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(72) Inventors:
• **Jelveh, Hossein**
3480 Fredensborg (DK)
• **Rossing Kraft, Christian**
4000 Roskilde (DK)
• **Petersen, Bo**
2870 Dyssegård (DK)

(71) Applicant: **Audientes A/S**
2830 Virum (DK)

(74) Representative: **Weinrich, Søren Gert**
SGW Patent IVS
Hybenhaven 7
3060 Esbjerg (DK)

(54) **ADAPTATION METHODS FOR HEARING AID AND HEARING AID INCORPORATING SUCH ADAPTATION METHODS**

(57) The present invention relates to a method for user-administered adaptation/acclimatization to the use of a hearing aid, which hearing aid is provided with a user-operable volume control and means for setting an adaptation mode of the hearing aid comprising at least a non-adapted mode and a fully adapted mode, according to which method, when choosing the non-adapted mode, the insertion gain of the hearing aid depends on the frequency (f_A) and on the setting (Vol) of the user-op-

erable volume control in such a manner that a given change (ΔVol) of the setting of the volume control results in a change of insertion gain ($\Delta \text{INSG}(f_A, \text{HL})$) at one or more of said given frequencies (f_A) that is a function ($F(f_A, \text{HL})$) of the hearing loss at each respective of said frequencies (f_A) when said hearing loss is at or above a given level (dBHL) at that specific frequency (f_A). The invention further relates to a hearing aid configured to implement the method of the invention.

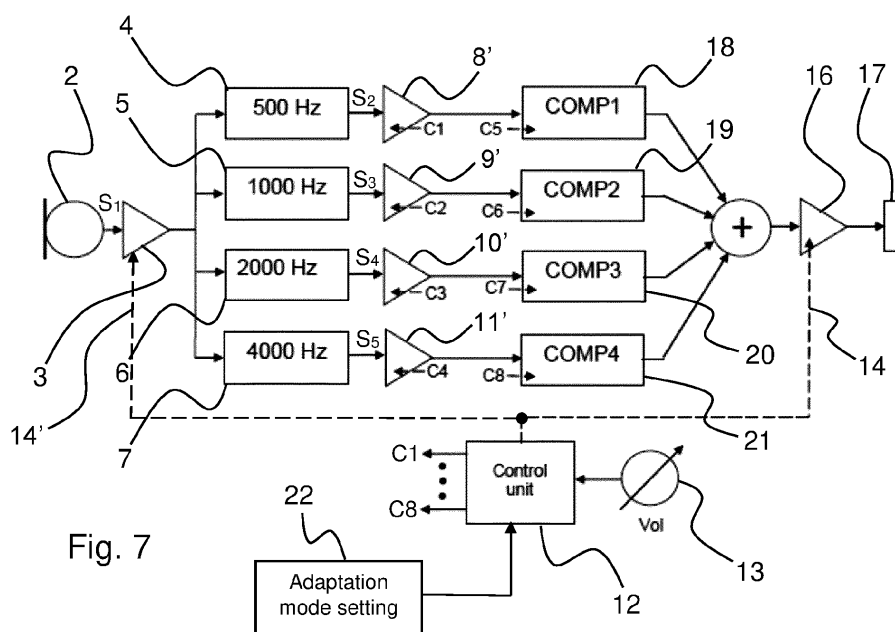


Fig. 7

Description

TECHNICAL FIELD

[0001] The present invention relates to the field of hearing aids, more specifically to self-fitting hearing aids, i.e. hearing aids that are configured such that a hearing-impaired user can adjust the hearing aid himself/herself without the aid of a trained audiologist and/or external equipment and nevertheless obtain a hearing aid adjustment that is close to optimal. Still more specifically, the invention relates to adaptation/acclimatization methods for such hearing aids and hearing aids that are configured to apply such methods.

BACKGROUND OF THE INVENTION

[0002] Adaptation/acclimatization of hearing aids is essential since most users, when getting their first hearing aid, already have a certain hearing loss, and hence getting full hearing restored typically leads to frustration, stress and potentially to rejecting the use of the hearing aid.

[0003] Several hearing aids today already have so-called adaption managers, where a hearing specialist can manually change the gain and compression for the user, but this requires the user to come to the clinic multiple times.

[0004] Other hearing aid manufacturers have built-in software that automatically over a pre-defined period of time will increase the gain from a level below the optimal gain for that hearing loss to a final, optimal gain and change the compression with certain time intervals. This latter solution may work quite well if the hearing professional has a good feeling of how fast the specific user can/will adapt to the hearing aid, but for some users it may go too slow and for others too fast.

[0005] The inherent challenge in many modern hearing aids is that they, due to their small size, do not have sufficient space for volume keys, and hence the user has no method to manually adapt the hearing aid to his needs at different levels of the adaptation, nor adapt to different situations (except for maybe built-in listening programs which purpose are often different than for adaptation purposes).

[0006] Even existing devices with volume keys do not necessarily satisfy the adaptation needs of the user, since volume keys in all known cases work in a "linear" way, reducing or amplifying all frequencies equally when turning down or up the volume.

DEFINITIONS

[0007] Throughout this specification, the following definitions apply:

REIG (Real-Ear Insertion Gain) expresses the actual gain provided by a hearing aid that is placed in the

ear canal of a user relative to the gain of the open ear. The real-ear insertion gain is the difference in dB between the sound pressure level at a given position in the ear canal generated by a hearing aid placed on the ear of the user (the so-called "aided ear response") and the sound pressure level generated at the same position in the ear canal when no hearing aid is placed on the ear (the so-called "open ear response") when the user is situated in a given surrounding sound field. The term "real-ear" indicates that the insertion gain is actually measured in the user's ear.

A-REIG: Adapted user REIG. This describes the real ear insertion gain that the user prefers after he/she is fully adapted/acclimatized to the use of a particular hearing aid.

N-REIG: Novice user REIG. This is the gain that a typical / average first-time user would prefer right after fitting the hearing aid for the first time. This can according to some studies be on the order of 15 dB lower than A-REIG for the frequency where the user has the biggest hearing loss.

DISCLOSURE OF THE INVENTION

[0008] Based on the above background, the present invention provides according to a first aspect a method for user-administered adaptation/acclimatization to the use of a hearing aid, which hearing aid is provided with a user-operable volume control and means for setting an adaptation mode of the hearing aid comprising at least a non-adapted mode and a fully adapted mode, according to which method, when choosing the non-adapted mode, the insertion gain of the hearing aid depends on the frequency (f_A) and on the setting (Vol) of the user-operable volume control in such a manner that a given change (ΔVol) of the setting of the volume control results in a change of insertion gain ($\Delta\text{INSG}(f_A, \text{HL})$) at one or more of said given frequencies (f_A) that is a function ($F(f_A, \text{HL})$) of the hearing loss at each respective of said frequencies (f_A) when said hearing loss is at or above a given level (dBHL) at that specific frequency (f_A).

[0009] In an embodiment of the first aspect, the function ($F(f_A, \text{HL})$) is increasing with increasing hearing loss (HL).

[0010] In an embodiment to the first aspect, the method comprises the steps of:

- a) based on the user's hearing loss, at a plurality of given frequencies (f_A) determining a prescribed insertion gain $G_p(f_A)$ at each of said frequencies (f_A);
- b) providing the user with the hearing aid adjusted to $G_p(f_A)$;
- c) setting the hearing aid in the non-adapted mode;
- d) instructing the user to adjust the volume control of the hearing aid such that the the sound provided

by the hearing aid is experienced as pleasant in the user's everyday surroundings;

e) instructing the user, after a period of time, to re-adjust the volume control, if the user finds that the sound produced by the hearing aid could be improved;

f) repeating steps (e) and (f) during an adaptation period to allow the user to determine the finally chosen adjustment of the volume control;

g) when the user has reached a setting of the volume control that the user finds provides the best possible sound reproduction of the hearing aid in the user's everyday acoustic environments, setting the mode of the hearing aid to the fully adapted mode.

[0011] In an embodiment of the first aspect, the change of insertion gain is obtained by in each of a predetermined number of frequency bands $B(f_A)$, each comprising one of said frequencies f_A , changing the gain of the hearing aid of that particular frequency band.

[0012] In an embodiment of the first aspect, the change of insertion gain is obtained by providing a controllable compression means in each of the frequency bands, where the compression characteristics of each individual of the controllable compression means depend on the setting of the volume control.

[0013] In an embodiment of the first aspect, the compression threshold of each of the individual compression means is a function of the volume control setting.

[0014] In an embodiment of the first aspect, the input/output characteristic of each of the individual controllable compression means comprises more than one threshold, whereby different degrees of compression, i.e. different compression ratios, can be applied in different input ranges.

[0015] In an embodiment of the first aspect, the one or more thresholds of the individual controllable compression means is controlled by the volume control setting,

[0016] In an embodiment of the first aspect, the compression ratio of each of said individual compression means is a function of the volume control setting.

[0017] In an embodiment of the first aspect, the change of insertion gain at each of said frequencies f_A is obtained by in each of said predetermined number of frequency bands $B(f_A)$ changing the gain of the hearing aid of that particular frequency band and by changing the compression characteristics in each of these frequency bands.

[0018] According to a second aspect of the present invention there is provided a method of switching between adaptation modes of a hearing aid based on the user's usage pattern of the hearing aid based on a determination of whether the user has been partly or totally adapted to the use of the hearing aid, where the method comprises:

- If the user has used the hearing aid in on-position for more than a first predetermined period of time, the status of the hearing aid is regarded as partly

adapted;

- or
- If the user chose to turn the volume to "A-REIG" setting within a second predetermined period, the status of the hearing aid is regarded as fully adapted, and the hearing aid is changed to "fully adapted mode", where volume controls work in a linear way, i.e. a given change of volume control setting results in the same change of insertion gain at all frequencies/in all frequency bands.

[0019] According to a third aspect of the present invention there is provided hearing aid provided with means for user-administered adaptation/acclimatization to the use of the hearing aid, which hearing aid is provided with:

- a) a user-operable volume control,
- b) an input transducer configured to convert an acoustic input signal to an electric output signal which output signal is provided, with or without amplification, to a filter bank providing respective second output signals to respective insertion gain determining units, each of which provides a third output signal;
- c) a combining unit (such as an adder) configured to receive the third output signals and to provide a fourth output signal that is a combination of the third output signals;
- d) output amplifier means configured to receive the fourth output signal and to provide a fifth output signal to an output transducer configured to convert the fifth output signal to an acoustic signal that can be provided to the outer ear of the user;
- e) a control unit configured to provide control signals to each respective of said controllable insertion gain determining units based on the setting of the user-operable volume control;
- f) an adaptation mode setting unit that provides the control unit with information on the chosen adaptation mode of the hearing aid.

[0020] In an embodiment of the third aspect, the control unit provides, when the adaptation mode setting unit is set to adaptation, each respective of the controllable insertion gain determining units with a respective control signal such that a given change of the volume control setting (ΔVol) results in a corresponding change of insertion gain ($\Delta INSG$) of each of the controllable insertion gain units that is greater, the higher the user's hearing loss in the respective frequency band is, when the hearing loss is above a predefined frequency dependent threshold, and constant when the hearing loss is below this threshold.

[0021] In an embodiment of the third aspect, the controllable insertion gain determining units are controllable gain units.

[0022] In an embodiment of the third aspect, the controllable insertion gain determining units are controllable

compression units.

[0023] In an embodiment of the third aspect, the compression threshold of each respective compression unit depends on the setting of the volume control.

[0024] In an embodiment of the third aspect, the compression ratio of each respective compression unit depends on the setting of the volume control.

[0025] In an embodiment of the third aspect, the input/output characteristic of each of the individual controllable compression means comprises more than one threshold, whereby different degrees of compression, i.e. different compression ratios, can be applied in different input ranges.

[0026] In an embodiment of the first aspect, the one or more thresholds of the individual controllable compression means is controlled by the volume control setting.

[0027] In an embodiment of the third aspect, the controllable insertion gain determining units are a combination of controllable gain units and controllable compression units configured such that for any given of said frequency bands either solely a controllable insertion gain unit is used or solely a controllable compression unit is used, or a combination of a controllable insertion gain unit and a controllable compression unit is used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Further benefits and advantages of the present invention will become apparent after reading the detailed description of non-limiting exemplary embodiments of the invention in conjunction with the accompanying drawings, wherein

figure 1 shows a plot of insertion gain (dB) as a function of frequency for a number of different settings of the volume control relating to an embodiment of the invention;

figure 2 shows a table illustrating the effect of changes of the volume control setting on insertion gain (dB) at different frequencies relating to another embodiment of the invention;

figure 3 shows a surface plot of insertion gain (dB) as a function of frequency and volume control setting relating to still another embodiment of the invention;

figure 4 shows tables of input-output characteristics for three different settings of the volume control relating to an embodiment of the invention that applies frequency and volume control setting dependent compression;

figure 5 shows the effect of the setting of the volume control on insertion gain of an embodiment of a hearing aid according to the invention;

figure 6 shows a schematic block diagram of an em-

bodiment of a hearing aid applying non-linear gain as a function of volume control setting according to the principles of the invention; and

figure 7 shows a schematic block diagram of an embodiment of a hearing aid applying frequency and volume control setting dependent compression according to the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0029] The principles of the invention will be illustrated by various embodiments hereof. It is however understood that a person skilled in the art may conceive other embodiments than those shown and described in the detailed description of the invention and that the scope of the invention is defined by the independent claims.

[0030] With reference to figure 1 there is shown a plot of insertion gain at four frequencies: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. In the plot, the solid line shows A-REIG relating to a rather severely hearing-impaired user who has the highest hearing loss at 4kHz.

[0031] As shown in figure 1, the volume control (which in the present embodiment may comprise a number of discrete steps) is functioning a non-linear manner between the A-REIG and the N-REIG thereby reducing/amplifying the sounds more per step at the frequencies where the user has a higher hearing loss, while working in a linear manner above and below A-REIG and N-REIG. The functioning of the volume control above A-REIG and below N-REIG is suggested in one embodiment of the invention to be linear, but since N-REIG (and even A-REIG) are based on a chosen prescription method (such as the half-gain rule or a NAL fitting rule) they may not necessarily apply to all users, and the volume control may alternatively vary the insertion gain in a non-linear/percentagewise manner as a function of the user's hearing loss also above A-REIG and below N-REIG.

[0032] Referring to the table shown in figure 2 there is shown an alternative effect on insertion gain to the one shown in figure 1. It is however understood that all of plots and tables shown in figures 1 through 4 are only non-limited examples of the effect of the present invention and that the principles of the invention could be embodied in many other ways that would all fall within the scope of the protection rendered by the independent claims.

[0033] The percentage change of 5% used in the implementation shown in figure 1 can be changed if necessary according to the specific circumstances such as hearing loss and user preferences. The change should and could depend on the users hearing loss at the "worst" frequency and based on a general rule that a change of less than 2dB is not possible to hear (for any person). Alternatively, the change of insertion gain for each press of the volume key or step of a volume control could be 2dB at the frequency with the largest hearing loss and could for other frequencies be less than 2dB, depending

on the hearing loss at each frequency and percentage wise to the frequency with the worst hearing loss. An example of the effect of volume control changes that is different from that of figure 1 is shown in the table in figure 2.

[0034] With reference to figure 3 there is shown a surface plot of insertion gain (dB) as a function of frequency and volume control setting relating to still another embodiment of the invention. In this example, the maximum insertion gain of 40 dB is obtained at 6 kHz and the insertion gain surface shows an insertion gain that would typically be used to compensate for a typical age-related sensory-neural hearing loss. Contrary to the insertion gain curves shown in figure 1, the non-linear dependency on volume control setting is maintained to the maximum setting (Volume = 10) of the hearing aid, but it is of course also possible to apply a linear dependency on volume control setting above a certain volume control setting, for instance Volume = 8 in the figure.

[0035] The first three figures relate to the first aspect of the invention, in which only a non-linear gain is applied. Embodiments relating to the second aspect of the invention, in which compression is used to reduce loudness to facilitate adaptation/acclimatization to the use of a hearing aid shown in figure 4.

[0036] With reference to figures 4a, 4b and 4c, there are shown tables of input-output characteristics for three different settings of the volume control relating to an embodiment of the invention that applies frequency and volume control setting dependent compression. In the shown example, the volume control can be set between maximum (10 equal to 100%) and minimum (0 equal to 0%). The three volume control settings that are shown in figure 4 correspond to: 8 (80%), 7 (70%) and 6 (60%) and the tables are limited to frequencies of 4000 Hz, 3000 Hz, 2000 Hz and 1000 Hz. Of course, compression could also be applied at other frequencies if desired. The compression effect that is shown in the shaded cells of the tables is in this embodiment obtained by varying the compression threshold and maintaining the compression ratio, but it would also be possible to vary any of the other parameters that characterize audio compression such as compression ratio or attack and release time.

[0037] The effect of the adaptation of a user with a specific hearing loss to the user of a hearing aid according to the present invention, reference is made to figures 4a, 4b and 4c that show a non-limiting example of the use of the adaptation principles according to the present invention.

[0038] As shown in figure 4a, a novel (un-adapted) user of a hearing aid may require a prescribed insertion gain at 4 kHz of 30 dB, at 3 kHz of 25 dB, at 2 kHz of 20 dB and at 1 kHz of 15 dB. This insertion gain as a function of frequency is obtained with the volume control set to position 8 as shown in figure 4a. With this setting of the volume control, no compression is applied. The hearing aid is now set in adaptation mode and the user tries the hearing in his normal acoustic environments during an

adaptation period.

[0039] When using the hearing aid in his/her everyday environment, the user finds the output from the hearing aid at Vol = 8 much too loud and in fact a setting corresponding to Vol = 6 is preferred. With this setting of the volume control, the compressor becomes active about a certain frequency-dependent threshold (for instance at an input level of between 50 and 55 dB SPL at 4 kHz) and thereby limits the loudness of input levels in excess of 50 to 55 dB SPL at 4 kHz.

[0040] After a certain period of time, for instance some weeks, the user finds that he/she would actually prefer a volume control setting at 7, as the loudness at this setting is no longer annoying and the sound quality and speech intelligibility is actually improved by this increased volume control setting.

[0041] Finally, after being fully adapted to using the hearing aid, the user finds that the initial volume control setting of 8 (that corresponded to the prescribed setting) is in fact the best, as the loudness is no longer annoying, and the quality of the sound provided by the hearing aid is better at this setting than at the lower settings of the volume control. The user is now fully adapted to the hearing aid according to this embodiment of the invention, and the hearing aid is set to the fully adapted mode.

[0042] It is understood that a somewhat similar scenario could also have been observed with the other embodiments of the invention, for instance with the non-linear gain embodiments according to the first aspect of the invention.

[0043] With reference to figure 5 there is shown a non-limiting example of the effect of the setting of the volume control on insertion gain of an embodiment of a hearing aid according to the invention. The dependency of insertion gain (dB) on volume control setting is shown at the frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 5000 Hz and 6000 Hz for a change of volume control setting from maximum (10) to minimum (0).

[0044] Referring to the arrows indicated by I, II and III, respectively, it can be seen that for a frequency of 4000 Hz, a change (Δ Vol) of the volume control from 9 to 7.4 results in a change of insertion gain of 7.5 dB. At 2000 Hz, the corresponding change in insertion gain is only 4 dB and at 1000 Hz the change in insertion gain is further reduced to about 3 dB.

[0045] The method according to the invention can be implemented in a hearing aid according to the invention of instance as set out below. It is understood that other implementations of the adaptation method according to the invention can also be contemplated without deviating from the scope of the invention as defined by the claims.

[0046] With reference to figure 6 there is shown a schematic block diagram of an embodiment of a hearing aid applying non-linear gain as a function of frequency and volume control setting according to the principles of the invention.

[0047] The hearing aid that is generally indicated by reference numeral 1 comprises a microphone 2 the out-

put signal S_1 of which is provided to an amplifier 3 that provides an amplified version of the microphone signal S_1 to a filter bank that in the shown - non-limiting - embodiment comprises four bandpass filters 4, 5, 6, 7 having passbands at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. It is understood that fewer or more filter bands could alternatively have been used for instance corresponding to all standard audiometry frequencies and that the bandwidths of the filters can be chosen as desired. The respective bandpass filters provide filtered output signals S_2 , S_3 , S_4 and S_5 respectively.

[0048] The filtered output signals are provided to respective controllable gain units 8, 9, 10, 11, the gains of which can be controlled by control signals C_1 , C_2 , C_3 , C_4 provided by a control unit 12.

[0049] The respective output signals S_6 , S_7 , S_8 , S_9 from the controllable gain units 8, 9, 10, 11 are combined in a combination unit 15 thereby providing a combined output signal S_{10} that is used to drive a hearing aid output transducer 17 (called loudspeaker or telephone). The output amplified 16 may not necessarily be needed if the combined output signal S_{10} is powerful enough to drive the output transducer 17.

[0050] The control signals C_1 , C_2 , C_3 , C_4 are provided by the control unit 12 based on the setting of the adaptation mode setting unit 22 and the setting of the volume control 13. By means of the adaptation setting unit, there can be chosen at least between an adaptation mode in which the adaptation method of the invention is applied by the hearing aid and a fully adapted mode as described in the disclosure of the invention.

[0051] With reference to figure 7 there is shown a schematic block diagram of an embodiment of a hearing aid applying frequency and volume control setting dependent compression according to the principles of the invention. Also, in this embodiment the hearing aid comprises a microphone 2 a microphone amplifier 3 and a filter bank 4, 5, 6, 7 that may be identical to the one used in the embodiment shown in figure 6 or configured otherwise as desired. Furthermore, controllable gain units 8', 9', 10', 11' may be connected to the respective outputs from the filter bank, although these gain units can also form an integral part of each respective controllable compressor units 18, 19, 20, 21. The relevant characteristics, such as compression threshold and/or compression ratio of each separate of the controllable compression units 18, 19, 20, 21 can be controlled by control signals C_5 , C_6 , C_7 and C_8 which are provided by the control unit 12 based on signals from the adaptation mode unit 22 and the setting of the volume control 13.

[0052] In both embodiments shown in figures 6 and 7, line 14 indicates that, when the hearing aid is in the fully adapted mode, the output of the hearing aid can simply be controlled by the user by varying the gain of the output amplifier 16. Furthermore, line 14' indicates that also the input amplifier 3 can optionally be controlled by the control unit 12 for instance based on the setting to the volume control 13.

[0053] Although the embodiments of the hearing aid according to the invention are shown as simple block diagrams that for instance could be implemented as analog circuits, in practical implementations at least a number of these functional blocks may be implemented digitally and executed by appropriate software incorporated in the hearing aid. Thus, the block diagrams shown in figures 6 and 7 primarily serve to illustrate the functional contents of the hearing aid according to the invention.

Claims

1. A method for user-administered adaptation/acclimatization to the use of a hearing aid, which hearing aid is provided with a user-operable volume control and means for setting an adaptation mode of the hearing aid comprising at least a non-adapted mode and a fully adapted mode, according to which method, when choosing the non-adapted mode, the insertion gain of the hearing aid depends on the frequency (f_A) and on the setting (Vol) of the user-operable volume control in such a manner that a given change (Δ Vol) of the setting of the volume control results in a change of insertion gain (Δ INSG(f_A , HL)) at one or more of said given frequencies (f_A) that is a function ($F(f_A$, HL) of the hearing loss at each respective of said frequencies (f_A) when said hearing loss is at or above a given level (dBHL) at that specific frequency (f_A).
2. A method according to claim 1, where said function ($F(f_A$, HL)) is increasing with increasing hearing loss (HL).
3. A method according to claim 1 or 2 comprising the steps of:
 - a) based on the user's hearing loss, at a plurality of given frequencies (f_A) determining a prescribed insertion gain $G_p(f_A)$ at each of said frequencies (f_A);
 - b) providing the user with the hearing aid adjusted to $G_p(f_A)$;
 - c) setting the hearing aid in the non-adapted mode;
 - d) instructing the user to adjust the volume control of the hearing aid such that the sound provided by the hearing aid is experienced as pleasant in the user's everyday surroundings;
 - e) instructing the user, after a period of time, to readjust the volume control, if the user finds that the sound produced by the hearing aid could be improved;
 - f) repeating steps (e) and (f) during an adaptation period to allow the user to determine the finally chosen adjustment of the volume control;
 - g) when the user has reached a setting of the

volumen control that the user finds provides the best possible sound reproduction of the hearing aid in the user's everyday acoustic environments, setting the mode of the hearing aid to the fully adapted mode.

4. A method according to claim 1, 2 or 3, wherein said change of insertion gain is obtained by in each of a predetermined number of frequency bands $B(f_A)$ each comprising one of said frequencies f_A changing the gain of the hearing aid of that particular frequency band. 5
5. A method according to claim 1, where said change of insertion gain is obtained by providing a controllable compression means (18, 19, 20, 21) in each of said frequency bands, where the compression characteristics of each individual of said controllable compression means depend on the setting of the volume control. 10
6. A method according to claim 5, wherein the input/output characteristic of each of said individual controllable compression means comprises more than one threshold, whereby different degrees of compression can be applied in different input ranges. 15
7. A method according to claim 5 or 6, wherein the one or more thresholds of the individual controllable compression means is controlled by the volume control setting, 20
8. A method according to claim 5, 6 or 7, where the compression threshold of each of said individual compression means is a function of the volume control setting. 25
9. A method according to claim 5, 6 or 7, where the compression ratio of each of said individual compression means is a function of the volume control setting. 30
10. A method according to any of the preceding claims 4 to 9, wherein said change of insertion gain at each of said frequencies f_A is obtained by in each of said predetermined number of frequency bands $B(f_A)$ changing the gain of the hearing aid of that particular frequency band and by changing the compression characteristics in each of these frequency bands. 35
11. A method of switching between adaptation modes of a hearing aid based on the user's usage pattern of the hearing aid based on a determination of whether the user has been partly or totally adapted to the use of the hearing aid, where the method comprises: 40
 - If the user has used the hearing aid in on-position for more than a first predetermined period

of time, the status of the hearing aid is regarded as partly adapted;

- or

- If the user chose to turn the volume to "A-REIG" setting within a second predetermined period, the status of the hearing aid is regarded as fully adapted, and the hearing aid is changed to "fully adapted mode", where volume controls work in a linear way, i.e. a given change of volume control setting results in the same change of insertion gain at all frequencies/in all frequency bands.

12. A hearing aid provided with means for user-administered adaptation/acclimatization to the use of the hearing aid, which hearing aid is provided with:
 - a) a user-operable volume control (13),
 - b) an input transducer (2) configured to convert an acoustic input signal to an electric output signal (S_1), which output signal (S_1) is provided, with or without amplification (3), to a filter bank (4, 5, 6, 7) providing respective second output signals (S_2, S_3, S_4, S_5) to respective insertion gain determining units (8, 9, 10, 11), each of which provides a third output signal (S_6, S_7, S_8, S_9);
 - c) a combining unit (15) configured to receive said third output signals (S_6, S_7, S_8, S_9) and to provide a fourth output signal (S_{10}) that is a combination of the third output signals (S_6, S_7, S_8, S_9);
 - d) output amplifier means (16) configured to receive said fourth output signal (S_{10}) and to provide a fifth output signal (S_n) to an output transducer (17) configured to convert the fifth output signal (S_n) to an acoustic signal that can be provided to the outer ear of the user;
 - e) a control unit (12) configured to provide control signals (C_1, C_2, C_3, C_4) to each respective of said controllable insertion gain determining units (8, 9, 10, 11) based on the setting of the user-operable volume control (13);
 - f) an adaptation mode setting unit (22) that provides the control unit (12) with information on the chosen adaptation mode of the hearing aid.

13. A hearing aid according to claim 12, wherein said control unit (12), when the adaptation mode setting unit (22) is set to adaptation, provides each respective of said controllable insertion gain determining units (8, 9, 10, 11) with a respective control signal (C_1, C_2, C_3, C_4) such that a given change of the volume control setting (ΔVol) results in a corresponding change of insertion gain ($\Delta INSG$) of each of the controllable insertion gain units (8, 9, 10, 11) that is greater, the higher the user's hearing loss in the respective frequency band is, when the hearing loss is above a predefined frequency dependent thresh-

old, and constant when the hearing loss is below this threshold.

14. A hearing aid according to claim 12 or 13, wherein said controllable insertion gain determining units are controllable gain units. 5
15. A hearing aid according to claim 12 or 13, wherein said controllable insertion gain determining units are controllable compression units (18, 19, 20, 21). 10
16. A hearing aid according to claim 15, wherein the compression threshold of each respective compression unit depends on the setting of the volume control (12). 15
17. A hearing aid according to claim 15, wherein the compression ratio of each respective compression unit depends on the setting of the volume control (12). 20
18. A hearing aid according to any of the preceding claims 12 to 17, wherein the input/output characteristic of each of said individual controllable compression means (18, 19, 20, 21) comprises more than one threshold, whereby different degrees of compression can be applied in different input ranges. 25
19. A method according to claim 18, wherein the one or more thresholds of the individual controllable compression means is controlled by the volume control setting, 30
20. A hearing aid according to any of the preceding claims 12 to 19, wherein said controllable insertion gain determining units are a combination of controllable gain units and controllable compression units (18, 19, 20, 21) configured such that for any given of said frequency bands either solely a controllable insertion gain unit is used or solely a controllable compression unit is used or a combination of a controllable insertion gain unit and a controllable compression unit is used. 35
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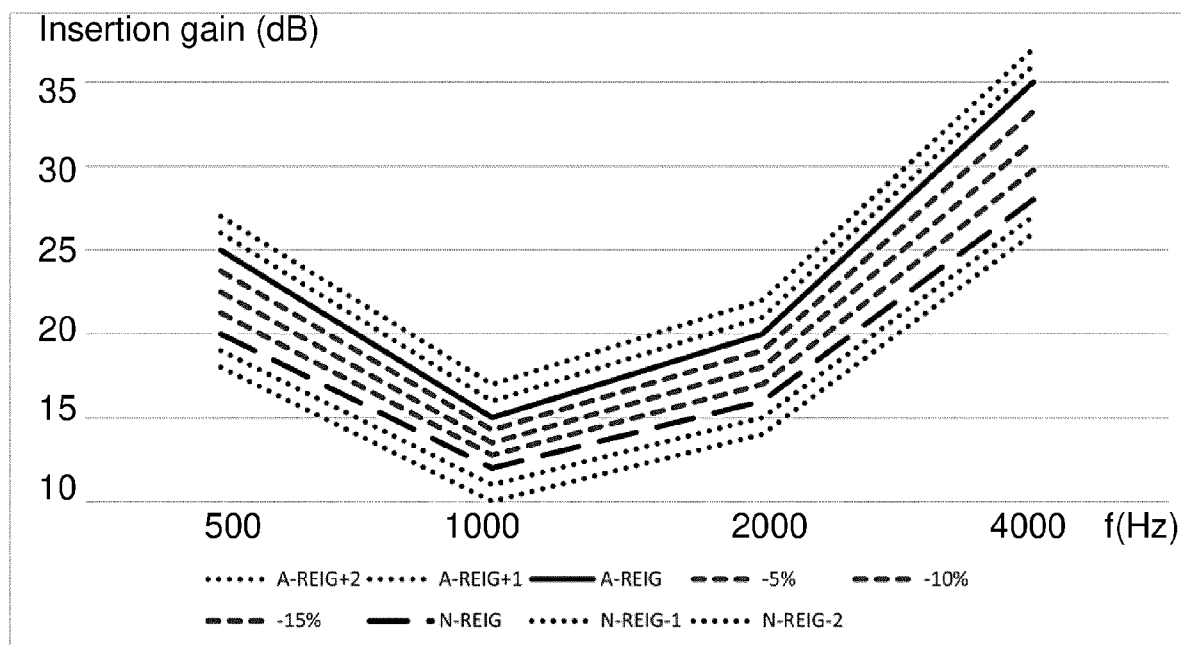


Fig. 1

Description	Impact on the frequency with the highest hearing loss	Impact on other frequencies	Notes
Volume above, if available	Same procedure as below	Same procedure as below	
Volume +2	+4dB to REIG	+4dB to REIG	
Volume +1	+2dB to REIG	+2dB to REIG	
A-REIG Volume 0	A-REIG with no modification	A-REIG with no modification	
Volume -1	-2dB compared to REIG	Less than 2 dB lower, and relative to the hearing loss difference to the frequency with the highest loss.	Example: Highest hearing loss frequency is at 8kHz, 60 dB loss. User has a 40 dB loss at 4kHz, so the volume level at 4k is lowered by $40/60 \times 2\text{dB} = 1.33\text{dB}$. This also means that frequencies with no loss are not lowered until later
Volume -2	-4dB compared to REIG	As above, percentage wise decrease	
Volume -3	-6dB compared to REIG	As above, percentage wise decrease	
Volume -4	-8dB compared to REIG	As above, percentage wise decrease	
Default level after any new fitting.	-10dB compared to REIG	As above, percentage wise decrease	Default fitting for all is hence 10 dB lower for worst frequency, other frequencies are less than 10 dB
Volume -5	-12dB compared to REIG	As above, percentage wise decrease	
Volume -6	-14dB compared to REIG	As above, percentage wise decrease	
N-REIG Volume -7	-14dB compared to REIG	As above, percentage wise decrease	We are here 14.7dB under REIG for High and Low frequencies and 4.9 dB below
Volume -8	-2dB from above (so -16dB)	-2dB from above	We are BELOW Best level for new users, and ANYthing below is / could linear
Volume -9	Same procedure as above	Same procedure as above	Etc
Etc			

Fig. 2

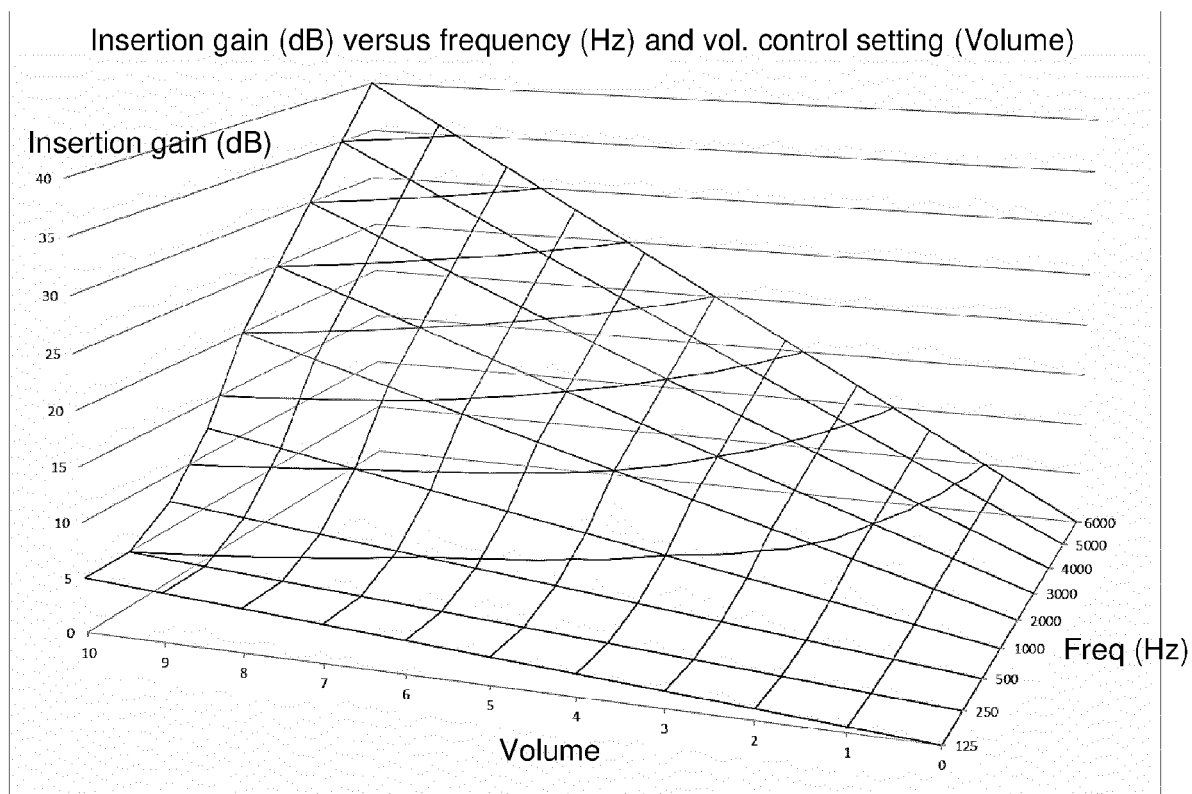


Fig. 3

Volume control setting = 8																		
f(Hz)	In (dB SPL)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110
4000	Out (dB SPL)	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
3000	Out (dB SPL)	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135
2000	Out (dB SPL)	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
1000	Out (dB SPL)	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
Volume control setting = 7																		
f(Hz)	In (dB SPL)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110
4000	Out (dB SPL)	55	60	65	70	75	80	85	90	92	99	101	103	105	107	109	111	113
3000	Out (dB SPL)	55	55	60	65	70	75	80	85	90	97	99	101	103	105	107	109	111
2000	Out (dB SPL)	50	50	55	60	65	70	75	80	85	90	97	99	101	103	105	107	109
1000	Out (dB SPL)	45	45	50	55	60	65	70	75	80	85	90	97	99	101	103	105	107
Volume control setting = 6																		
f(Hz)	In (dB SPL)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110
4000	Out (dB SPL)	50	55	60	65	70	72	74	76	78	80	82	84	86	88	90	92	94
3000	Out (dB SPL)	45	50	55	60	65	70	72	74	76	78	80	82	84	86	88	90	92
2000	Out (dB SPL)	40	45	50	55	60	65	70	72	74	76	78	80	82	84	86	88	90
1000	Out (dB SPL)	35	40	45	50	55	60	65	70	72	74	76	78	80	82	84	86	88

Fig. 4

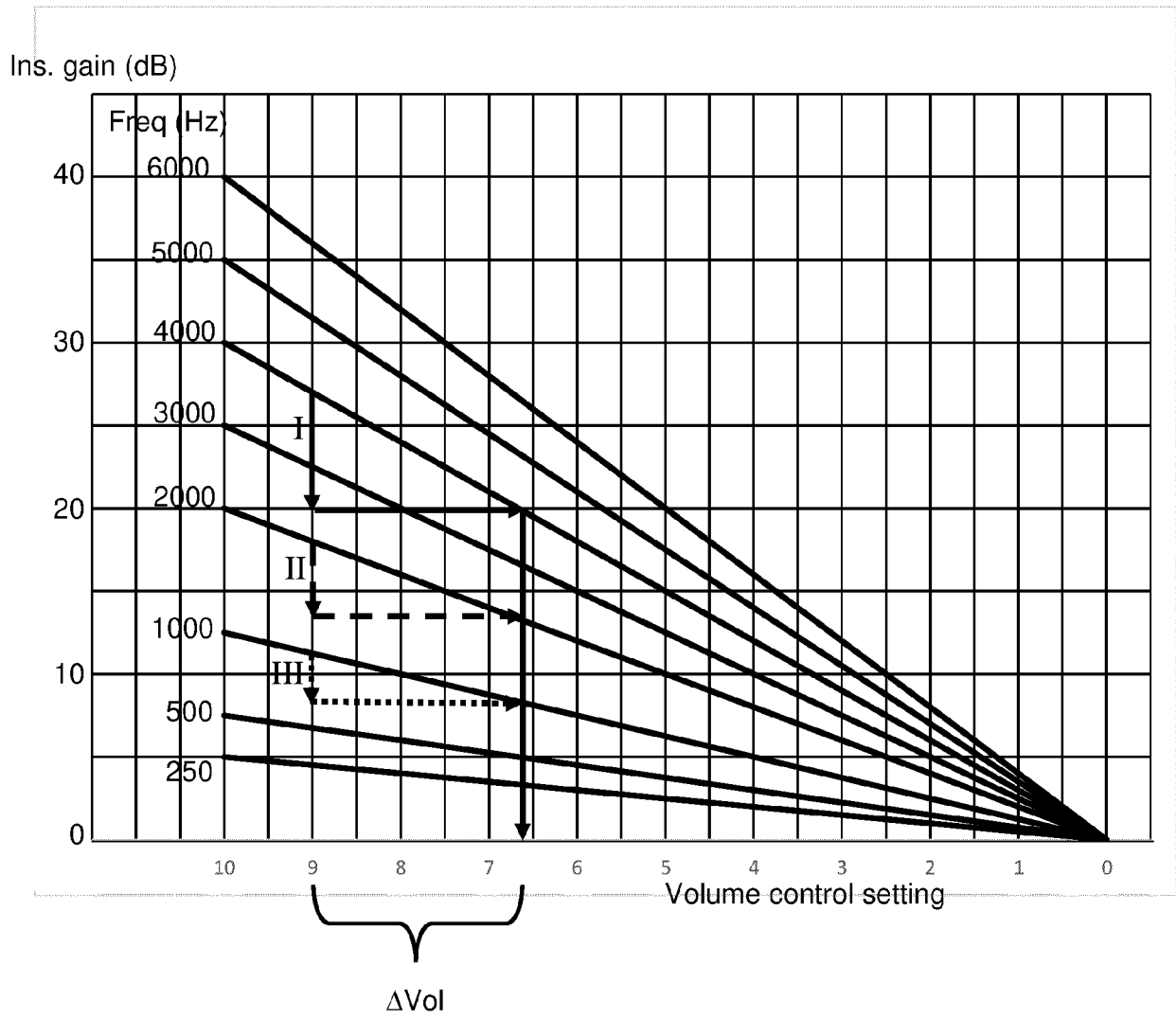
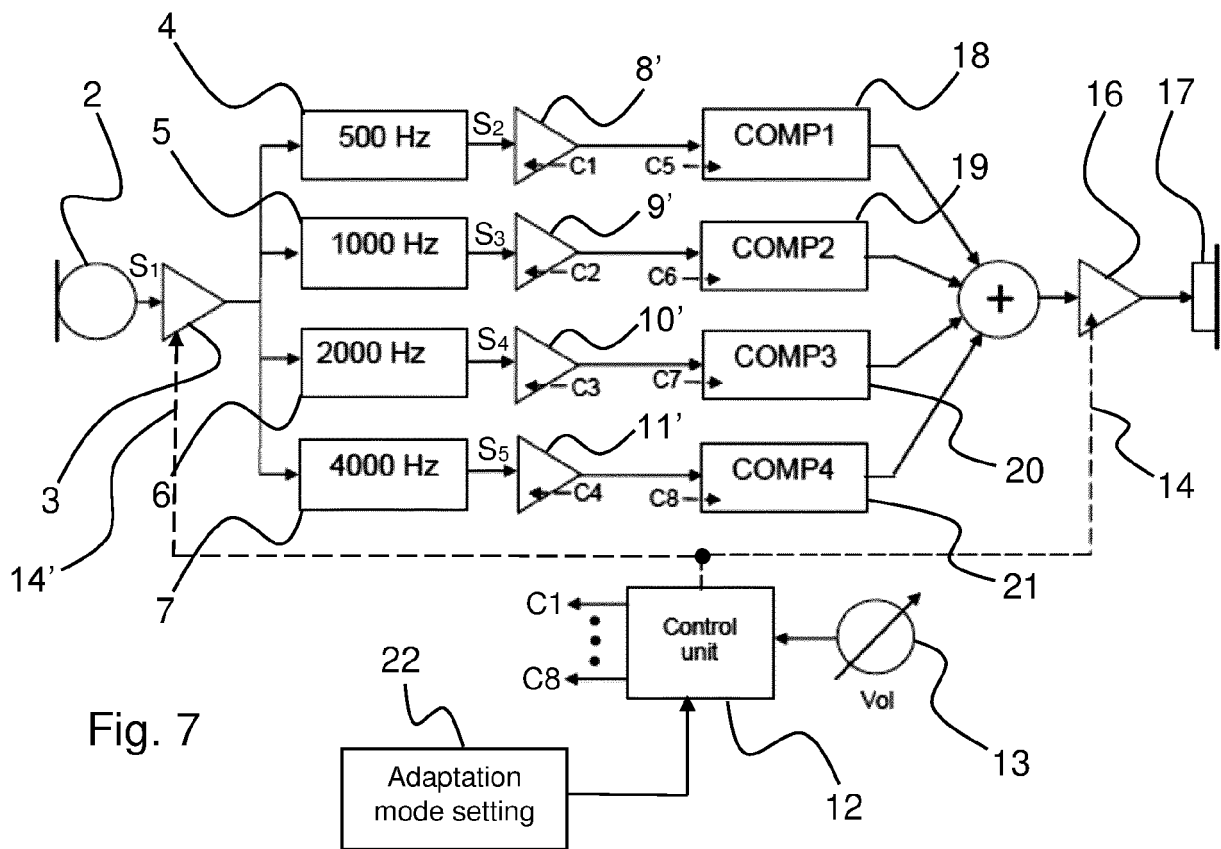
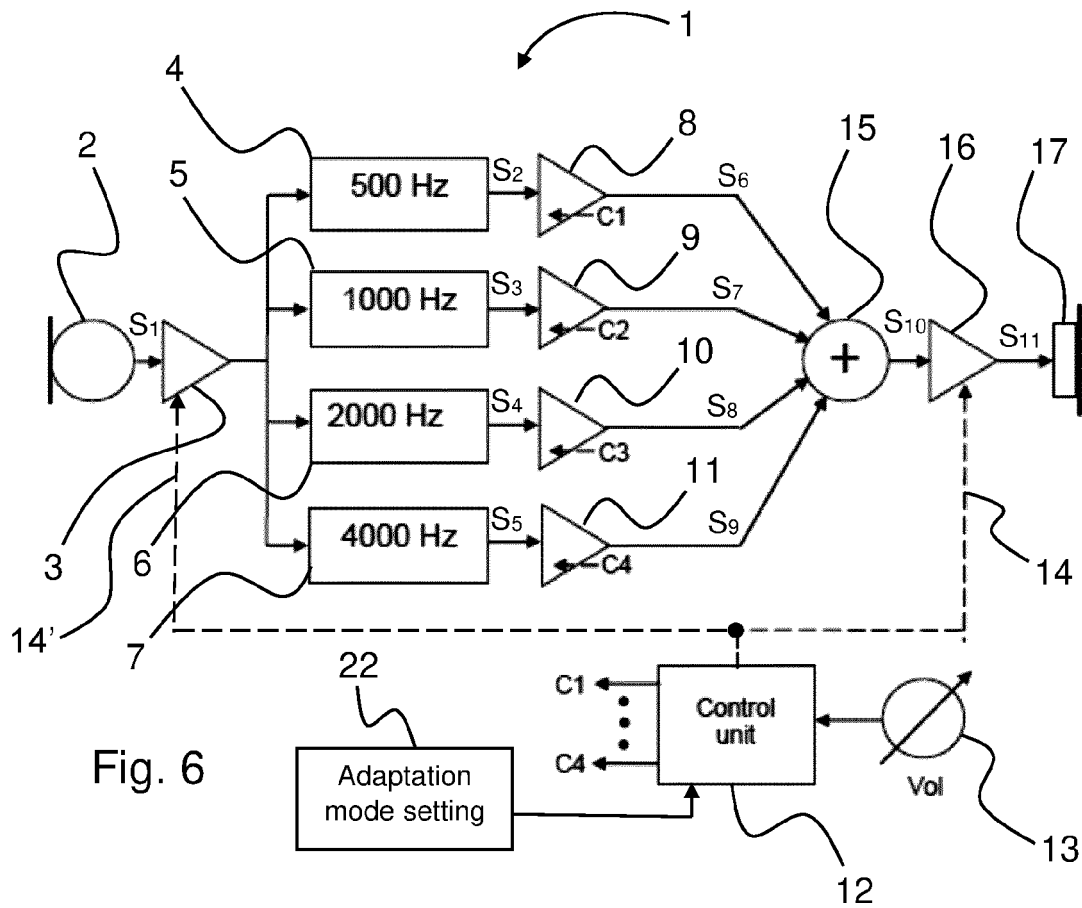


Fig. 5





EUROPEAN SEARCH REPORT

Application Number

EP 21 02 0358

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	DE 10 2020 114026 A1 (APPLE INC [US]) 3 December 2020 (2020-12-03) * paragraph [0014] - paragraph [0037] * * paragraph [0093] - paragraph [0101] * * figures 1-10, 21A-23 * -----	1-10, 12-20	INV. H04R25/00
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Y	EP 3 614 380 A1 (MIMI HEARING TECH GMBH [DE]) 26 February 2020 (2020-02-26) * paragraph [0051] - paragraph [0062] * * paragraph [0069] - paragraph [0084] * * figures 2-4C,10-12 * -----	5-10, 15-20	
A	EP 3 783 918 A1 (SONOVA AG [CH]) 24 February 2021 (2021-02-24) * the whole document * -----	1,12	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 3 783 921 A1 (SONOVA AG [CH]) 24 February 2021 (2021-02-24) * paragraph [0045] * * paragraph [0050] - paragraph [0058] * * figures 1,3,4 * -----	1,12	H04R
A	US 2020/413206 A1 (GAJSTUT ENRIQUE [US]) 31 December 2020 (2020-12-31) * abstract; figures 1-2A * -----	1,12	
The present search report has been drawn up for all claims			

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EPO FORM 1503 03:82 (P04C01)

Place of search	Date of completion of the search	Examiner
The Hague	14 December 2021	Streckfuss, Martin
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		



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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-10, 12-20

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number

EP 21 02 0358

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-10, 12-20

The single general technical concept of the subject-matter of claims 1 - 10 and 12 - 20 relates to frequency-selective gain adjustments for self-fitting hearing aid devices.

2. claim: 11

The single general technical concept of the subject-matter of independent claim 11 relates to usage pattern analysis for a determination of a user adaptation status for a self-fitting hearing aid device.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 02 0358

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-12-2021

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