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Description

The invention relates to a method for operating a hearing device and to a hearing device with improved feedback suppression through the use of an optimised frequency filter.

A frequent problem with hearing devices is the feedback between the output of the hearing device and the input, which makes itself evident as annoying whistling. Figure 1 shows the principle of acoustic feedback. A hearing device 1 has a microphone 2 which receives an acoustic useful signal 10, converts it into an electrical microphone signal 11 and outputs it to a signal processing unit 3. In the signal processing unit 3 the microphone signal 11 undergoes processing such as preparation, amplification and output to an earpiece 4 as an electrical earpiece signal 12. In the earpiece 4 the electrical earpiece signal 12 is converted back into an acoustic output signal 13, and output to the eardrum 7 of a hearing aid wearer.

The problem now is that part of the acoustic output signal 13 reaches the input of the hearing device 1 via an acoustic feedback path 14 where it superimposes itself on the useful signal 10 and is picked up by the microphone 2 as a sum signal. With an unfavourable phase position and amplitude of the fed back output signal the result is annoying feedback whistling. With open hearing aid supply in particular the attenuation of the acoustic feedback is low, which exacerbates the problem.

Adaptive systems for feedback suppression have been available for some time as a solution. These involve simulating the acoustic feedback path 14 in the hearing device 1 digitally. The simulation is undertaken for example by means of an adaptive compensation filter 5 which is fed by the earpiece signal 12. After filtering in the compensation filter 5, a filtered compensation signal 15 is subtracted from the microphone signal 11. In the ideal case the effect of the acoustic feedback path 14 is cancelled out by this and a feedback-free input signal 16 is produced for the signal processing unit 3.

For an effective feedback suppression a regulation or adaptation of filter coefficients of the adaptive compensation filter 5 is required. To this end the microphone signal 11 is evaluated with the aid of a detection unit 6 and investigated for possible feedback. Artefacts can also be produced however by the regulation or adaptation of the filter coefficients, since with an adaptive compensation filter 5 which is not set optimally, additional signal components will be created or feedback whistling will occur. EP 1 033 063 B1 discloses a hearing device with feedback suppression wherein, for improving the feedback suppression, two adaptive compensation filters operating in parallel are employed.

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A high correlation between useful signal 10 and feedback signal 14 represents a major problem for an optimum feedback suppression, because input signal components will also be addressed by the correlation and incorrect adaptations of the compensation filter can occur.

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A solution to this problem is disclosed in JASA Vol. 94, pt. 6, 1993-Dec., 3248 ff. A useful signal is decorrelated from a fed back noise signal by the frequency of the output signal of a hearing device and thereby the frequency of the fed back signal being shifted in relation to the frequency of the useful signal.

20

Unfortunately the frequency shifts or distortions also cause clearly perceptible artefacts. A distortion at low frequencies is not possible as a rule since in the low frequency range the human hearing reacts very sensitively to distortions. Therefore mostly only the high frequencies are shifted. Despite this the result can be an audible "detuning" of the useful signal.

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Considerably more unpleasant are overlay artefacts in which a signal shifted in frequency and a non-shifted signal are perceived at the same time which leads with tonal signals to a marked modulation or fluctuation or to a roughness. Acoustic overlays are almost inevitable which arise through the inflow of direct sound, through the vent for example.

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As a result of construction overlays can however also arise from non-ideal split-band filters. To enable only high-frequency frequency components to be shifted, these must be separated from the low-frequency components. This requires a frequency filter, also called a split-band filter. The filter cannot however carry out
5 ideal separation, which means that disruptive overlays result in the area of the limit frequency of the filter.

Depending on the frequency shift, these overlays will be perceived as amplitude modulation or as signal roughness. In all cases described the overlays are disruptive, especially when an input signal involves music or more generally tonal
10 signals.

Known filters in hearing devices are of the Butterworth type. They are not ideal and have a finite frequency overlap at their limit frequency GF. Figure 2 shows
15 an example of the frequency curve of a 9th-order type Butterworth frequency filter of a hearing device with a limit frequency GF of 900 Hz. The curves K1, K2 show the amplitude D in dB as a function of the frequency F in Hz in the range 0 to 1150 Hz. The curve K1 shows a low-pass characteristic and the curve K2 a high-pass characteristic. The sum curve K3 of the curves K1 and K2 produces a
20 flat, constant frequency response. The curve K4 compared to the curve K2 shows a high-path characteristic shifted by 25 Hz to higher frequencies.

With an addition of the signal components according to the curves K1 and K3 the result is, above all in the area of the limit frequency G2, overlays which cannot
25 be ignored of signal components shifted in frequency and not shifted, which in an output signal of the hearing device is perceived as modulation or heavy roughness. Both effects are disruptive and are perceived by the hearing device wearer mostly markedly more strongly than frequency shifting.

30 The object of the invention is to reduce the perception of artefacts of a frequency shifting in hearing devices.

In accordance with the invention the desired object is achieved with a hearing device and the method of the independent claims.

The invention claims a hearing device with an adaptive feedback suppression unit and a signal processing unit. The hearing device also comprises a low-pass filter characterised by a first limit frequency that couples a low frequency signal component out of an output signal of the signal processing unit, a high-pass filter characterised by a second limit frequency that couples a high-frequency signal component out of the output signal of the signal processing unit, and a frequency shifting unit which shifts the frequency of the high-frequency signal component to higher frequencies. Between the first and the second limit frequency there exists a predeterminable distance or a gap. Signal distortions caused by a frequency shift are effectively suppressed by the different limit frequencies. The reason is that fewer overlapping shifted and unshifted signal components arise in this way. This enables a feedback suppression to operate continuously at higher frequencies. The suppression is then undertaken quickly.

In a development the distance can be between 20 Hz and 50 Hz in size. Trials have shown that a distance between the limit frequencies of this size is sufficient.

In a further form of embodiment of the invention the frequency shift of the high-frequency signal component can amount to 10 Hz to 30 Hz. An acoustic feedback suppression is optimised by this.

Furthermore the hearing device comprises an adder in which the low-frequency signal component and the high-frequency signal component shifted in frequency are summed, with an output signal of the hearing device being formed.

Preferably the low-pass filter and/or the high-pass filter can be embodied as Cauer filters (also referred to as elliptical filters). The great edge steepness of this filtered type more effectively prevents signal distortions.

The invention also claims a method for frequency shifting in a hearing device.
The method comprises the following steps:

- 5 - Coupling out a low-frequency signal component from a signal-processed microphone signal (at the output of a signal processing unit) by a low-pass filter characterised by a first limit frequency,
- Coupling out a high-frequency signal component from a signal-processed microphone signal (at the output of a signal processing unit) by a high-pass filter characterised by a second limit frequency, with a
10 predeterminable distance or a gap being present between the first and the second limit frequency, and
- Shifting the frequency of the high-frequency signal component to higher frequencies.

- 15 In a development of the method the distance between the limit frequencies can be selected between 20 Hz and 50 Hz.

In a further form of embodiment of the method the frequency of the high-frequency signal component can be shifted by 10 Hz to 30 Hz.

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The method preferably also comprises an addition of the low-frequency signal component and the high-frequency signal component shifted in the frequency, with an output signal of the hearing device being formed.

- 25 In addition the low-pass filter and/or the high-pass filter can be designed as a Cauer filter.

Further special features and advantages of the invention are evident from the explanations of exemplary embodiments given below, which refer to schematic
30 drawings.

In the drawings:

Figure 1: shows a block diagram of a hearing device with acoustic feedback and feedback suppression according to the prior art,

Figure 2: shows a frequency curve of a 9th-order Butterworth frequency filter
5 according to the prior art,

Figure 3: shows a block diagram of a hearing device with feedback suppression and a frequency filter, and

10 Figure 4: shows frequency curves of two Cauer filters.

Figure 3 shows a hearing device 1 with a microphone 2 picking up an acoustic input signal 101 and with an earpiece 4 outputting an acoustic output signal 13. As described above, a part of the output signal 13 is fed back via a feedback
15 path 14 to the microphone 2 of the hearing device 1, wherein it is overlaid with a useful signal 10 to form an input signal 101. The microphone 2 converts the acoustic input signal 101 into an electrical microphone signal 102.

Any acoustic feedback that might arise is detected with the aid of a feedback
20 suppression unit 17, simulated from an earpiece input signal 108 and added as an inverted feedback suppression signal 109 to the microphone signal 102 in a second adder 22. At the output of the second adder 22 a feedback-suppressed microphone signal 107 is thus produced which is fed to a signal processing unit 3. An output signal 103 of the signal processing unit 3 is fed to the input of a
25 frequency filter with a low-pass filter 18 and a high-pass filter 19.

A low-pass output signal 105 is available at the output of the low-pass filter 18 and a high-pass output signal 104 is available at the output of the high-pass filter 19. The high-pass output signal 104 is shifted with the aid of a frequency
30 shift unit 25 by around 10 Hz to 30 Hz towards higher frequencies. The frequency-shifted high-pass output signal 106 is added in a first adder 21 to the low-pass output signal 105.

An earpiece input signal 108 is available at the output of the first adder 21, which is converted by the earpiece 4 into the acoustic output signal 13.

In accordance with the invention the low-pass filter 18 and the high-pass filter
5 19 have different limit frequencies GF1, GF2, whereby practically no disruptive overlay effects can arise from original signal components and frequency-shifted signal components. Preferably the two filters 18, 19 are elliptical filters, also referred to as Cauer filters. They possess an especially steep edge, which can bring about an extreme reduction of an undesired signal overlay in the filter
10 overlap area in addition to the different choice of the limit frequencies.

The invention is able to be used both for hearing devices with one microphone and for devices with a number of microphones. With a number of microphones there are also a number of feedback suppression units and a number of invent-
15 tive frequency filters which are supplied by different signal-processed microphone signals.

Frequency curves K5, K6, K7, K8, K9, K10 of corresponding Cauer filters employed in accordance with the invention are shown in Fig. 4. The two diagrams
20 of Figure 4 show the amplitude D in dB as a function of the frequency F in kHz for a frequency range of 650 Hz to 1150 Hz.

The upper diagram of Figure 4 shows the frequency curves K5, K6 of first Cauer filters with a narrow and deep notch of the sum frequency curve K7 as a result of a corresponding embodiment of the first Cauer filter. The distance be-
25 tween the first limit frequency GF1 of the low-pass (curve K5) and the second limit frequency GF2 of the high-pass (curve K6) is selected relatively small. The first limit frequency GF1 lies at around 890 Hz, the second limit frequency GF2 at around 910 Hz.

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The lower diagram of Figure 4 shows the frequency curves K8, K9 of second Cauer filters with a broader and less deep notch of the sum frequency curve as a result of a corresponding embodiment of the second Cauer filters. A wider gap

is selected between the first limit frequency GF1 of the low-pass (curve K8) and the second limit frequency GF2 of the high-pass (curve K9). The first limit frequency GF1 lies at around 880 Hz and the second limit frequency GF2 at around 920 Hz.

5

Trials have shown that the invention generates significantly lower signal disturbances in the hearing devices with frequency shifting, because no duplicated frequency components occur, which would cause a rough sound.

10 List of reference characters

1	Hearing device
2	Microphone
3	Signal processing unit
4	Earpiece
5	Compensation filter
6	Detection unit
7	Eardrum
10	Useful signal
11	Microphone signal
12	Earpiece signal
13	Output signal
14	Feedback path
15	Compensation signal
16	Input signal
17	Feedback suppression unit
18	Low-pass filter with first limit frequency GF1
19	High-pass filter with second limit frequency GF2
20	Frequency shift unit
21	First adder
22	Second adder

101	Input signal with acoustic feedback
102	Microphone signal
103	Output signal of signal processing unit 3
104	High-pass output signal
105	Low-pass output signal
106	Frequency-shifted high-pass output signal
107	Feedback-suppressed microphone signal
108	Earpiece input signal
109	Feedback suppression signal
D	Attenuation in dB
F	Frequency in kHz
GF	Limit frequency of the Butterworth filter
GF1	First limit frequency
GF2	Second limit frequency
K1	Frequency curve of a Butterworth low-pass filter
K2	Frequency curve of a Butterworth high-pass filter
K3	Sum frequency curve of the two Butterworth filters
K4	Frequency curve of a Butterworth high-pass filter shifted in frequency
K5	Frequency curve of a first Cauer low-pass filter
K6	Frequency curve of a first Cauer high-pass filter
K7	Sum frequency curve of the two first Cauer filters K5, K6
K8	Frequency curve of a second Cauer low-pass filter
K9	Frequency curve of a second Cauer high-pass filter
K10	Sum frequency curve of the two second Cauer filters K5, K6

Patentkrav

1. Høreapparat (1) med

- 5 - en tilbagekoblingsundertrykningsenhed (17), og
 - en signalforarbejdningssenhed (3)

kendetegnet ved:

- 10 - et ved hjælp af en første grænsefrekvens (GF1) karakteriseret lavpasfilter (18), som fra et udgangssignal (103) fra signalforarbejdningssenheden (3) udkobler en lavfrekvent signaldel (105),
 - et ved hjælp af en anden grænsefrekvens (GF2) karakteriseret højpasfilter (19), som fra signalforarbejdningssenhedens (3) udgangssignal (103)
15 udkobler en højfrekvent signaldel (104),
 - en frekvensforskydningsenhed (20), som forskyder den højfrekvente signaldel (104) til højere frekvenser, og
 - en første adderer (21), hvori den lavfrekvente signaldel (105) og den inden for frekvenserne forskudte højfrekvente signaldel (106) summeres,
20 hvoraf der dannes et udgangssignal (13) fra høreapparatet (1),
 - hvorved den første og den anden grænsefrekvens (GF1, GF2) er forskellig.

2. Høreapparat (1) ifølge krav 1,

25 **kendetegnet ved,**

at den første og den anden grænsefrekvens' (GF1, GF2) afstand er imellem 20 Hz og 50 Hz stor.

3. Høreapparat (1) ifølge krav 1 eller 2,

30 **kendetegnet ved,**

at den højfrekvente signaldels (104) frekvensforskydning udgør 10 Hz til 30 Hz.

4. Høreapparat (1) ifølge et af de foregående krav,

kendetegnet ved,

at lavpasfilteret (18) og/eller højpasfilteret (19) er tildannet som cauer-filter.

5. Fremgangsmåde til frekvensforskydning i et høreapparat (1), **kendetegnet ved:**

- en udkobling af en lavfrekvent signaldel (105) fra et signalforarbejdende mikrofonsignal (103) ved hjælp af et ved hjælp af en første grænsefrekvens (GF1) karakteriseret lavpasfilter (18),
- 10 - en udkobling af en højfrekvent signaldel (104) fra det signalforarbejdende mikrofonsignal (103) ved hjælp af et ved hjælp af en anden grænsefrekvens (GF2) karakteriseret højpasfilter (19),
- hvorved den første og den anden grænsefrekvens (GF1, GF2) er forskellig,
- 15 - en forskydning af den højfrekvente signaldel (104) til højere frekvenser, og
- en addition af den lavfrekvente signalandel (105) og den inden for frekvenserne (F) forskudte højfrekvente signaldel (106),
- hvorved der dannes et udgangssignal (13) fra høreapparatet (1).

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6. Fremgangsmåde ifølge krav 5,

kendetegnet ved,

at afstanden imellem den første og den anden grænsefrekvens (GF1, GF2) vælges imellem 20 Hz og 50 Hz.

25

7. Fremgangsmåde ifølge krav 5 eller 6,

kendetegnet ved,

at den højfrekvente signaldels (104) frekvenser (F) forskydes 10 Hz til 30 Hz.

- 30 8. Fremgangsmåde ifølge et af kravene 5 til 7,

kendetegnet ved,

at lavpasfilteret (18) og/eller højpasfilteret (19) tildannes om cauer-filter.

FIG 1

Prior art

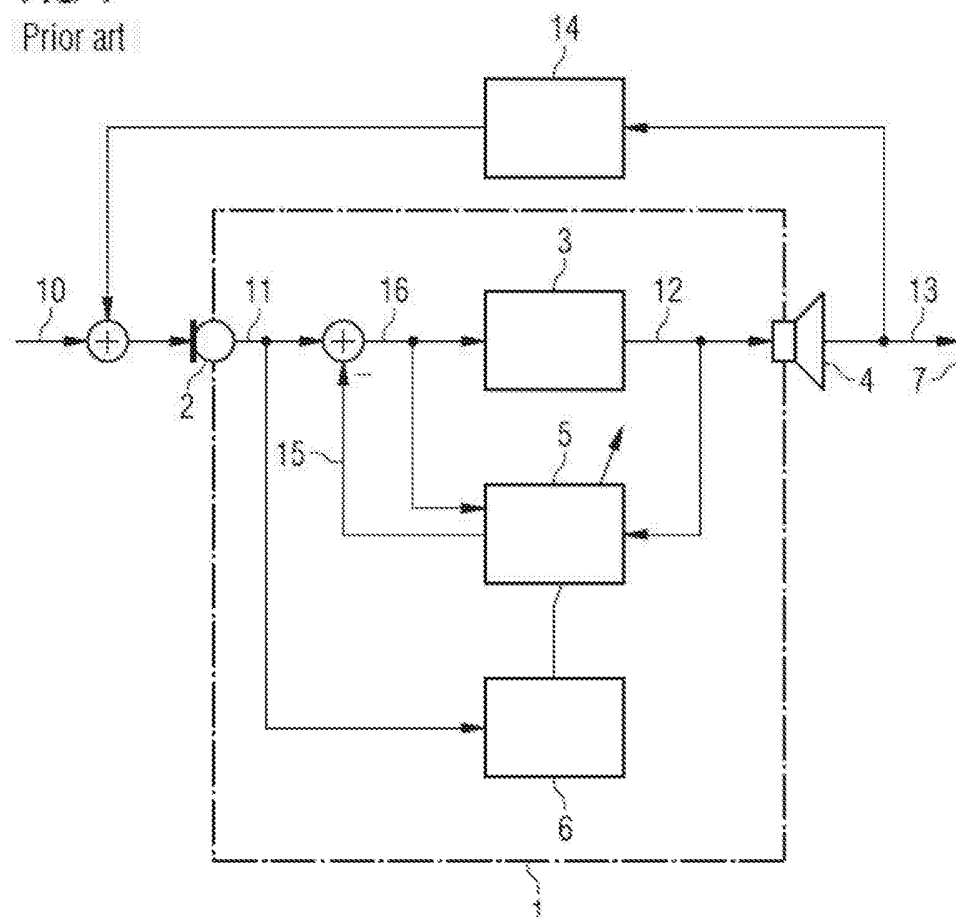
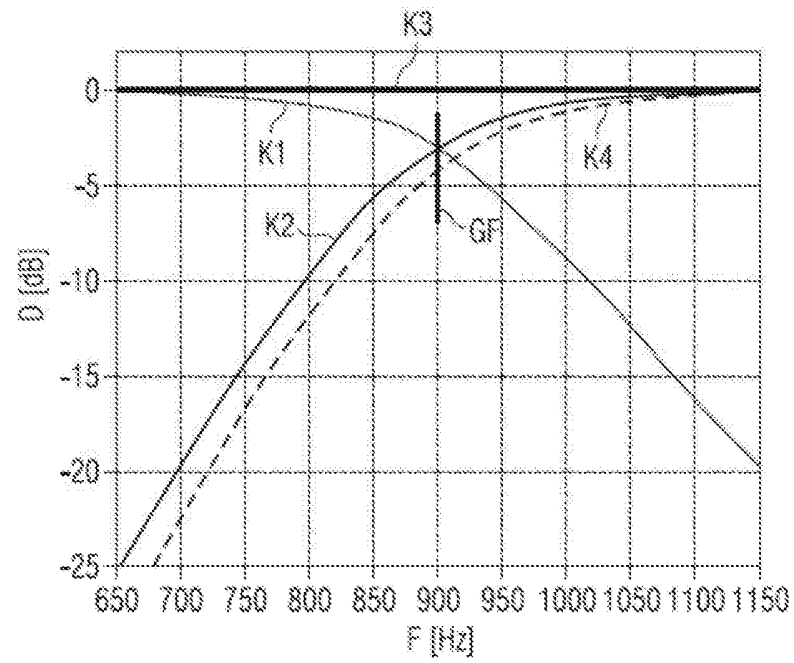


FIG 2

Prior art



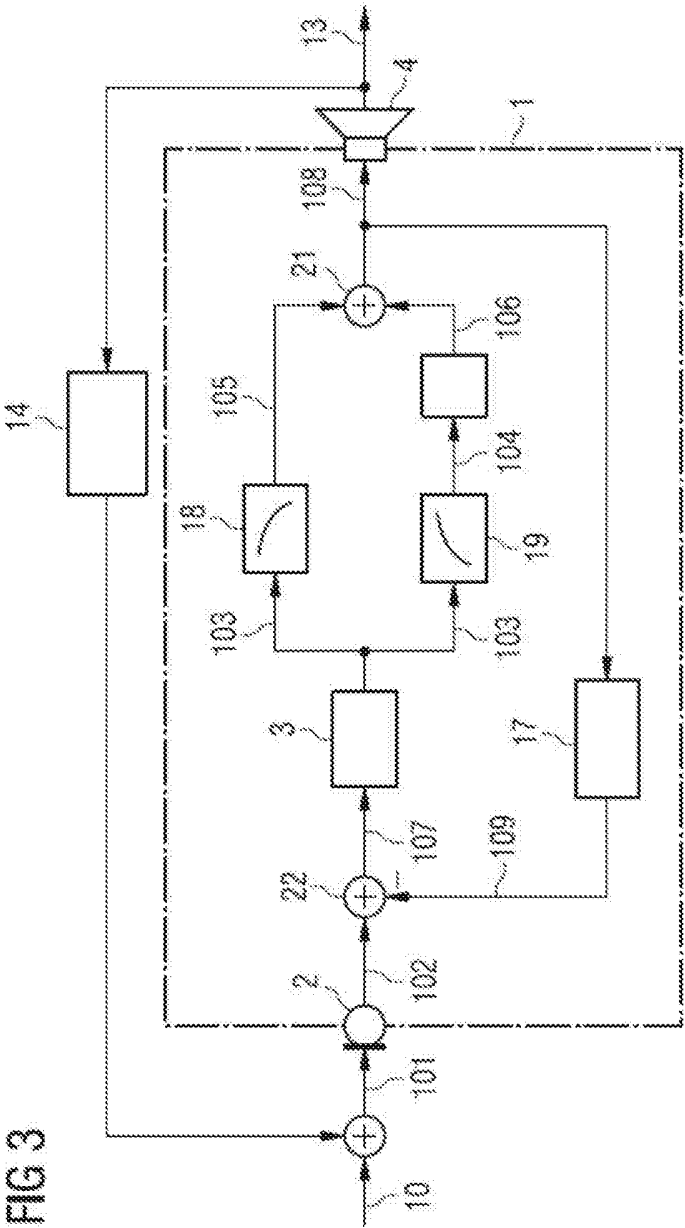


FIG 4

