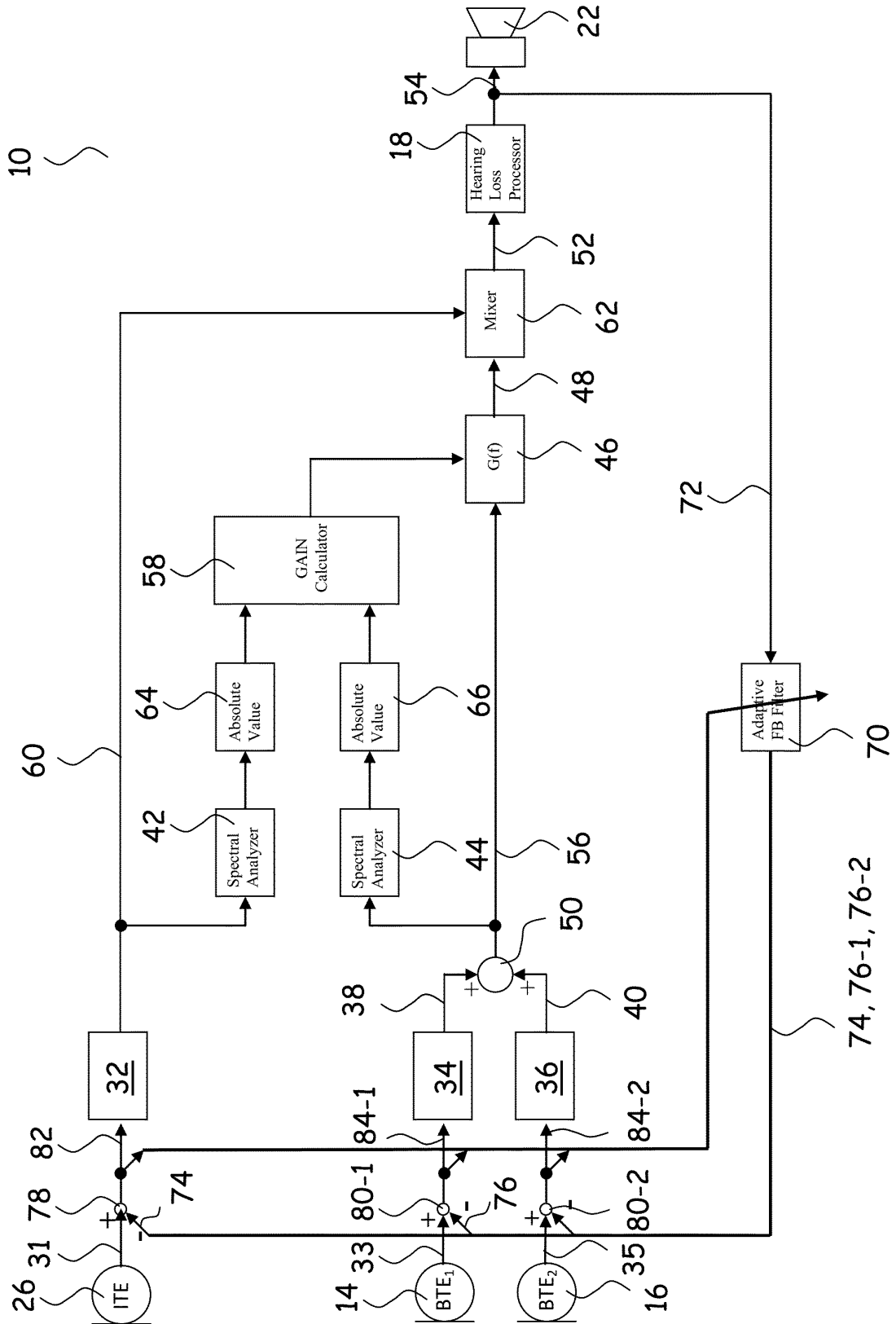


Fig. 7

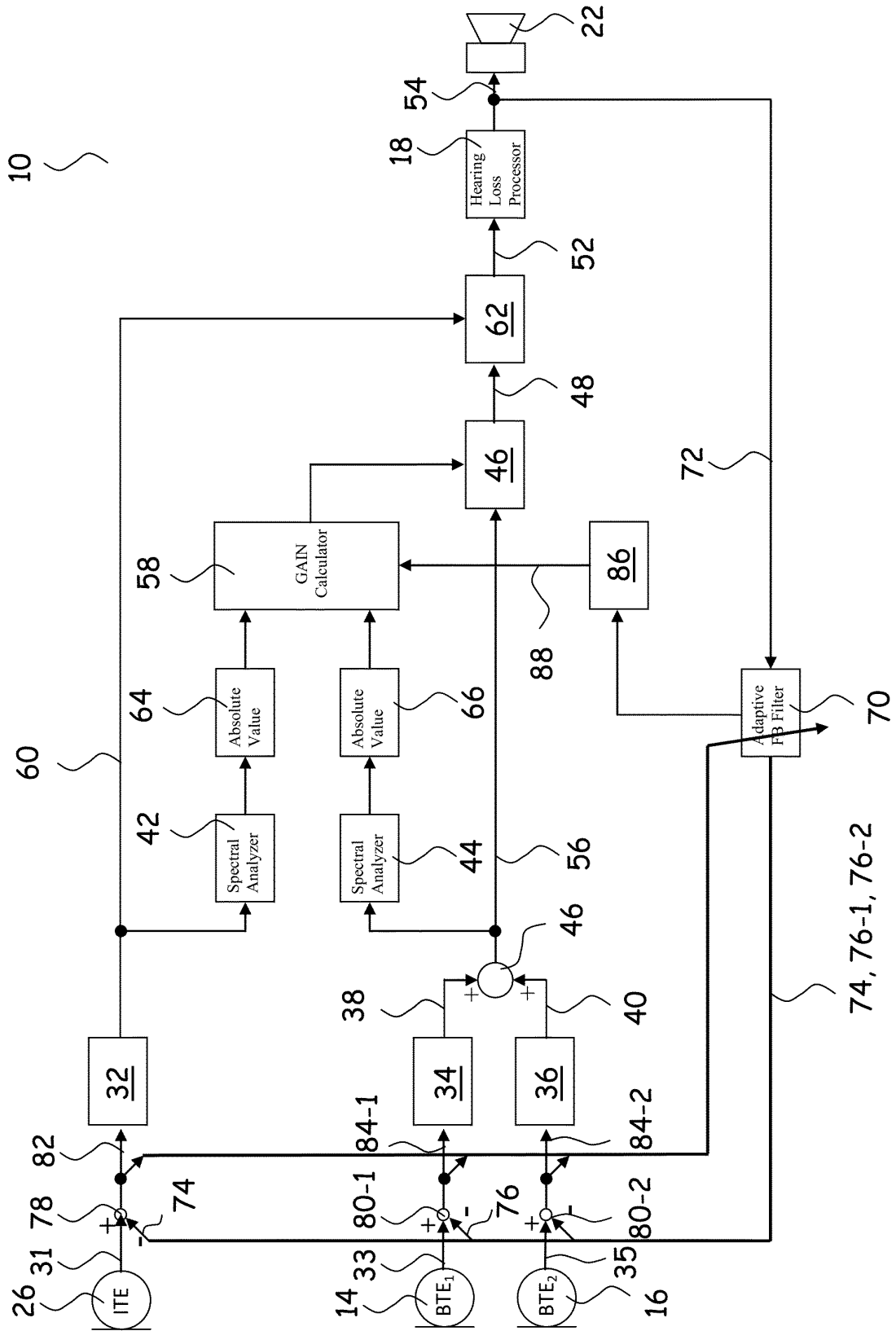


Fig. 8

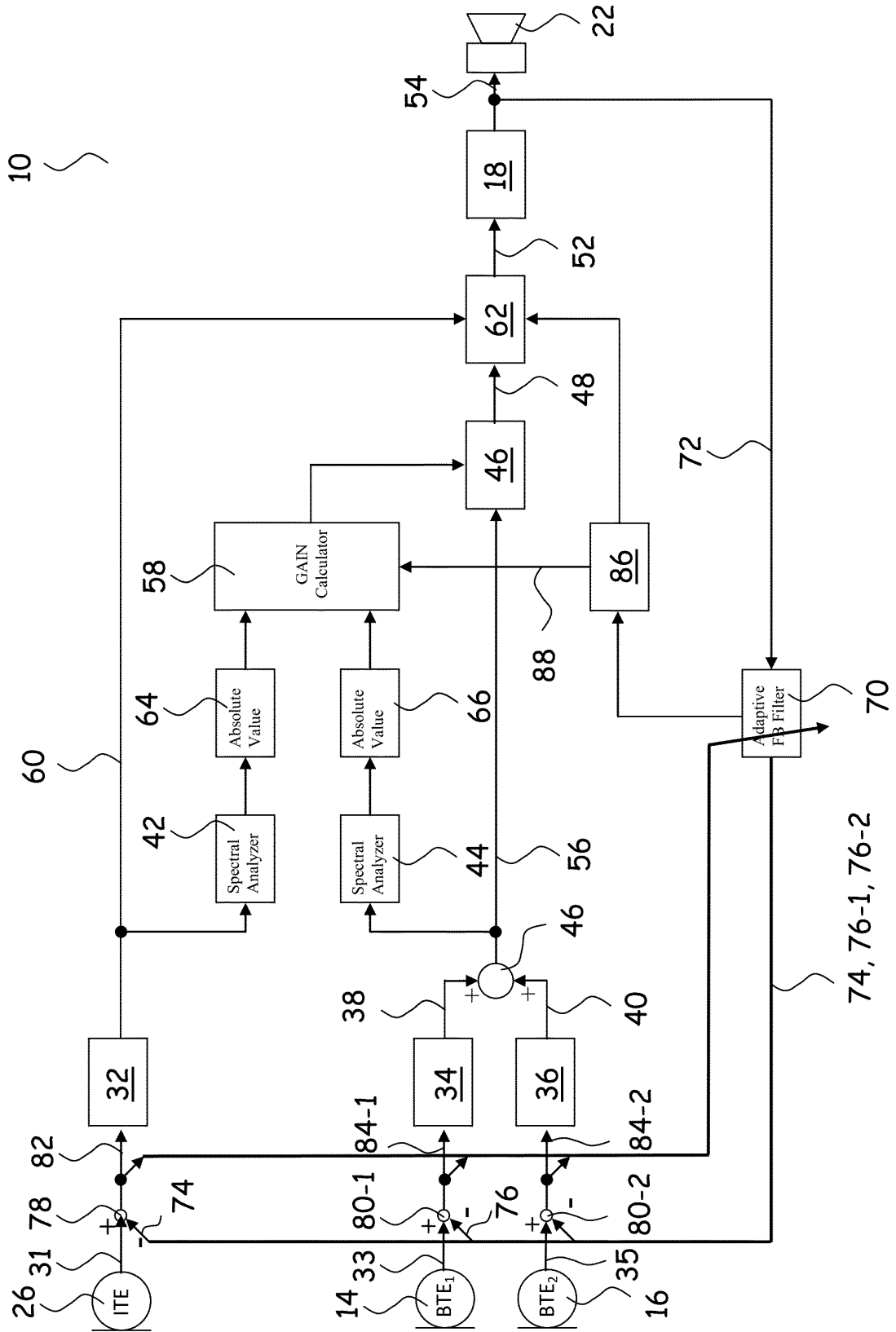


Fig. 9

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 2010092016 A1 [0016]
- US 2004136541 A1 [0017]