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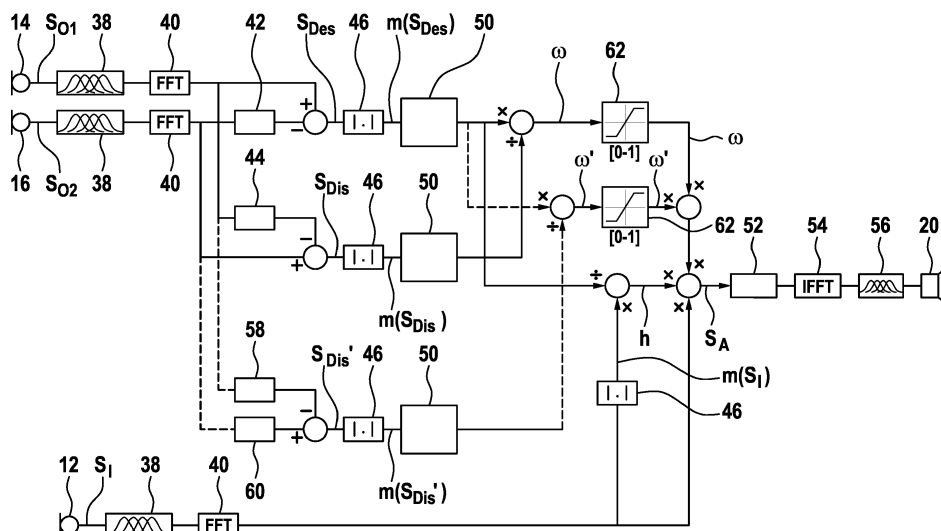
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(54) **REDUCING NOISE IN A SOUND SIGNAL OF A HEARING DEVICE**

(57) A method for reducing noise in a sound signal of a hearing device (10) comprises: receiving an inside channel sound signal (S_i) from a first microphone (12) in an ear channel of a user, a first outside channel sound signal (S_{O1}) from a second microphone (14) outside of the ear channel and a second outside channel sound signal (S_{O2}) from a third microphone (16) outside of the ear channel; determining a desired signal (S_{Des}) from the first and second outside channel sound signals (S_{O1} ,

S_{O2}) and a disturb signal (S_{Dis}) from the first and second outside channel sound signals; determining a frequency band dependent weight factor (ω) by dividing a magnitude value of the desired signal (S_{Des}) in a frequency band through at least a magnitude value of the disturb signal (S_{Dis}) in the frequency band; and generating a noise reduced sound signal (S_A) by multiplying the inside channel sound signal (S_i) with the weight factor (ω).

Fig. 4



Description

FIELD OF THE INVENTION

- 5 **[0001]** The invention relates to a method, a computer program and a computer-readable medium for reducing noise in a sound signal of a hearing device.

BACKGROUND OF THE INVENTION

- 10 **[0002]** Hearing aids are wearable devices, which are designed to compensate a hearing loss of the person or user wearing the hearing aid. It may be that sound signals acquired by the hearing aid are frequency dependent amplified, which would be too silent to be heard by the user. This frequency dependent amplification may be individually adjusted to the hearing loss of the user. Furthermore, it may be possible that specific components of the sound signals, such as speech or desired sound sources, are amplified with respect to disturb sound.

- 15 **[0003]** There are basically two methods, how such desired sound sources may be amplified.

- [0004]** In the first method, two microphones are used, and the sound signals from the two microphones are processed in such a way, that a direction dependent amplification is achieved. This is usually called beamforming. Sound from a specific direction, usually to the front of the user, is amplified, which sound from other directions is damped. It is known that with the aid of beamforming, the signal-to-noise ratio of a hearing aid may be improved by 3 to 8 dB with respect to omnidirectional sound processing. Beamforming may be performed in the time domain and in the frequency domain and may be controlled differently in different frequency bands.

- [0005]** The second method tries to filter the energy from disturb signals. The sound spectrum of a disturb source is estimated, for example during a speech pause, in which only the disturb source is present. After the speech pause, the spectrum may be subtracted from the overall sound signal. However, this method is usually only applicable in situations with only slow varying spectral information. Furthermore, artifacts, like so called "musical noise", may be generated, which reduce the quality of the desired sound signal.

- 25 **[0006]** In general, there are two types of hearing aids, which are used by persons with hearing losses.

- [0007]** The first type is called behind-the-ear hearing aids, which are carried behind the ear. These behind-the-ear hearing aids usually have two or more microphones provided in its housing, which signals may be used for beamforming. Behind-the-ear hearing aids may have the advantages that an ear channel insert (such as an otoplastics) may be designed acoustically more closed or more opened, as desired.

- [0008]** The second type of hearing aids is called in-the-ear or in-the-channel hearing aids, which are completely or nearly completely carried in the ear channel. These types of hearing aids may have the advantage that their microphone is positioned at the entrance of the ear channel, such that it acquires sound signals, which have already been formed by the ear and other components of the head, which results to a rather natural hearing experience.

- 35 **[0009]** In particular, the spectral information from the concha is lost for behind-the-ear hearing aids, which spectral information is important for distinguishing the direction of a sound source. Furthermore, the spectral information plays a role in elevation perception, externalization, and a natural spatial perception.

- [0010]** US 2010/0 329 492 A1 relates to a method for reducing noise in an input signal of a hearing aid, in which the sound signals from two microphones are transformed into a desired signal and a disturb signal. The disturb signal may be frequency depended amplified with a weight function based on a Wiener filter.

DESCRIPTION OF THE INVENTION

- 45 **[0011]** It is an objective of the invention to provide a hearing device, with a natural hearing experience and a good noise reduction.

- [0012]** This objective is achieved by the subject-matter of the independent claims. Further exemplary embodiments are evident from the dependent claims and the following description.

- 50 **[0013]** A first aspect of the invention relates to a method for reducing noise in a sound signal of a hearing device. The method may be performed automatically by a computing device of the hearing aid. The hearing device may be a hearing aid wearable by a user of the hearing device and/or may comprise further components, which may be situated remote from a component at the ear or in the ear of the user.

- [0014]** According to an embodiment of the invention, the method comprises: receiving an inside channel sound signal from a microphone in an ear channel of a user of the hearing device, a first outside channel sound signal from a microphone outside of the ear channel and a second outside channel sound signal from a further microphone outside of the ear channel. In a first step of the method, at least three sound signals may be acquired. The inside channel sound signal may be acquired inside the ear channel. The first and second outside channel sound signals may be acquired outside of the ear channel, for example with a component of the hearing device behind the ear.

[0015] It has to be noted that "in the ear channel" may mean a position (such that of a microphone) at the entrance of the ear channel or between the entrance and the eardrum.

[0016] A sound signal in general may be a signal from a microphone that is digitized by a computing device of the hearing aid for further processing. It may be that the sound signals mentioned above are transformed into the frequency domain, for example with a FFT (fast Fourier transform).

[0017] According to an embodiment of the invention, the method further comprises: determining a desired signal from the first and second outside channel sound signals and a disturb signal from the first and second outside channel sound signals. In a further step of the method, the sound signals from the first and second microphone outside of the ear channel are transformed into signals, which are indicative of a desired sound source and a disturb sound source.

[0018] In general, the desired signal may be indicative of a desired sound source and/or the disturb signal may be indicative of one or more disturb sound sources. The desired signal may be a signal comprising more spectral information from a desired sound source as from one or more disturb sources. Here, spectral information may comprise frequency band dependent amplitudes and/or phases of the sound signal. For example, the desired sound signal and the disturb signal may be determined by adding and/or subtracting the first and second outside channel sound signals, which may be filtered before adding and/or subtracting. The desired signal and the disturb signal may be determined by beamforming.

[0019] It also may be possible that the first outside channel sound signal is acquired with a microphone nearer to a desired sound source as the microphone, which acquires the second outside channel sound signal and which is nearer to a disturb sound source.

[0020] According to an embodiment of the invention, the method further comprises: determining a frequency band dependent weight factor by dividing a magnitude value of the desired signal in a frequency band through at least a magnitude value of the disturb signal in the frequency band. In the next step of the method, a weight factor for multiplication with the inside channel sound signal may be determined solely from the desired signal and the disturb signal. The weight factor for reducing the disturb sound may be determined independently from the sound signal in the ear channel, which may result in a good signal-to-noise ratio.

[0021] The weight factor is frequency band dependent, i.e. there may be a value for the weight factor for each frequency band that is processed with the method. For example, the respective sound signals may be Fourier transformed into frequency bins, each of which may be seen as a frequency band. Then, for every frequency bin, the weight factor may be determined.

[0022] The weight factor is determined from magnitude values of the desired signal and disturb signal. A magnitude value may be a (real) value that only depends on the amplitude of the sound signal and not its phase. For example, when the sound signals are provided with complex numbers, the magnitude value may be a function of the absolute value of the complex numbers.

[0023] The magnitude value may be a function of the sound pressure of the sound signal in the frequency band, which is equivalent to an absolute value of a complex valued sound signal, or may be a function of the energy of the sound signal in the frequency band, which is equivalent to a square of the absolute value of a complex valued sound signal.

[0024] The weight value may be determined by dividing the magnitude value of the desired signal through at least the magnitude value of the disturb signal, i.e. through a denominator comprising the magnitude of the disturb signal. As will be mentioned below, the denominator may comprise further factors and/or summands.

[0025] According to an embodiment of the invention, the method further comprises: determining a frequency band dependent correction factor by dividing a magnitude value of the inside channel sound signal in a frequency band through a magnitude value of at least one of the disturb signal and desired signal. In a further step of the method, a correction factor is determined, which may account for the different sound levels of the inside channel sound signal and the outside channel sound signals. The correction factor may be determined by dividing a magnitude value of the inside channel sound signal through the magnitude value of the disturb signal, the desired signal or a sum thereof. The magnitude value of the inside channel sound signal may be determined as the magnitude values for the other signals as described above.

[0026] According to an embodiment of the invention, the method further comprises: generating a noise reduced sound signal by multiplying the inside channel sound signal with the weight factor and optionally the correction factor. In the end, the weight factor and optionally the correction factor are used for adjusting the inside channel sound signal. Again, this calculation is performed per frequency band. It has to be noted that the weight factor and the correction factor are real values, which by multiplication only adjusts the amplitude of the inside channel sound signal but not its phase. Thus, the phase information of the inside channel sound signal is not changed.

[0027] The adjusted inside channel sound signal may be further processed by the hearing device to compensate for hearing losses of the user. For example, the adjusted inside channel sound signal may be frequency band dependent amplified with preset amplification factors individually chosen for the user.

[0028] With the method, hearing devices may be provided with the ability to modify spectral acoustic information in the ear channel of a user in such a way, that disturbing sound sources are damped but such that acoustic features (cues) of desired sound sources are maintained. These acoustic features may comprise a filtering of the sound by the concha. This may have positive effects on a spatial resolution of sound sources, an externalization, a distance perception, a

source wideness and problems with exchange of front and back.

[0029] According to an embodiment of the invention, the frequency band dependent weight factor is the magnitude value of the desired signal in the frequency band divided through the magnitude value of the disturb signal in the frequency band. This may be beneficial, when the disturb signal is noise and therefore never equal to 0. In combination with a restriction of the weight factor to a range with upper border equal to 1, for a small disturb signal, the weight factor becomes 1 and the inside channel sound signal is not modified. Furthermore, musical noise, which may be generated by other weight functions during fast changing situations, may be avoided.

[0030] According to an embodiment of the invention, the frequency band dependent weight factor is the magnitude value of the desired signal in the frequency band divided through the sum of the magnitude value of the desired signal in the frequency band and the magnitude value of the disturb signal in the frequency band. Such a weight factor may model a Wiener filter, which also may effectively remove contributions of the disturb signal from the inside channel sound signal. This weight factor may be used, when the weight factor is not restricted to a range and/or compressed.

[0031] According to an embodiment of the invention, the method further comprises: determining at least one further disturb signal from the first and second outside channel sound signals; and multiplying the noise reduced sound signal with at least one further frequency band dependent weight factor, which is determined from the further disturb signal and the desired signal. It is possible that not only one but two or more disturb signals are used for adjusting the inside channel sound signal. Every disturb signal may be used for determining a weight factor as described above. All these weight factors may be multiplied with the inside channel sound signal. For example, for different disturb sound sources (which may lie in different directions), different disturb signals may be used.

[0032] According to an embodiment of the invention, the magnitude value of the desired signal and the magnitude value of the disturb signal are averaged with a moving average before the frequency band dependent weight factor is determined from them. The weight factors and/or the correction factors may be determined repeatedly for short time intervals, in which the respective signals are transformed into the frequency domain. It may be that the magnitude values input into the weight factor and/or the correction factors are averaged for several of these time intervals, for example with a moving average. This also may reduce musical noise.

[0033] According to an embodiment of the invention, the weight factor is multiplied with a frequency band dependent factor. It may be that for further optimizing, the weight factor is adjusted with constant frequency dependent factors. For example, specific frequency bands may be damped in general more strongly as others.

[0034] According to an embodiment of the invention, the correction factor is multiplied with a frequency band dependent factor. For example, with such a constant factor, the transfer function between different microphone positions inside the ear channel and outside the ear channel may be modeled. It also may be that the nominator and/or denominator of the correction factor may be multiplied with constant frequency dependent factors, for example for modeling such transfer functions.

[0035] According to an embodiment of the invention, the method further comprises: restricting the weight factor and/or the correction factor to a value range. In general, these factors or the product of these factors may be restricted to values bigger than a lower bound and/or to values smaller than an upper bound. This may be achieved by setting values greater and/or smaller than the respective bound to the respective bound.

[0036] According to an embodiment of the invention, a compressor function is applied to the weight factor and/or the correction factor, which moves the values of the weight factor and/or the correction factor within the value range. It also may be that the restriction to a value range may be achieved by a function, changes the values of the weight factor and/or correction factor in such a way, that after the transformation, no values lie outside the desired value range any more.

[0037] According to an embodiment of the invention, the value range is within 0 to 1. A lower bound of the value range may be 0 or greater. An upper bound of the value range may be 1 or lower.

[0038] According to an embodiment of the invention, the desired signal is a beamformed signal, which is amplified towards a desired direction and damped in an opposite direction and/or the disturb signal is a beamformed signal, which is damped towards the desired direction and amplified towards the opposite direction. One possibility of transforming the desired signal and the disturb signal is by beamforming. In this case, it may be assumed that the desired sound source is in the desired direction, such as a front direction of the user and the disturb sound sources are located in another direction. This may be modeled with a beamformed disturb signal in the opposite direction, such as the back direction of the user.

[0039] According to an embodiment of the invention, the desired signal is determined by filtering the second outside channel sound signal and subtracting the filtered second outside channel sound signal from the first outside channel sound signal. Also, the disturb signal may be determined by filtering the first outside channel sound signal and subtracting the filtered first outside channel sound signal from the second outside channel sound signal. A beamformed signal may be determined from the sound signals of two different microphones by filtering one of the sound signals of one of the microphones with a frequency (band) dependent filter and subtracting the other signal. In this case, filtering may comprise frequency (band) dependent damping of the respective signal. It has to be noted that not only one but further disturb signals may be determined by filtering both outside channel sound signals with different filters.

[0040] According to an embodiment of the invention, the magnitude value of a signal in a frequency band is a value depending on an energy of the signal in the frequency band. A magnitude value of the desired signal, the disturb signal and or the first and second outside channel sound signal may be determined per frequency band, such as for a specific frequency bin. From the signal components in the frequency band and/or bin, an energy of the signal in this band and/or

bin may be determined. The magnitude value then may be a function of this energy.

[0041] In the case, these signals are encoded with complex numbers, the energy may be based on the square of the absolute values of the complex numbers.

[0042] It may be that the magnitude value of a signal in a frequency band is the signal energy of the respective signal in the frequency band. In this case, the magnitude value may be determined by multiplying the corresponding complex numbers with its conjugate.

[0043] It also may be that the magnitude value of a signal in the frequency band is the sound pressure of the respective signal in the frequency band. The sound pressure is proportional to a square root of the energy and/or may be determined directly from the absolute value of the complex numbers used for encoding the respective signal.

[0044] Further aspects of the invention relate to a computer program for reducing noise in a signal of a hearing device, which, when being executed by a processor, is adapted to carry out the steps of the method as described in the above and in the following as well as to a computer-readable medium, in which such a computer program is stored.

[0045] For example, the computer program may be executed in a processor of a hearing aid, which, for example, may be carried by the user behind the ear. The computer-readable-medium may be a memory of this hearing aid.

[0046] In general, a computer-readable medium may be a floppy disk, a hard disk, an USB (Universal Serial Bus) storage device, a RAM (Random Access Memory), a ROM (Read Only Memory), an EPROM (Erasable Programmable Read Only Memory) or a FLASH memory. A computer-readable medium may also be a data communication network, e.g. the Internet, which allows downloading a program code. The computer-readable medium may be a non-transitory or transitory medium.

[0047] A further aspect of the invention relates to a hearing device, which comprises a first microphone adapted for being put in an ear channel of a user; a second microphone adapted for being arranged outside of the ear channel, a third microphone adapted for being arranged outside of the ear channel; and a computing device adapted for performing the method as described in the above and in the following.

[0048] The three microphones may be mechanically interconnected within one device. However, it also may be possible that the microphone on the ear channel is provided by a hearing aid and the other two microphones outside of the ear channel are provided by a further device, which is mechanically separated from the hearing aid.

[0049] According to an embodiment of the invention, the hearing device is a hearing aid adapted for being carried at an ear of the user, which comprises the first microphone in a device component for being put in the ear channel and which comprises the second and third microphone in a device component behind the ear. For example, the hearing aid may have an open insert for the ear channel, which carries the in-the-ear microphone and which has an opening, such that sound from the environment can enter the ear channel. The insert may be connected to a device component behind the ear, which carries the two further microphones.

[0050] According to an embodiment of the invention, the hearing device comprises a hearing aid which comprises the first microphone in a device component for being put in the ear channel. The hearing device comprises a further device communicatively interconnected with the hearing aid and comprising the second and/or third microphone. In this case, the hearing aid may be an in-the-ear hearing aid, which is completely provided in the ear channel. The further device may be a component behind the ear, which may or may not be directly mechanically interconnected with the in-the-ear hearing aid. However, it also may be that the further device is a pen with two microphones, a smartphone, etc., which may be carried by the user in his hands.

[0051] It has to be understood that features of the method as described in the above and in the following may be features of the computer program, the computer-readable medium and the hearing device as described in the above and in the following, and vice versa.

[0052] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] Below, embodiments of the present invention are described in more detail with reference to the attached drawings.

Fig. 1 schematically shows a hearing device according to an embodiment of the invention.

Fig. 2 schematically shows a hearing device according to a further embodiment of the invention.

Fig. 3 schematically shows a hearing device according to a further embodiment of the invention.

Fig. 4 shows a diagram illustrating a method for reducing noise in a sound signal of a hearing device according to an embodiment of the invention.

Fig. 5A, 5B and 5C are diagrams illustrating beamformed signals.

[0054] The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0055] Fig. 1 shows a hearing device 10, which comprises an in-the-ear microphone 12, which is adapted for being arranged in the ear channel of a user, and two outside-the-ear microphones 14, 16, which are adapted for being arranged outside the ear channel.

[0056] A computing device 18 receives sound signals S_I , S_{O1} , S_{O2} from the microphones 12, 14, 16 and produces an adjusted sound signal S_A , which is output by a loudspeaker 20 to be heard by the user.

[0057] In particular, the first outside channel sound signal S_{O1} and the second outside channel sound signal S_{O2} are used for determining a desired signal and one or more disturb signals from which a frequency dependent factor is determined, which is multiplied with the inside channel sound signal S_I for generating the adjusted sound signal S_A .

[0058] Fig. 2 shows an embodiment of the hearing device 10, which is a hearing aid 22, which comprises an in-the-channel component 24 and a behind-the-ear component 26. The behind-the-ear component 26 provides the two microphones 14, 16 in a housing 28. This housing 28 also may accommodate the computing device 18. The in-the-channel component 24, which is carried substantially or completely inside the ear channel, provides the microphone 12, for example at an outside end, and the loudspeaker 20, for example at an inside end. It has to be noted that the microphone 12 may be arranged inside the ear channel or at an outer end, i.e. the entrance of the ear channel.

[0059] Both components 24, 26 may be interconnected with a communication line 30, which is used for transmitting the signals S_I and S_A .

[0060] Fig. 3 shows a further embodiment of the hearing device 10, which comprises a hearing aid 22 with solely an in-the-ear component 24, which provides the microphone 12 and the loudspeaker 20. The computing device 18 also may be provided in the in-the-ear component 24. The hearing aid 22 may be wireless communicatively connected with one or two devices 32, which provide the microphones 14, 16. In one embodiment, the two microphones 14, 16 are provided by one mechanically connected component, such as a pen, a smartphone, etc. In another embodiment, the microphone 14 is located near a desired sound source 34 and the microphone 16 is located near a disturb sound source 36.

[0061] Fig. 4 shows a diagram that illustrates a method that may be performed with the hearing aid 10. All the steps described in the following may be performed by the computing device 18.

[0062] For performing the following calculations, the outside channel sound signals S_{O1} and S_{O2} as well as the inside channel sound signal S_I are demodulated by demodulators 38 into respective digital signals and after that transformed into the frequency domain. This transformation is performed by Fourier transformation blocks 40, which apply a fast Fourier transformation (FFT) onto the respective digitized signal S_{O1} , S_{O2} and S_I .

[0063] For example, each signal S_{O1} , S_{O2} , S_I may be cut into time frames, of for example 50 μ s. These frames may be transformed into for example 100 Hz width frequency bands or bins, which for example cover the signals up to 20 kHz. A frequency band of a frame may be represented by a complex number after the transformation.

[0064] In the following, the frequency bands of the respective signals after the transformation will be denoted with $S_{O1,i}(t_j)$, $S_{O2,i}(t_j)$, $S_{I,i}(t_j)$, where i indicates the frequency band and t_j the time frame.

[0065] In general, the method is based on the assumption that the desired sound source 34 and disturb sound source 36 have different spectral information at different time points, i.e. that the amplitudes and the phases of the corresponding sound signals are different at different time points. Since the sound pressure fields of several sources 34, 36 may be added by superposition, also the spectral information is a sum of the components of the several sources 34, 36.

[0066] When known, the components of the disturb sound sources 36 for a sound signal in the ear channel may be subtracted, which results in a selective damping of these components in this sound signal.

[0067] As shown in Fig. 4, a desired signal S_{Des} and a disturb signal S_{Dis} are determined from the first and second outside channel sound signals S_{O1} , S_{O2} in the following way.

[0068] The desired signal S_{Des} is determined by filtering the second outside channel sound signal S_{O2} with a filter 42 and subtracting the filtered second outside channel sound signal S_{O2} from the first outside channel sound signal S_{O1} . As shown in Fig. 5A, the desired signal S_{Des} may be a beamformed signal, which is amplified towards a desired direction, i.e. the direction towards the desired sound source 34 and damped in an opposite direction. This damping form is also called cardioid shaped damping.

[0069] Also, the disturb signal S_{Dis} may be a beamformed signal, which is damped towards the desired direction and amplified towards the opposite direction, as shown in Fig. 5B. The disturb signal S_{Dis} may be determined by filtering the first outside channel sound signal S_{O1} with a filter 44 and subtracting the filtered first outside channel sound signal S_{O1} from the second outside channel sound signal S_{O2} .

[0070] The filters 42, 44 may frequency dependent amplify the signal S_{O2} , for example by multiplying a frequency frame dependent constant to the value in each frequency band.

[0071] It is possible that the desired signal S_{Des} and the disturb signal S_{Dis} are determined in another way from the outer channel sound signals S_{O1} , S_{O2} . For example, signal coherence and modulation of these signals may be used for separating the signals S_{Des} and S_{Dis} . It also may possible that, as in the case of Fig. 3 with two microphone devices 32 with one nearer to the respective sound source 34, 36 as the other, S_{Des} is simply set to S_{O1} and S_{Dis} is simply set to S_{O2} .

[0072] In general, the disturb signal S_{Dis} contains substantially the spectrum of the disturb source 36, i.e. which frequencies with amplitudes and phases are generated from the disturb source 36. Analogously, the desired signal S_{Des} contains substantially the spectrum of the desired source 34, i.e. which frequencies with amplitudes and phases are generated from the desired source 36.

[0073] It has to be noted that, since both sound signals S_{O1} and S_{O2} have been acquired outside of the ear channel and/or outside of the ear, the signals S_{Des} and S_{Dis} do not contain components of the filtering of the ear and head of the user.

[0074] Since the previous calculations may be performed per time frame t_j and per frequency band i , the results are values $S_{Des,i}(t_j)$ and $S_{Dis,i}(t_j)$.

[0075] From these values, magnitude values $m(S_{Dis,i}(t_j))$ and $m(S_{Des,i}(t_j))$ are determined with the blocks 46. In general, each magnitude value of a signal in a frequency band i may be a value depending on the signal energy in the frequency band i . When the values $S_{Des,i}(t_j)$ and $S_{Dis,i}(t_j)$ are complex numbers, then their absolute value is proportional to the sound pressure and the square of the absolute value, which may be determined by multiplying the respective complex number with its conjugate, is proportional to the signal energy. The signal energy, the signal pressure or a function thereof may be used as magnitude value.

[0076] The magnitude value $m(S_{Des,i}(t_j))$ of the desired signal (S_{Des}) and the magnitude value $m(S_{Dis,i}(t_j))$ of the disturb signal (S_{Dis}) may be averaged with a moving average, for example a weighted moving average. It also may be possible that a moving average is directly performed on the signals S_{Dis} and S_{Des} and that the magnitude values $m(S_{Des,i}(t_j))$, $m(S_{Dis,i}(t_j))$ are determined afterwards.

[0077] From the magnitude values $m(S_{Des,i}(t_j))$, $m(S_{Dis,i}(t_j))$, a weight factor ω is determined, which may be calculated for every time frame t_j and every frequency band. In general, the frequency band dependent weight factor $\omega_i(t_j)$ is determined by dividing the magnitude value $m(S_{Des,i}(t_j))$ of the desired signal S_{Des} through a function of the magnitude value $m(S_{Des,i}(t_j))$ of the disturb signal S_{Dis} . This function may be linear in the magnitude value $m(S_{Des,i}(t_j))$ and/or may comprise further summands.

[0078] As a first example, the weight factor $\omega_i(t_j)$ may be proportional to the magnitude value $m(S_{Des,i}(t_j))$ of the desired signal S_{Des} divided through the magnitude value $m(S_{Dis,i}(t_j))$ of the disturb signal S_{Dis} .

$$\omega_i(t_j) = \alpha_i * m(S_{Des,i}(t_j)) / m(S_{Dis,i}(t_j))$$

[0079] Such a weight factor ω may be beneficial, when there is always noise in the disturb signal S_{Dis} and a division by zero is not critical. Especially, when the weight factor ω is compressed (see below), the spectrum of the adjusted signal S_A is not altered, when the noise in the signal S_{Dis} is low.

[0080] As also shown in the above formula, the weight factor w may be multiplied with a frequency band dependent constant factor α_i , which for example may weigh the damping of the weight factor per frequency band.

[0081] It also may be possible to determine the weight factor w with a Wiener filter. In this case, the weight factor $\omega_i(t_j)$ may be proportional to the magnitude value $m(S_{Des,i}(t_j))$ of the desired signal S_{Des} divided through the sum of the magnitude value $m(S_{Des,i}(t_j))$ of the desired signal S_{Des} and the magnitude value $m(S_{Dis,i}(t_j))$ of the disturb signal S_{Dis} .

$$\omega_i(t_j) = \alpha_i * m(S_{Des,i}(t_j)) / (m(S_{Des,i}(t_j)) + m(S_{Dis,i}(t_j)))$$

[0082] The noise reduced sound signal S_A may then be determined by multiplying the inside channel sound signal S_i with the weight factor ω .

$$S_{A,i}(t_j) = \omega_i(t_j) * S_{i,i}(t_j)$$

[0083] In the signal S_A , the contributions from the disturb sound source 36 are suppressed, which influences of the ear and the head of the user using the hearing device 10 are still present. This may result in a more natural hearing experience.

[0084] The noise reduced sound signal S_A may be further processed with a frequency dependent filter and/or amplification and/or compression, as shown with block 52. This filter and/or amplification and/or compression may be individually adjusted to the hearing deficiencies of the user. In general, block 52 may provide further hearing aid functionality.

[0085] In block 54, the further processed sound signal may be transformed back with an inverse fast Fourier transformation (IFFT), may be modulated with block 56 and may be output by the loudspeaker 20.

[0086] It may be possible that not only one weight factor ω is determined, but that two or more weight factors ω' are determined, which are based on different disturb signals S_{Dis} .

[0087] As shown in Fig. 4, a further disturb signal S_{Dis}' may be determined from the first and second outside channel sound signals S_{O1} , S_{O2} . The further disturb signal S_{Dis}' may be determined by applying a first filter 58 to the first outside channel sound signal S_{O1} and a second filter 60 to the second outside channel sound signal S_{O2} . For generating the further disturb signal S_{Dis}' , both filtered signals may be subtracted from each other. The filters 58, 60 may operate like the filters 42, 44. For example, the further disturb signal S_{Dis}' may be a beamformed signal as shown in Fig. 5C, which may have more than one desired direction and/or more than one disturb direction.

[0088] Analogously to the weight signal ω , a further frequency band dependent weight factor ω' may be determined from the further disturb signal S_{Dis} and the desired signal S_{Des} . Also the weight factor ω' may be multiplied to the inside channel sound signal S_i for determining the noise reduced sound signal S_A .

$$S_{A,i}(t_j) = \omega_i(t_j) * \omega_i'(t_j) * S_{i,i}(t_j)$$

[0089] Note that the weight factors also may be weighted relatively to each other via multiplication with respective constant factors α_i (see above), which also then may be frequency independent.

[0090] As further shown in Fig. 4, it is also possible to additionally multiply a frequency dependent correction factor h to the one or more weight factors ω , ω' . For example, the correction factor h may be used for optimally weighting the frequency components of the weight factor w with respect to each other.

[0091] For determining the factor h , also from the FFT transformed inside channel sound signal $S_{i,i}(t_j)$, a magnitude value $m(S_{i,i}(t_j))$ is determined. It also may be that before or after the magnitude value $m(S_{i,i}(t_j))$ is determined, either inside channel sound signal $S_{i,i}(t_j)$ or the magnitude value $m(S_{i,i}(t_j))$ is averaged with a moving average or a weighted moving average.

[0092] The frequency band dependent and time frame dependent correction factor $h_i(t_j)$ is determined by dividing the magnitude value $m(S_{i,i}(t_j))$ of the inside channel sound signal S_i through the magnitude value of at least one of the desired and disturb sound signal S_{Des} , S_{Dis} .

[0093] Possible implementations of the correction factor h are

$$h_i(t_j) = (\beta_i * m(S_{i,i}(t_j))) / (\gamma_i * (m(S_{Des,i}(t_j)) + m(S_{Dis,i}(t_j))))$$

$$h_i(t_j) = (\beta_i * m(S_{i,i}(t_j))) / (\gamma_i * m(S_{Des,i}(t_j)))$$

$$h_i(t_j) = (\beta_i * m(S_{i,i}(t_j))) / (\gamma_i * m(S_{Dis,i}(t_j)))$$

[0094] The correction factor h , its nominator and/or its denominator may be multiplied with further frequency band dependent factors β_i , γ_i , which may model transfer functions between the position of the microphone 12 in the ear channel and the microphones 14, 16.

[0095] In this case, the noise reduced sound signal S_A is determined by multiplying the inside channel sound signal S_i with the one or more weight factors ω , ω' and the correction factor h .

$$S_{A,i}(t_j) = h_i(t_j) * \omega_i(t_j) * \omega_i'(t_j) * S_{i,i}(t_j)$$

[0096] A further possibility is that the one or more weight factors ω , ω' and/or the correction factor h are restricted to a value range. For example, the value range may be 0 to 1 or a subinterval therefrom. An example for this is shown in

Fig. 4 with two compressors 62, each of which restricts the weight factors ω and ω' . It may be possible that such a compressor 62 is also applied to the correction factor h .

[0097] The compressor 62 restricts the values $h_i(t_j)$, $\omega_i(t_j) * \omega'_i(t_j)$ within the range. This may be possible with a cutoff, which sets values outside of the range to the respective bound of the range. However, it also may be possible to move values outside the value range within the value range in a more complicated manner.

[0098] Alternatively, it is possible that a compressor is applied to the product of the one or more weights and/or the correction factor h .

[0099] It may be that the lower bound of the value range is greater than 0, such that no complete suppression of noise is possible. An upper bound of 1 may be beneficial, since in the case of no or nearly no noise, no distortion may take place.

[0100] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art and practising the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or controller or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SYMBOLS

[0101]

10	hearing device
12	in-the-ear microphone
14	outside-the-ear microphone
16	outside-the-ear microphone
18	computing device
20	loudspeaker
S_I	inside channel sound signal
S_{O1}	first outside channel sound signal
S_{O2}	second outside channel sound signal
22	hearing aid
24	in-the-channel component
26	behind-the-ear component
28	housing
30	communication line
32	microphone device
36	demodulator
40	FFT block
42	filter
44	filter
S_{Des}	desired signal
S_{Dis}	disturb signal
S_{Dis}'	further disturb signal
46	magnitude value block
$m(S_{Des})$	magnitude value of desired signal
$m(S_{Dis})$	magnitude value of disturb signal
$m(S_I)$	magnitude value of inside channel sound signal
$m(S_{Dis}')$	magnitude value of further disturb signal
48	moving average block
ω	weight factor
ω'	further weight factor
h	correction factor
52	hearing aid function block
54	IFFT block
56	modulator
58	filter

60 filter
62 compressor

5 Claims

1. A method for reducing noise in a sound signal of a hearing device (10), the method comprising:

receiving an inside channel sound signal (S_I) from a first microphone (12) in an ear channel of a user of the hearing device (10), a first outside channel sound signal (S_{O1}) from a second microphone (14) outside of the ear channel and a second outside channel sound signal (S_{O2}) from a third microphone (16) outside of the ear channel;

determining a desired signal (S_{Des}) and a disturb signal (S_{Dis}) from the first and second outside channel sound signals (S_{O1} , S_{O2});

determining a frequency band dependent weight factor (ω) by dividing a magnitude value of the desired signal (S_{Des}) in a frequency band through at least a magnitude value of the disturb signal (S_{Dis}) in the frequency band; generating a noise reduced sound signal (S_A) by multiplying the inside channel sound signal (S_I) with the weight factor (ω).

2. The method of claim 1,

wherein the frequency band dependent weight factor (ω) is the magnitude value of the desired signal (S_{Des}) in the frequency band divided through the magnitude value of the disturb signal (S_{Dis}) in the frequency band.

3. The method of claim 1,

wherein the frequency band dependent weight factor (ω) is the magnitude value of the desired signal (S_{Des}) in the frequency band divided through the sum of the magnitude value of the desired signal (S_{Des}) in the frequency band and the magnitude value of the disturb signal (S_{Dis}) in the frequency band.

4. The method of one of the previous claims, further comprising:

determining a frequency band dependent correction factor (h) by dividing a magnitude value of the inside channel sound signal (S_I) in a frequency band through a magnitude value of at least one of the desired signal (S_{Des}) and disturb signal (S_{Dis}) in the frequency band;

generating the noise reduced sound signal (S_A) by multiplying the inside channel sound signal (S_I) with the weight factor (ω) and the correction factor (h).

5. The method of one of the previous claims, further comprising:

determining at least one further disturb signal (S_{Dis}') from the first and second outside channel sound signals (S_{O1} , S_{O2});

multiplying the noise reduced sound signal (S_A) with at least one further frequency band dependent weight factor (ω'), which is determined from the further disturb signal (S_{Dis}) and the desired signal (S_{Des}).

6. The method of one of the previous claims,

wherein the magnitude value of the desired signal (S_{Des}) and the magnitude value of the disturb signal (S_{Dis}) are averaged with a moving average (50) before the frequency band dependent weight factor (ω) is determined from them.

7. The method of one of the previous claims, further comprising:

restricting the weight factor (ω) and/or the correction factor (h) to a value range;

wherein a compressor function (62) is applied to the weight factor (ω) and/or the correction factor (h), which moves the values of the weight factor (ω) and/or the correction factor (h) within the value range;

wherein the value range is within 0 to 1.

8. The method of one of the previous claims,

wherein the desired signal (S_{Des}) is a beamformed signal, which is amplified towards a desired direction and damped in an opposite direction;

wherein the disturb signal (S_{Dis}) is a beamformed signal, which is damped towards the desired direction and amplified

towards the opposite direction.

5 9. The method of one of the previous claims,
wherein the desired signal (S_{Des}) is determined by filtering the second outside channel sound signal (S_{O2}) and
subtracting the filtered second outside channel sound signal (S_{O2}) from the first outside channel sound signal (S_{O1});
wherein the disturb signal (S_{Dis}) is determined by filtering the first outside channel sound signal (S_{O1}) and subtracting
the filtered first outside channel sound signal (S_{O1}) from the second outside channel sound signal (S_{O2}).

10 10. The method of one of the previous claims,
wherein the magnitude value of a signal in a frequency band is a value depending on an energy of the signal in the
frequency band; or
wherein the magnitude value of a signal in a frequency band is the signal energy of the respective signal in the
frequency band; or
15 wherein the magnitude value of a signal in the frequency band is the sound pressure of the respective signal in the
frequency band.

11. A computer program for reducing noise in a signal of a hearing device (10), which, when being executed by a
processor, is adapted to carry out the steps of the method of one of claims 1 to 10.

20 12. A computer-readable medium, in which a computer program according to claim 11 is stored.

13. A hearing device (10), comprising:

25 a first microphone (12) adapted for being put in an ear channel of a user of the hearing device (10);
a second microphone (14) adapted for being arranged outside of the ear channel;
a third microphone (16) adapted for being arranged outside of the ear channel;
a computing device (18) adapted for performing the method of one of claims 1 to 10.

30 14. The hearing device (10) of claim 13,
wherein the hearing device (10) is a hearing aid (22) adapted for being carried at an ear of the user, which comprises
the first microphone (12) in a device component (24) for being put in the ear channel and which comprises the
second and third microphone (14, 16) in a device component (26) behind the ear.

35 15. The hearing device (10) of claim 13,
wherein the hearing device (10) comprises a hearing aid (22) which comprises the first microphone (12) in a device
component (24) for being put in the ear channel;
wherein the hearing device (10) comprises a further device (32) communicatively interconnected with the hearing
aid (22) and comprising the second microphone (14) and/or third microphone (16).

Fig. 1

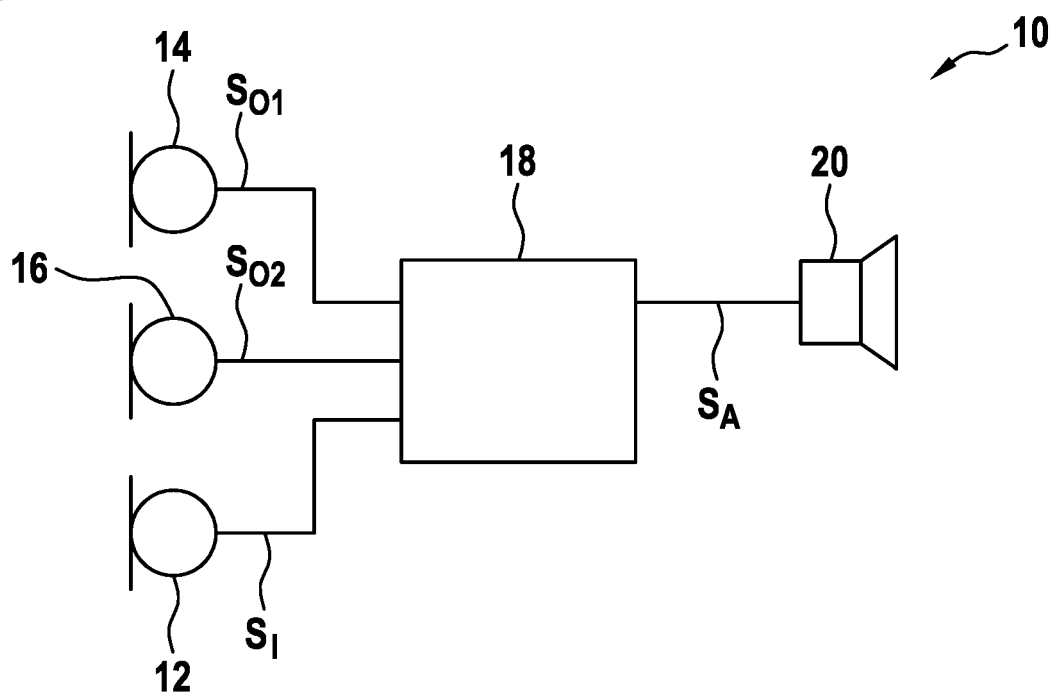


Fig. 2

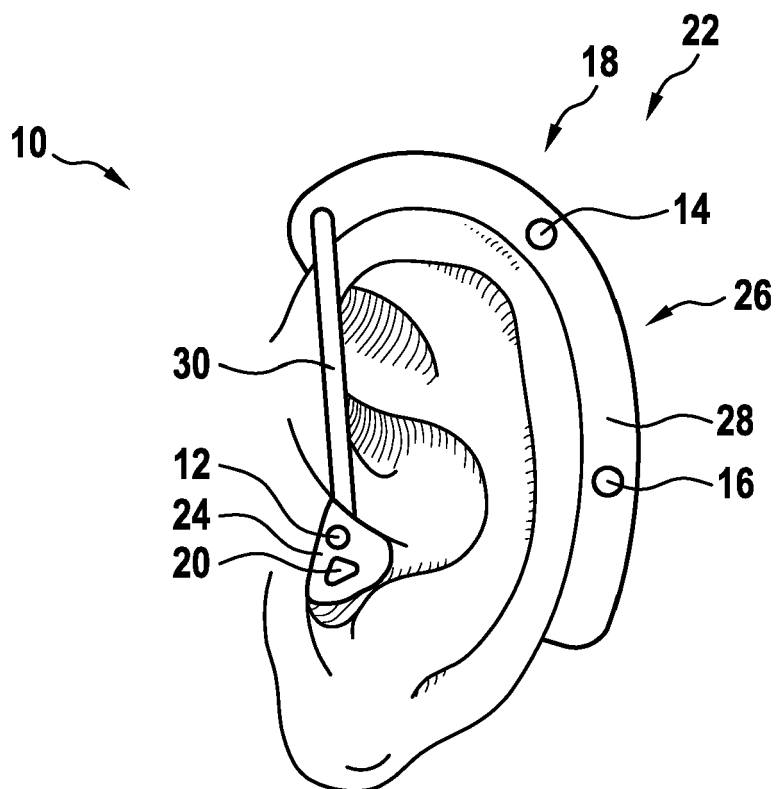


Fig. 3

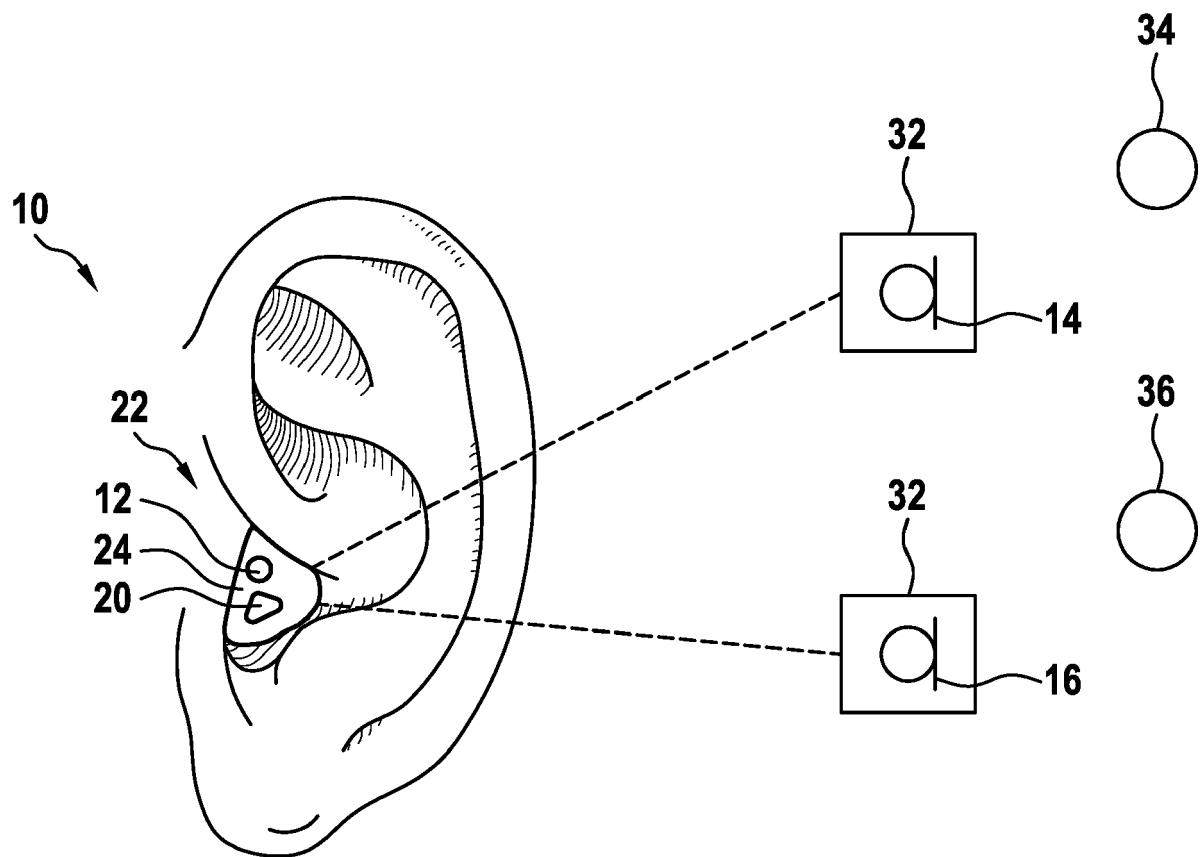


Fig. 4

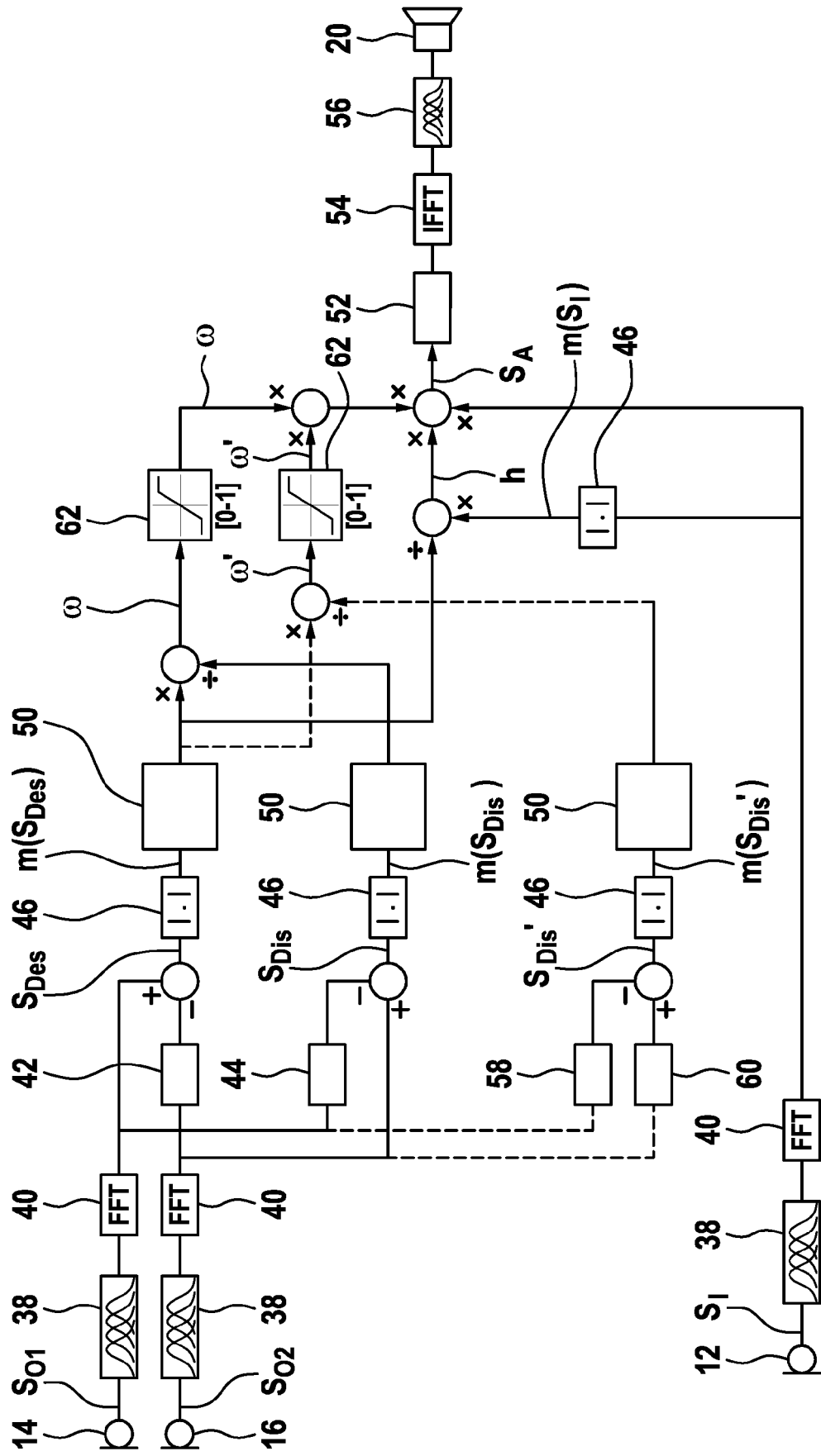


Fig. 5A

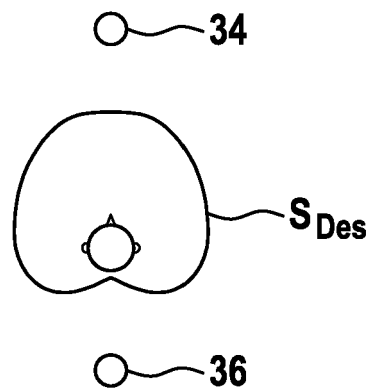


Fig. 5B

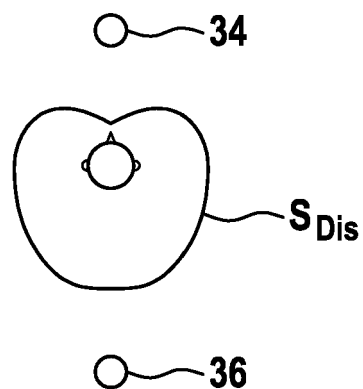
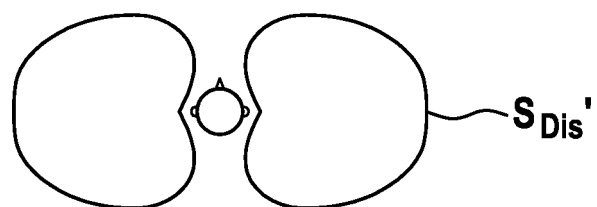


Fig. 5C





EUROPEAN SEARCH REPORT

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 EP 17 20 9252

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