The invention relates to a method for operating a hearing device and to a device for carrying out said method in order to switch between various hearing programs for adaptation to an instantaneous acoustic environmental situation. According to the invention, signals or parameters \( (b_1, ..., b_m) \) of a transfer function are modified in a continuous manner in order to form a...
(57) **Abstract (continued):**
continuous transition from an instantaneous value to a desired value. The advantage of the invention is that a person wearing a hearing device is no longer required to experience switching to a new hearing program as an abrupt process.
Title: METHOD FOR OPERATING A HEARING DEVICE AND HEARING DEVICE

Bezeichnung: VERFAHREN ZUM BETRIEB EINES HÖRGERÄTES SOWIE EIN HÖRGERÄT

Abstract: The invention relates to a method for operating a hearing device and to a device for carrying out said method in order to switch between various hearing programs for adaptation to an instantaneous acoustic environmental situation. According to the invention, signals or parameters (b₁, ..., bₘ) of a transfer function are modified in a continuous manner in order to form a continuous transition from an instantaneous value to a desired value. The advantage of the invention is that a person wearing a hearing device is no longer required to experience switching to a new hearing program as an abrupt process.
Veröffentlicht:  
— mit internationalen Recherchenbericht  
— vor Ablauf der für Änderungen der Ansprüche geltenden Frist; Veröffentlichung wird wiederholt, falls Änderungen einreten  

(57) Zusammenfassung: Zur Umschaltung zwischen unterschiedlichen Hörradiosprogramm zu Anpassung an eine momentane akustische Umgebungsstimulierung ist ein Verfahren zum Betrieb eines Hörradios sowie eine Vorrichtung zur Durchführung des Verfahrens angegeben. Signale oder Parameter (b_1, ..., b_m) einer Übertragungsfunktion werden erfindungsgemäß in stetiger Weise zur Bildung eines stetigen Übergangs von einem momentanen zu einem gewünschten Wert geändert. Damit wird der Vorteil erhalten, dass ein Hörradienter in Hörradiosprogrammumschaltung nicht mehr als abrupten Schaltvorgang empfindet.
METHOD FOR OPERATING A HEARING DEVICE AND HEARING DEVICE

The present invention is related to a method to operate a hearing device according to the pre-characterizing part of claim 1 as well as to a hearing device to perform the method.

Modern hearing devices can be adjusted to different acoustic surround situations by selecting a hearing program which is best suited for a momentary acoustic surround situation. Thereby, the operation of the hearing device is adjusted optimally to the needs of the user of the hearing device.

The selection of a hearing program can either be done by a remote control or over a switch at the hearing device. The switching from one hearing program to another is performed in an abrupt manner in that the parameters of the momentary used hearing program are changed within a short time. As a result thereof, a sudden hearing quality change occurs which is perceived by the hearing device user and which is sensed as unnatural. This is in particular the case if switching of hearing programs takes place automatically - as e.g. described in international patent application WO 01/22790 -, i.e. the switching occurs at an unexpected time. It has been established that for an automatic
switching from one hearing program, which weights the received acoustic signals according to their direction of occurrence (so-called "beam former"), to an other hearing program, which does not perform any direction-dependent weighting, a sudden and unexpected quality change occurs, which can be heard clearly and which can confuse the hearing device user.

From the European Patent having the publication number EP-B1-0 064 042 such a hearing device is known which incorporates the aforementioned drawbacks resulting from an abrupt switching from one hearing program to another.

Furthermore, reference is made to the European patent application having the publication number EP-A1-0 674 464 in which a hearing device is described having a controller which alters one or several parameters of the transfer function in function of input values of the momentary surround situation by applying the principle of fuzzy logic. The alteration of the parameters is thereby formed by suddenly and in direct dependency of the momentary acoustic surround situation or according to simplified assumptions, respectively. The known hearing device based on this principle is characterized by a complicated assembly which is in particular a result of an adjustment made to the complete transfer function according to the momentary conditions reflecting the acoustic surround situation. In addition, the known hearing device is limited to having one single microphone.
It is therefore an object of the present invention to provide a simple and improved method for switching from one hearing program to another.

This object is achieved by the measures given in claim 1. Advantageous embodiments of the present invention as well as a hearing device to perform the method are given in further claims.

The present invention has the following advantages: By providing a number of different hearing programs of which one can be selected to operate the hearing device, and by adjusting parameters resulting from the hearing program switching from a momentary value to a desired value in a smooth manner to form a smooth transition, the switching is not perceived as an abrupt event by the hearing device user. The hearing program switching perceived as discomfort could have been eliminated by the present invention.

In the context of the present invention the term "parameter" not only means single coefficient values of the transfer function of a hearing device, but also signals as described e.g. in connection with the embodiments according to Fig. 1.
Preferred embodiments of the present invention are hereinafter described by way of example referring to the following drawings, in which

5   Fig. 1 shows a block diagram of a first arrangement according to the present invention for a hearing device with direction-dependent characteristic;

Fig. 2 shows a block diagram of a second arrangement according to the present invention in which the alteration of single parameters of a hearing device transfer function is provided;

Fig. 3 shows a block diagram of a specific embodiment of the arrangement according to Fig. 2; and

Fig. 4 shows a block diagram of a specific embodiment for the alteration of single parameters.

In Fig. 1, a block diagram is shown of a part of a hearing device having two microphones M1 and M2 for the recording of acoustic signals. Reference is made to a first embodiment of a hearing device in which direction-dependent information is being processed, which means that for such a known hearing device the possibility is given to treat acoustic signals coming for a certain direction in a preferred manner compared to acoustic signals coming form a
different place. On the other hand, there is a need that, under certain circumstances, direction-dependent processing of recorded acoustic signals is not wanted. In this case, it is provided that the direction-dependent processing of the signals is being switched off. This can be reached in particular by switching off one of the two microphones M1 and M2, respectively, which results in the processing of only one acoustic signal in the hearing device.

In Fig. 1 the input stage of such a hearing device is shown. The two outputs of the microphones M1 and M2 are being fed to a signal processing unit 1 in which the signals - whether they are available in digital or in analogue form - are being processed in a so-called "beam forming"-algorithm. Further information regarding the beam forming-algorithm is disclosed, for example, in the international patent application having the publication number WO 99/04598.

The output signal of the signal processing unit 1 now only contains the acoustic signal parts which are coming from the desired direction, which signal parts are being processed in further processing units (not shown in Fig. 1) of the hearing device, before these signal parts are being fed to the hearer of the hearing device (not shown in Fig. 1 as well).
According to Fig. 1, a first and a second multiplicator unit 3 and 5, respectively, as well as a first and a second summator unit 4 and 6 are being provided to switch on and switch off, respectively, the consideration of direction-dependent information. By \( P \), a switching state is described which can bear the values "0" or "1", whereas the momentary switching state \( P \) is fed to a filter unit 2. The output signal of the filter unit 2 is fed to the first summator unit 4 - after having reversed its algebraic sign - as well as to a first multiplicator unit 3 to which also the output signal of the signal processing unit 1 is being fed. The constant value "1" is being fed to the first summator unit 4 as second input signal. Furthermore, the output signal of the first summator unit 4 is being fed to the second multiplicator unit 5 having a second input signal to which the first microphone \( M_1 \) is connected. Finally, the output signals of the first and the second multiplicator unit 3 and 5, respectively, are fed to the second summator unit 6 in order to obtain an output signal \( u \) which - as has been already stated above - is being further processed in further processing units of the hearing device, if need be, before being fed to the hearer of the hearing device.

In the following, the functionality of the first embodiment of the present inventions is being described:

If the switching state \( P \) has the value "0", the acoustic signal recorded by the microphone \( M_1 \), assuming steady state, is being switched through to the output \( u \) without
being further processed. In other words, a hearing program is provided which does not take into consideration any direction-dependent information, i.e. all signals being recorded by the microphone M1 are treated equally, independent of their angle of incidence. Such a signal is also identified by the term "omni signal".

If the switching state P has the value "1", the reversed case occurs, assuming again steady state: Instead of the switching-through of the output signal of the microphone M1 alone to the output signal u, the output signal already generated in the signal processor unit 1 is now switched through to the output u. Thereby, a signal is provided in this switching state P as output signal u which incorporates specific, namely direction-dependent, signal parts. The output signal u is also identified by the term "directional signal".

As has been already described, the switching from one hearing program to an other, i.e. from the "omni signal" to the "directional signal" and vice versa, can result in confusion of the hearing device user, especially in case the switching is done automatically, i.e. without any ado by the hearing device user, in other words, if the switching is a surprise for the hearing device user. According to the present invention, it is therefore provided that a smooth transition is arranged for a state change of a switching state P in order to obtain a smooth transition from an "omni signal" to a "directional signal".
and vice versa, respectively. Therefore, it is provided for a preferred embodiment of the present invention to realize a low-pass filter of first order in the filter unit 2, which low-pass filter preferably has a time constant of approx. 1 second. It is also conceivable to use a ramp generator or a similar algorithm instead of a low-pass filter in order to realize a smooth transition.

The filter unit 2 causes a weighting of the outputs of the signal processing unit 1 and of the first microphone M1 in that the output of the signal processing unit 1 is directly multiplied by the output signal of the filter unit 2, in that, furthermore, the output of the first microphone M1 is multiplied by the inverted output of the filter unit 1, which output is being increased by the value of "1", and in that, finally, the two weighted signals are added together in the second summator unit 6. The values of the switching state P are equal to "0" or equal to "1" as can be seen from Fig. 1. Accordingly, also the output signal of the filter unit 2 is within this range, but all values between the two extreme values can be adapted.

In a further embodiment of the present invention, it is feasible that an extended range than [0 ... 1] can be used in order to obtain different mixing ratios and/or different amplification factors.
In Fig. 2, a block diagram is shown of a further embodiment of a hearing device according to the invention, which block diagram is again shown in part and schematically. In this embodiment of the present invention, an algorithm for noise canceling is being used. Therefore, a transfer function is determined in the signal processing unit 1 in which an input signal from the microphone M1 is being processed. Output signal u of the signal processing unit 1 is treated, as already in the embodiment according to Fig. 1, in further processing units in the hearing device, if need be, and is being finally fed to the hearer of the hearing device.

The transfer function generated in the signal processor unit 1 has a number of parameters $a_1$ to $a_n$ and $b_1$ to $b_n$, respectively, whereas the parameters $a_1$ to $a_n$ remain unchanged if another hearing program is selected. The parameters $b_1$ to $b_n$ are being changed by a different hearing program selection. According to the present invention, filter units $2_1$, to $2_n$ are provided as a consequence to the description of the embodiment according to Fig. 1, which filter units $2_1$ to $2_n$ have input values corresponding to the parameters $b_1$ to $b_n$ in order to obtain a smooth transition from the momentary value of a parameter to a predefined target value. The parameter values being smoothed in the filter units $2_1$ to $2_n$ as well as the unchangeable values of the parameters $a_1$ to $a_n$ are being fed to the signal processing unit 1 in which the transfer function is being determined.
For further explanation of the more general embodiments of the invention according to Fig. 2, a specific embodiment of the invention is shown in Fig. 3. Besides the parameters $a_1$ to $a_n$ which experience no change by switching from one hearing program to another, a parameter MaxAtt is adjustable. Thereby, the parameter MaxAtt obtains either the value of "0" or the value $x$. For the use of an algorithm to suppress noise, the parameter MaxAtt corresponds to the maximum attenuation of a noise suppression of the type "spectral subtraction" which is applied to increase the signal noise ratio (SNR).

In contrast to the embodiment according to Fig. 2, the output signal $u$ is not directly determined by the signal processing unit 1 in the embodiment according to Fig. 3, but an attenuation factor $k$ is determined using the signal processing unit 1, which attenuation factor $k$ is applied to the output signal of the microphone M1 over a multiplicator unit 3. The output signal of the multiplicator unit 3 corresponds then to the signal $u$ which is further processed, as the case may be, according to the above mentioned explanation.

The filter unit 2 again can be realized in an embodiment explained in connection with the one according to Fig. 2.
Furthermore, it is feasible that the two embodiments according to Fig. 1 and according to Figs. 2 and 3, respectively, are combined.

In Fig. 4, a possible embodiment of the invention, again in a block diagram, is shown, which embodiment is used to change or adjust, respectively, a parameter, whereby the additional possibility is given to force a parameter change without delay in a direct manner, i.e. by bypassing the filter unit 2.

For the embodiment according to Fig. 4, it is provided that a parameter obtains a value a or a value a+Δa, namely in dependency on a selection of a hearing program, whereby a switch is determined by a state change of a switch state P which obtains a value "0" or "1". In the steady state, the signal x has a value a if the switch state P has a value "0", and a value a+Δa if the switch state P has a value "1".

For a state change, a smooth transition from one value to another is formed again using a filter unit 2, whereby a limiter unit 12 provided after the filter unit 2 is used in order that a maximum and minimum value, respectively, is not trespassed.
Furthermore, an oversteer unit is identified by the reference sign 13 with which a parameter change is directly effected by bypassing the filter unit 2. Therewith, a possibility is given to manually select a desired hearing program by the hearing device user, which hearing program is taking effect immediately after its selection, i.e. the generation of a smooth transition is therewith omitted knowingly. Thereby, the hearing device user is in a position to better estimate the possible performance of the new hearing program. In connection with the oversteer unit 13, it is possible that the hearing device user also obtains the possibility to select any value for x in the given range between a and a+Δa. It is provided, over the oversteer unit 13, that any value between "±1" may have effect on the signal path over the summator unit 16 and not only the values "0" and "1" in order to increase or decrease, respectively, the value of the signal x. In order that the value of the signal x does not trespass the given limits a and a+Δa, respectively, the limiter unit 12 is provided which limits the output signal of the summator unit 16 between the value "0" and "1", respectively.

In dependence on the aforesaid explanations, it is provided that a smooth transition is generated in the sense of the above explanation whenever an automatic hearing program switching occurs. In other words, the switching state P according to Figs. 1 and 4 is being undertaken automatically with the aid of an algorithm to recognize the momentary acoustic surround situation. In connection with
the recognition of the momentary acoustic surround situation, reference is made to the two international patent applications with the publication numbers WO 01/20965 and WO 01/22790, which contents are herewith incorporated by reference.

In a further embodiment of the present invention, it is provided that the values for the switching state \( P \) can take any values in the range between "0" and "1".

It is pointed out that basically all parameters, which are changed within the scope of a hearing program switching, obtain a smooth transition according to the present invention. As examples, the following parameters are mentioned which are processed either alone or in combination according to the aforesaid explanations:

- maximum attenuation;
- width of registration, i.e. direction sharpness of a beam former;
- amplification;
- compression;
- scaling;
- operating point of a noise suppression unit according to Fig. 3;
- time constant of the compression;
- compression knee point;
- limiter;
- operating point of the suppression unit for the signal feedback;
- operating point of a recognition unit of the acoustic surrounding.
CLAIMS:

1. Method for operating a hearing device in which one of several possible hearing programs can be selected at a given time in order to adjust to a momentary acoustic surround situation, in that parameters \( (b_1, \ldots, b_m) \) of a transfer function provided between a microphone \((M_1, M_2)\) and a hearer can be changed, characterized in that the parameters \( (b_1, \ldots, b_m) \) to be changed according to the hearing program switching are adjusted from a momentary value to a desired value in a smooth manner in order to provide a smooth transition form one hearing program to another.

2. Method according to claim 1, characterized in that the smooth transition from a momentary value of a parameter \( (b_1, \ldots, b_m) \) to a desired value is extended over a given time range.

3. Method according to claim 1 or 2, characterized in that the smooth transition from a momentary value of a parameter \( (b_1, \ldots, b_m) \) to a desired values corresponds to a step response of a low-pass filter.

4. Method according to claim 1 or 2, characterized in that the smooth transition from a momentary value of a parameter

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(b_1, \ldots, b_m) to a desired value is generated using a ramp generator.

5. Method according to one of the preceding claims, characterized in that one or several of the following parameters (b_1, \ldots, b_m) are used as parameters (b_1, \ldots, b_m):

- maximum attenuation or reduction, respectively;
- width of registration, i.e. direction focusing of a beam former;
- amplification;
- compression;
- scaling;
- operating point of a noise suppression unit according to Fig. 3;
- time constant of the compression;
- compression knee point;
- limiter;
- operating point of the suppression unit for the signal feedback;
- operating point of a recognition unit of the acoustic surrounding.

6. Method according to one of the preceding claims, characterized in that the momentary acoustic surround situation is recognized automatically and that a suitable
hearing program is selected according to the recognized momentary acoustic surround situation.

7. Method according to one of the preceding claims, characterized in that a hearing program is selected by a manual intervention over an oversteer unit (13) at the hearing device, or by a remote control having effect on the hearing device, whereby the selected hearing program is taking effect immediately after selection.

8. Hearing device to perform the method according to one of the claims 1 to 7, characterized in that means (2) for generating a smooth transition are provided, whereas the means cause a smooth transition of parameters \( (b_1, \ldots, b_m) \) from a momentary value to a desired value, which parameters are affected by a hearing program switching.

9. Hearing device according to claim 8, characterized in that the means (2) for generating a smooth transition feature low-pass characteristics.

10. Hearing device according to claim 8, characterized in that the means to form a smooth transition comprise a ramp generator.

11. Hearing device according to one of the claims 8 to 10, characterized in that an oversteer unit (13) is provided
which has, seen in a signal flow direction, an influence after the means (2) for generating a smooth transition.