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Hearing aid with noise suppression and corresponding noise suppression method

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(56) Related Art

WO 1996/032776 A2

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Abstract

Hearing aid with noise suppression and corresponding noise suppression method

Concurrent signal paths going past the hearing aid bring about interferences in the auditory canal. These interferences are compensated by estimating an interfering signal ($\hat{n}$) from the input signal (x) disturbed by interference from a microphone (2) and applying to the interfering signal ($\hat{n}$) a transfer function ($\hat{H}$), with which the concurrent acoustic signal path is simulated, thereby forming an interfering output signal ($\hat{n}\,\hat{H}$), and linking a usable output signal from a signal processing device (1) with the interfering output signal ($\hat{n}\,\hat{H}$). In this way, a noise suppression by directional microphone switching configurations can also be made possible when concurrent signal paths do not make it possible by conventional approaches.

Figure 1

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FIG 1

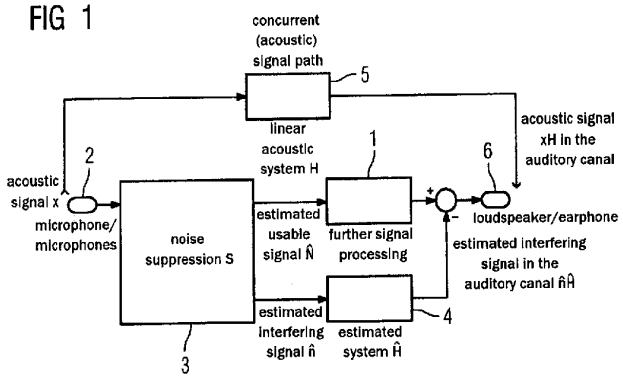
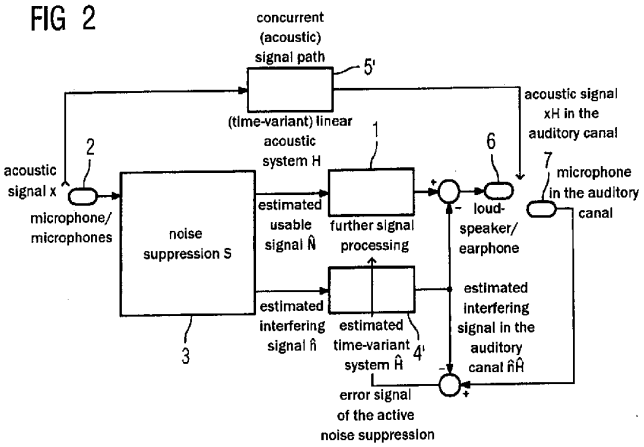


FIG 2



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PATENTS ACT 1990

COMPLETE SPECIFICATION

FOR A STANDARD PATENT

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Invention Title:	Hearing aid with noise suppression and corresponding noise suppression method

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

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Description

Hearing aid with noise suppression and corresponding noise suppression method

The present invention relates to a hearing aid with an estimating device for estimating a usable signal from an input signal disturbed by interference and a signal processing device for processing the usable signal to form a usable output signal. The present invention also relates to a method of suppressing noise at a hearing aid.

Those with impaired hearing often suffer from a reduced ability to communicate in noisy situations. To improve the signal-to-noise ratio, methods of noise reduction have been used for some time. For this purpose, in hearing aids the acoustic signal is picked up with the aid of one or more microphones and electrically processed in such a way that the signal-to-noise ratio is improved, and subsequently an interference-suppressed signal is output via an earphone in the auditory canal.

Depending on how the hearing aid is fitted, the acoustic signal may also enter the auditory canal directly, i.e. concurrently with an electrical processing path, and so impair the desired influence of the electrical signal processing. Typical concurrent signal paths arise for example in the case of hearing aids with open supply or ear adapters with venting holes. In particular, it is known that such concurrent signal paths can strongly impair the noise suppression based on the directional microphone method in the low-frequency range to about 1 kHz.

A hearing aid of the generic type is known for example from the document DE 198 13 512 A1. Here, too, the

noise suppression takes place with the impairment mentioned.

In addition, the document EP 1 304 902 A1 describes a method for interference elimination of a redundant acoustic signal in which the intensity of an interference is estimated and, dependent on the intensity of the interference, an input signal component is masked.

Thus, a need exists to provide a hearing aid with improved noise suppression. A need also exists to provide an improved method of noise suppression for hearing aids.

According to a first aspect of the present disclosure, there is provided a hearing aid with an estimating device for estimating a usable signal from an input signal disturbed by interference and a first signal processing device for processing the usable signal to form a usable output signal, it also being possible with the estimating device to estimate an interfering signal from the input signal disturbed by interference. Furthermore, the hearing aid has a second signal processing device, with which it is possible to simulate the transfer function of an acoustic path which is suitable for applying the transfer function to the interfering signal, thereby forming an interfering output signal. Subsequently, a linking device is required for linking the usable output signal with the interfering output signal.

According to a second aspect of the present disclosure, there is provided a method of suppressing noises at a hearing aid by estimating a usable signal from an input signal disturbed by interference and processing the usable signal to form a usable output signal, and also estimating an interfering signal from the input signal disturbed by interference, applying a transfer function with which

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an acoustic path is simulated to the interfering signal, thereby forming an interfering output signal, and linking the usable output signal with the interfering output signal. The acoustic path will generally pass by the hearing aid in an auditory canal. This is a relatively short distance, so that it is important to generate a compensating signal from the estimated interfering signal as quickly as possible with the second signal processing device. In this way it is possible to compensate as much as possible for the sound interference getting past the hearing aid to the eardrum.

The simulated transfer function may be linear. This reduces the computing time and consequently optimizes the interfering signal compensation. In addition, however, the transfer function may also be time-variant, so that for example the shifting of the hearing aid in the auditory canal can be taken into account.

Furthermore, the hearing aid may have an acoustic sensor, which, in the state of the hearing aid in which it is inserted in an auditory canal, can be placed or is placed at the end of the hearing aid that is facing the eardrum, so that its signal can be used for the dynamic variation of the simulated transfer function of the second signal processing device. In this way it is possible to take into account the acoustic state ahead of the eardrum to adapt the transfer function with the aid of a control loop.

The hearing aid may also have a coupling device, with which the usable output signal of the first signal processing device can be coupled to the second signal processing device for the variation of the simulated transfer function. In a further development, the coupling factor of the coupling device in hearing aid

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operation can be set or varied. It is advantageous if the interfering signal is strongly correlated with the usable signal, so that excessive damping of the usable signal can be prevented.

The present invention is now explained in more detail on the basis of the accompanying drawings, in which:

Figure 1 shows a block diagram of a hearing aid according to the invention with feeding in of an estimated interfering signal in phase opposition according to a first embodiment;

Figure 2 shows a block diagram of a hearing aid with additional microphone feedback according to a second embodiment; and

Figure 3 shows a block diagram of a hearing aid with variation of the interfering signal transfer in dependence on the usable signal according to a third embodiment.

The exemplary embodiments described below represent preferred embodiments of the present invention.

The hearing aid schematically represented in Figure 1 has as a central module a signal processing device 1. This performs the further signal processing of a usable signal picked up by the microphone or the microphones 2 and freed of noise by the noise suppression device 3. In the noise suppression device 3, a usable signal $\hat{N}$ and an interfering signal $\hat{n}$ are estimated from the input signal from the microphone 2 or from the number of microphones. While the estimated usable signal $\hat{N}$ is further processed in the signal processing device 1, an estimated system transfer function $\hat{H}$ is applied to the estimated interfering signal $\hat{n}$.

The transfer function $\hat{H}$ is obtained from a concurrent, acoustic signal path, which can be represented by a linear acoustic system 5 with a transfer function H. The input variable of the concurrent signal path is the same acoustic signal x that is also picked up by the microphone 2. At the end of the concurrent signal path, i.e. in the auditory canal, the acoustic signal xH is obtained on account of the multiplication by the transfer function H of the linear acoustic system 5. That the concurrent signal path is a linear acoustic system is undoubtedly a simplifying assumption, which has the purpose of making the signal processing device 4 that is used for estimating or simulating the concurrent signal path as simple as possible.

The output signal $\hat{n}\hat{H}$ of the signal processing device 4 with the transfer function $\hat{H}$ represents an estimate of the interfering signal xH which passes via the concurrent signal path into the auditory canal. This signal $\hat{n}\hat{H}$ is subtracted from the output signal of the signal processing device 1 and thereby fed in phase opposition into the auditory canal through the earphone or loudspeaker 6 of the hearing aid. In this way, the interfering signal xH and the antiphase, estimated interfering signal $\hat{n}\hat{H}$ are cancelled out in the auditory canal and the concurrent signal path is compensated, to the extent to which this is allowed by the difference in transit time between the acoustic signal path and the electrical signal path.

The hearing aid of a second embodiment of the present invention is schematically reproduced in Figure 2. By contrast with the first embodiment of Figure 1, it is taken into account in the second embodiment that the linear acoustic system 5' of the concurrent acoustic signal path is time-variant, or at least not known sufficiently well during the design of the hearing aid. Therefore, the transfer function $\hat{H}$ of the signal

processing device 4' is likewise made time-variant. For the variation of the transfer function $\hat{H}$, a microphone 7 or other sensor is used, and is to be introduced into the auditory canal. The signal obtained by the microphone is subtracted from the estimated signal $\hat{n}\hat{H}$ in order to obtain an error signal for the adaptive setting of the system 4' with the transfer function $\hat{H}$. The adaptive setting of the transfer function $\hat{H}$ may take place for example with an (N)LMS (Normalized Least Mean Square) algorithm, as long as the estimated interfering signal $\hat{n}$ is sufficiently uncorrelated with the usable signal at the hearing aid output.

If, however, the estimated interfering signal $\hat{n}$ correlates to a certain extent with the usable signal at the hearing aid output, the influence of the usable signal on the adaptation of the filter or the signal processing device 4' can be reduced by the transfer function $\hat{H}$, in that the usable signal is filtered by the coupling function G with a suitably chosen system 8. Such a system is represented in Figure 3 in a third exemplary embodiment. In addition to the system from Figure 2, the output signal of the signal processing device 1 is therefore picked off by the coupling device 8 and multiplied by the coupling function G. The resultant signal is subtracted from the microphone signal of the microphone 7 in the auditory canal and the estimated interfering signal $\hat{n}\hat{H}$ already subtracted from it, so that an error signal of the active noise suppression is obtained. This error signal is used for the variation of the transfer function $\hat{H}$ in the time-variant signal processing device 4'. It is possible in this way to prevent a usable signal that enters the auditory canal via the concurrent acoustic signal path, and would be interpreted there as an interfering signal, from being damped or suppressed.

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The other components that are not mentioned in connection with the description of Figure 2 and Figure 3 but are represented there correspond to those of Figure 1, so that reference is made to the relevant description.

To sum up, it can consequently be stated that the signal $\hat{n}\,\hat{H}$ fed into the auditory canal in phase opposition compensates for the interfering signal components xH of the acoustic signal x in the auditory canal. In particular, the noise suppression by directional microphone switching configurations can also be made possible when concurrent signal paths do not make it possible by conventional approaches.

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The claims defining the invention are as follows:

1. A hearing aid comprising:
   - an estimating device for estimating a usable signal from an input signal disturbed by interference, wherein with the estimating device it is also possible to estimate an interfering signal from the input signal disturbed by interference;
   - a first signal processing device for processing the usable signal to form a usable output signal;
   - a second signal processing device, with which it is possible to simulate the transfer function of an acoustic path, for applying the simulated transfer function to the interfering signal, thereby forming an interfering output signal; and
   - a linking device for linking the usable output signal with the interfering output signal.

2. The hearing aid as claimed in claim 1, the acoustic path passing by the hearing aid in an auditory canal.

3. The hearing aid as claimed in either one of claims 1 and 2, the simulated transfer function being linear.

4. The hearing aid as claimed in any one of the preceding claims, the simulated transfer function being time-variant.

5. The hearing aid as claimed in any one of the preceding claims, further comprising:
   an acoustic sensor, which, in the state of the hearing aid in which it is inserted in an auditory canal, can be placed or is placed at the end of the hearing aid that is facing the eardrum, so that its signal can be used for the dynamic variation of the

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simulated transfer function of the second signal processing device.

6. The hearing aid as claimed in any one of the preceding claims, further comprising:

a coupling device, with which the usable output signal of the first signal processing device can be coupled to the second signal processing device for the variation of the simulated transfer function.

7. The hearing aid as claimed in claim 6, it being possible for a transfer factor of the coupling device to be set in hearing aid operation.

8. A method of suppressing noises at a hearing aid, comprising the steps of:
- estimating a usable signal from an input signal disturbed by interference;
- processing the usable signal to form a usable output signal;
- estimating an interfering signal from the input signal disturbed by interference;
- applying to the interfering signal a transfer function with which an acoustic path is simulated, thereby forming an interfering output signal; and
- linking the usable output signal with the interfering output signal.

9. The method as claimed in claim 8, an acoustic signal being picked up between the hearing aid and the eardrum in an auditory canal and used for the dynamic variation of the simulated transfer function.

10. The method as claimed in either one of claims 8 and 9, the usable output signal being used for the variation of the simulated transfer function.

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11. The method as claimed in claim 10, the coupling of the usable output signal for the variation of the simulated transfer function taking place with a coupling factor which can be set.

12. A hearing aid substantially as described herein with reference to the accompanying drawings.

13. A method of suppressing noises of a hearing aid substantially as described herein with reference to the accompanying drawings.

DATED this twenty-eighth Day of March, 2006

Siemens Audiologische Technik GmbH

Patent Attorneys for the Applicant

SPRUSON & FERGUSON

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FIG 1

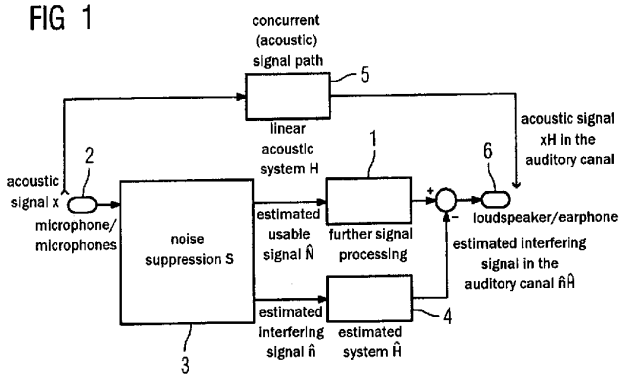


FIG 2

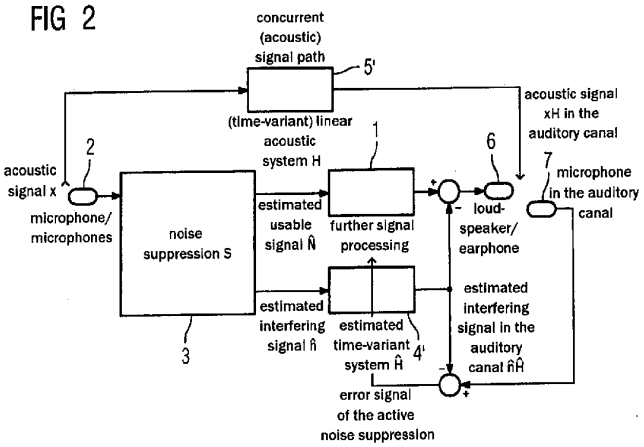
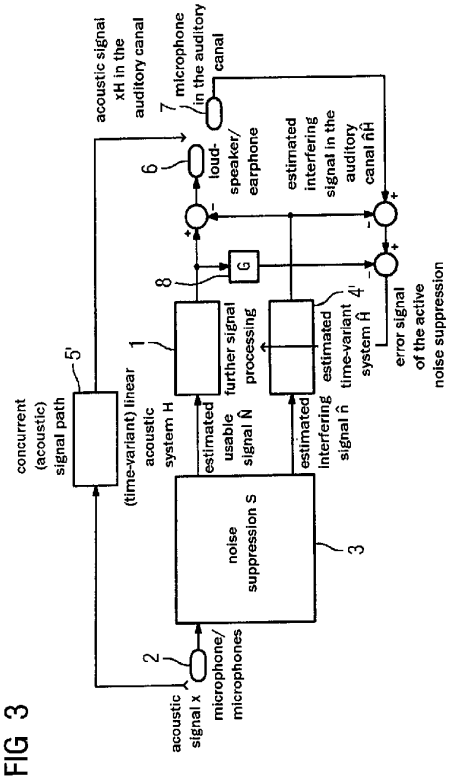


FIG 3


acoustic signal x
microphone/ microphones
2
noise suppression S
3
estimated usable signal Ñ
estimated interfering signal n̂
(time-variant) linear acoustic system H
concurrent (acoustic) signal path
5'
further signal processing
1
8
G
estimated time-variant system Ĥ
4'
acoustic signal xH in the auditory canal
6
loud-speaker/ earphone
7
microphone in the auditory canal
estimated interfering signal in the auditory canal ñĤ
error signal of the active noise suppression