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- (73) Patenthaver: **Sivantos Pte. Ltd., 18 Tai Seng Street , No. 08-08 , 18 Tai Seng, Singapore 539775, Singapore**
- (72) Opfinder: **KAMKAR-PARSI, Homayoun, Friedrich-Bauer-Str. 10, 91058 Erlangen, Tyskland
PUDER, Henning, Heuweg 27, 91058 Erlangen, Tyskland
Fischer, Eghart, Franz-Peter-Seifert-Strasse 3a, 91126 Schwabach, Tyskland
BOUCHARD, Martin, 42 Du Centenaire, Cantley, Ontario J8V 3L9, Canada
AS'AD, Hala, 704-210 Woodridge Cres, Nepean, Ontario K2B8E9, Canada**
- (74) Fuldmægtig i Danmark: **Chas. Hude A/S, H.C. Andersens Boulevard 33, 1780 København V, Danmark**
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**EP-A1- 2 347 603
EP-A1- 2 884 763
WO-A2-2007/028250
US-A1- 2004 252 852
US-A1- 2010 002 886**
**Hiroshi Saruwatari ET AL: "Binaural Hearing Aid Using Sound-Localization-Preserved MMSE STSA Estimator with ICA-Based Noise Estimation", , 31 December 2010 (2010-12-31), XP055342208, Retrieved from the Internet: URL:<http://www.iwaenc.org/proceedings/2010/HTML/Uploads/1058.pdf> [retrieved on 2017-02-03]
LOTTER ET AL: "Dual-Channel Speech Enhancement By Superdirective Beamforming", EURASIP JOURNAL OF APPLIED SIGNAL PROCESSING, HINDAWI PUBLISHING CO., CUYAHOGA FALLS, OH, US, vol. 2006, 1 January 2006 (2006-01-01), pages 1-14, XP007915506, ISSN: 1110-8657, DOI: 10.1155/ASP/2006/63297
CORNELIS B ET AL: "Theoretical Analysis of Binaural Multimicrophone Noise Reduction Techniques", IEEE TRANSACTIONS ON AUDIO, SPEECH AND LANGUAGE PROCESSING, IEEE, vol. 18, no. 2, 1 February 2010 (2010-02-01), pages 342-355, XP011329133, ISSN: 1558-7916, DOI: 10.1109/TASL.2009.2028374
HOMAYOUN KAMKAR-PARSI A ET AL: "Instantaneous Binaural Target PSD Estimation for Hearing Aid Noise Reduction in Complex Acoustic Environments", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 60, no. 4, 1 April 2011 (2011-04-01), pages 1141-1154, XP011349547, ISSN: 0018-9456, DOI: 10.1109/TIM.2010.2084690**

Fortsættes ...

DESCRIPTION

[0001] The invention relates to a method for operating a binaural hearing system, said binaural hearing system comprising a first hearing aid and a second hearing aid, wherein the first hearing aid generates a first reference signal from a sound signal by a first microphone, wherein the second hearing aid generates a second reference signal from a sound signal by a second microphone, wherein the first reference signal and the second reference signal are both used to derive a first binaural beamformer signal. The invention further relates to a binaural hearing system, comprising a first hearing aid and a second hearing aid, said binaural hearing system being configured to perform such a method.

[0002] Current state of the art binaural beamformers can provide noise reduction and preserve efficiently the binaural cues of the target speaker. Binaural cues enclosure all the acoustical information available to both ears of a listener for localizing a sound source. Now for an application in a binaural beamformer in which noise reduction is performed via the beamforming, the binaural cues of the target source are typically preserved, as the beamforming enhances sound from this direction. However, the typical sound environment does also comprise residual noise, which is to be reduced by the noise reduction, so that the binaural cues of the residual noise may be distorted. In particular, this may happen independently of whether the residual noise of the sound environment being a directional noise source or a superposition of few directional noise sources, or diffuse background noise. The distortion of the binaural cues of the residual noise causes a negative impact on the perception of the resulting acoustic scene.

[0003] Current state of the art solutions to this problem typically require information which may not be available neither measureable in real time applications. E. g., a solution based on the multi-channel Wiener filter requires a knowledge of statistics of the noise signals, which due to the presence of the target signals may not be available neither open to estimation. Likewise, solutions employing the interaural transfer functions assuming that for the type of noise present, the interaural transfer function is available, which in dynamic acoustic environments also is very often not the case. Another class of proposed solutions preserves the binaural cues of the noise as well as the target by applying a single real valued scalar common gain to each of the reference microphones on both sides of a hearing aid or a hearing system in order to produce the binaural outputs. However, the noise reduction is significantly reduced compared to normal beamforming methods.

[0004] US 2004/0252852 A1 teaches a binaural hearing system in which bandwise attenuation factors for the left ear signal and the right ear signal are determined, respectively, from the respective noise powers of said signals. The attenuation factors control the mixing ratio of a binaural beamforming signal to be output to the user of the hearing system. Each local signal may be added to the binaural beamforming signal according to an individually user-tailored coefficient for a better spatial perception.

[0005] It is therefore an object of the invention to find a method for operating a binaural hearing system, which permits the performance of noise reduction while still preserving as much as possible the binaural cues of the residual noise in the presence of a target sound signal. The method shall preferably achieve said object with no restrictions on the acoustic environment or on a signal-to-noise-ratio (SNR).

[0006] According to the invention the object is achieved by a method for operating a binaural hearing system, said binaural hearing system comprising a first hearing aid and a second hearing aid, wherein the first hearing aid generates a first reference signal from a sound signal by a first microphone, wherein the second hearing aid generates a second reference signal from a sound signal by a second microphone, wherein the first reference signal and the second reference signal are both used to derive a first binaural beamformer signal and a second binaural beamformer signal. Furthermore, the first reference signal and the second reference signal are used to determine a common gain, and from the first reference signal and the common gain a first common gain signal is derived, wherein at least for a number of frequency bands the first binaural beamformer signal is compared with the first common gain signal for classification with respect to a noise reduction, and the first binaural beamformer signal and the first common gain signal are mixed in dependence of said classification in order to obtain a first output signal. Embodiments of particular advantage are given in the dependent claims and the description following below.

[0007] The notion of a first microphone, or a second microphone, respectively, shall comprise any type of sound transducer which is set up to and capable to receive an acoustical wave pattern and to transduce this acoustical wave pattern into an electrical signal. The notion of a first binaural beamformer signal in particular shall comprise a signal with non-trivial spatial sensitivity characteristics. I. e., for a given probe reference sound source generating a fixed sound pressure level and the probe reference sound source being located in a far field at a fixed distance with respect to the distance between the first reference microphone and the second reference microphone, the binaural beamformer signal may in particular show a varying signal level for the probe reference sound source varying its angular position with respect to the assembly of the first reference microphone and the second reference microphone. To this end, the first reference signal and the second reference signal in particular may be combined as linear combinations with different gain factors and possibly a delay between the two mentioned signals.

[0008] The spatial characteristics of the first binaural beamformer signal may vary over different frequency bands of the binaural hearing system. The number of frequency bands for which the first binaural beamformer signal and the first common gain signal are compared and mixed in order to obtain a first output signal may depend on the implemented frequency decomposition given by a particular filtering process which is applied to the first reference signal and to the second reference signal, preferably in the same manner. The total number and mutual overlap of frequency bands may depend on the particular decomposition or filtering process employed.

[0009] The notion of a first common gain signal, or a second common gain signal, respectively, shall in particular comprise a signal whose spatial sensitivity characteristics are given only by the mechanical properties of the first reference microphone, or of the second microphone, respectively. In particular, for a given probe reference sound source generating a fixed sound pressure level and the probe reference sound source being located in a far field at a fixed distance to the first reference microphone, in a given frequency band the first common gain signal may in particular show the same variations in its signal level for the probe reference sound generator varying its angular position with respect to the first reference microphone as the first reference signal is showing when varying the angular position of the probe reference sound source. To his end, the common gain for a given frequency band may be derived as a scalar factor using the first reference signal and the second reference signal, and the scalar factor may be directly applied to the first reference signal in order to obtain the first common gain signal in said frequency band.

[0010] A similar consideration may hold for the second common gain signal. In particular, the first common gain signal and the second common gain signal each may show an approximately omnidirectional sensitivity characteristic.

[0011] In a binaural hearing system, different methods for noise reduction are possible. Depending on the hearing situation, especially in conversations where the user of the binaural hearing system may predominantly try to listen always to only one single target speaker at a time, a strong noise reduction - in terms of the target speaker SNR improvement - can be achieved by a highly directional beamforming, i.e., the spatial sensitivity characteristics of the beamformer signals are narrowly directed towards the target speakers location. This means that a sound signal whose source is located spaced apart from the target speaker is increasingly suppressed by the spatial sensitivity characteristics with increasing angular distance to the target speaker. This procedure achieves a good SNR for the target speakers' speech vs. background noise such as diffuse noise, but the sound signals of intervening non-target speakers are not only attenuated as a result of the noise reduction. Moreover, the binaural cues of these non-target sound signals get distorted by the binaural beamforming, causing the hearing of the user of the binaural hearing system to locate the non-target speakers at a different angular position with respect to the target speaker - the target direction of the binaural beamforming - than they are located in reality. Typically, when the user can see the real position of a non-target speaker, or more generally, a non-target sound source, this results in an uncomfortable mismatch between the visual and acoustic perception.

[0012] As the binaural beamforming typically is performed in a different way for different frequency bands, the method recognizes that whenever a strong noise reduction in the binaural beamforming is present in a given frequency band, the main signal energy stems from the target signal. However, if in a given frequency band, a lower level of noise reduction is present, the target signal is contributing less to the overall signal level. Even though the noise reduction is not as strong as for high-target-content frequency bands, it does still distort the binaural cues of non-target sound signals, in particular if the degree of noise reduction is lower not or not only due to a less directional beamforming but mainly due to the reduced

contribution of the target signal. However, in such a frequency band, there is far less penalty for the target signal's sound quality when "further deteriorating" somehow the noise reduction, as there is less target signal contribution present.

[0013] In this context, it is a major achievement of the invention to understand the interplay between the first binaural beamformer signal as a signal with possibly good noise reduction properties but distorting the binaural cues of non-target signals and the first common gain signal as a signal with possibly moderate noise reduction properties but preserving said binaural cues. As a result, for at least one of the above mentioned frequency bands in which a low degree of noise reduction is present, the output signal is given by a mixture of the first binaural beamformer signal and the first common gain signal. To this end, the degree of noise reduction is to be determined.

[0014] Furthermore, it is again a major achievement of the invention to not only use the first common gain signal for compensating possible losses of binaural cues in the first binaural beamformer signal, but also to compare the first binaural beamformer signal with the first common gain signal, taking into account thus the aforementioned interplay of these two signals, in order to classify them with respect to noise reduction. The comparison preferably is done in terms of a quantity which is a function of a degree of noise reduction. E.g., a function such as the absolute signal power can be taken for both signals and the presence or degree of noise reduction may be then inferred from the hierarchy established by the comparison of the signal powers. In an alternative implementation, the power difference of the two signals to be classified or their complex coherence may be compared to a threshold value, the result of the comparison indicating a stronger or a weaker presence of noise reduction in the first binaural beamformer signal.

[0015] In this context, the use of not only the first common gain's signal components for restoring the binaural cues in the output signal, but also its inherent information on a degree of noise reduction in a frequency band, is of particular advantage: at first, one might be tempted to directly take into account the first reference signal for comparison with the first binaural beamformer signal. However, the signal level of the first reference signal may strongly depend on the position of a sound signal's source, and its contribution to the residual noise level may be overestimated if the source is close to the first reference microphone and in the area which is shadowed off from the second reference microphone by the head of the user. In order to compensate for such strictly positional, monaural effects, it is of advantage taking the first common gain signal as the proper comparison match for the first binaural beamformer signal, since these effects are taken into account in the first common gain signal via the common gain, which is determined dependent on the first reference signal and the second reference signal. This way, the tradeoff between noise reduction and the preservation of the spatial perception via the spatial cues can be improved.

[0016] In a preferred embodiment, the first binaural beamformer signal is compared to the first common gain signal in a time-frequency domain, wherein the first output signal is obtained in the time-frequency domain. In particular, the whole signal processing may be performed in the

time-frequency domain. To this end, the first reference signal and the second reference signal, and, if present, further input signals, may be converted into the time-frequency domain via a fast Fourier transform (FFT) or a filterbank. This allows for tracking the temporal evolution of the spectral components of the signals involved. The first output signal is obtained in the time-frequency domain, as well, and may be optionally processed further and transformed back into the time domain before outputting it via a speaker or similar.

[0017] Preferably, for the classification of the first binaural beamformer signal and the first common gain signal at least one of the variables signal power, mean signal power and complex coherence function is taken into account. Preferably, the classification is performed with the signal components of a given frequency band in each of the involved frequency bands. The signal powers of the first binaural beamformer signal and the first common gain signal may be compared to each other in absolute terms. The mean signal powers may be taken as a mean value over a certain time window, e.g., one frame or a sequence of more frames, for a comparison. Furthermore, from the signal power of the first binaural beam former signal and the first common gain signal, the power difference may be taken as a suitable variable for comparison. To this end, the power difference may be compared to certain thresholds such as the mean value of the power difference over the given time window or the maximum or the minimum value of the power difference in said time window. The classification may be such that according to the result, a hierarchy or ordering of noise reduction content may be established, and the mixing of the first binaural beamformer signal and the first common gain signal may be according to the hierarchy or ordering.

[0018] Preferably, a similar hierarchy or ordering may also be established by using the complex coherence between the first binaural beamformer signal and the first common gain signal. The complex coherence of two signals is defined as the cross power spectral density (CPSD) of the two signals, normalized over the square root of the product of the two signals' auto power spectral densities (PSD). For a classification, the complex coherence may then be compared to a threshold value such as the mean value of the complex coherence over a given time window, and the comparison result may determine a mixing rule for the first output signal. Furthermore, as a result of the Cauchy-Schwartz inequality, the complex coherence will attain values between 0 and 1, such that a quantitative mixing rule in terms of a convex weighting coefficient for the first binaural beamformer signal and the first common gain signal may directly be taken as the complex coherence itself.

[0019] The major importance in which variable to use for the comparison of the first binaural beamformer signal and the first common gain signal and for their classification with respect to each other is that the variable may give a quantitative insight in the binaural noise reduction present in the binaural beamformer signal. Preferably, the variably chosen at least in principle may give such an insight in a monotonous, non-binary way.

[0020] In a preferred embodiment, at least for a number of frequency bands, the common gain is determined in each of said number of frequency bands from the first reference signal in the frequency band and the second reference signal in the frequency band, the first common gain

signal in the frequency band is derived from the common gain in the frequency band and the first reference signal in the frequency band, and a second common gain signal in the frequency band is derived from the common gain in the frequency band and the second reference signal in the frequency band. Defining an individual common gain for different frequency bands increases the sensitivity of the proposed method to properly detect noise reduction in a given frequency band and thus improves the classification of the first binaural beamformer signal and the first common gain signal accordingly, as well as the recovery of the binaural cues, since the performance of method in frequency bands with a low target signal content does not depend on the high-target-content frequency bands.

[0021] Preferably, in at least one frequency band below 2 kHz, more preferably below 1.5 kHz, a phase of the first output signal is derived from a phase of the first reference signal. In particular, in said at least one frequency band the phase of the first output signal may be given by the phase of the first reference signal. For lower frequencies such as up to 1.5 kHz, in certain cases up to 2 kHz, the interaural phase difference has a dominant effect on the perception of the binaural cues by a listener. The higher the frequencies, the less dominant is this effect. In this context it may be of further advantage to decide whether or not to derive the phase of the first output signal from the phase of the first reference signal according to the classification result of the first binaural beamformer signal and the first common gain signal in this frequency band. This assures that if the classification indicates a strong presence of noise reduction in the first binaural beam former signal, as the noise reduction distorts the binaural cues which in this frequency band are dominated by the interaural phase difference, the phase distortion of the binaural cues to be corrected for by the phase from the first reference signal.

[0022] Preferably, in at least one frequency band, more preferably above 2 kHz, a phase of the first output signal is derived from a phase of the first binaural beamformer signal. In particular, in said at least one frequency band the phase of the first output signal may be given by the phase of the first binaural beamformer signal. It may be of further advantage to decide whether or not to derive the phase of the first output signal from the phase of the first binaural beamformer signal according to the classification result of the first binaural beamformer signal and the first common gain signal in this frequency band. This is useful especially if either no significant noise reduction is present in the frequency band or if the interaural phase difference does not contribute significantly to the binaural cues in this frequency band.

[0023] In a preferred embodiment, for said number of frequency bands, the first binaural beamformer signal and the first common gain signal each are decomposed into a magnitude component and a phase component, and the magnitude component of the first binaural beamformer signal and the magnitude component of the first common gain signal are mixed in dependence of said classification in order to obtain a magnitude component of the first output signal.

[0024] In particular, the phase of the first output signal may be derived according to another classification due to a comparison of the first binaural beamformer signal and the first common gain signal, preferably in a different variable than the comparison for classifying the mixing of

the magnitudes. E.g., the mixing of the magnitude components can be done according to a classification obtained by comparing the absolute value of the complex coherence or the power difference, while the decision about which phase to take for the first output signal can be made by means of a classification employing the phase angle of the complex coherence.

[0025] In a preferred embodiment, the first hearing aid generates a first supplementary signal from a sound signal by a third microphone, wherein the second hearing aid generates a second supplementary signal from the sound signal by a fourth microphone, and wherein the first supplementary signal and the second supplementary signal are both taken into account to derive the first binaural beamformer signal and the second binaural beamformer signal. The notion of a third microphone, or a fourth microphone, respectively, shall comprise any type of sound transducer which is set up to and capable to receive an acoustical wave pattern and to transduce this acoustical wave pattern into an electrical signal. In modern binaural hearing systems and in particular, binaural hearing aids, for a better spatial sound perception more than just one microphone in a single hearing aid may be employed. The use of more than one microphone at one side, in combination with the microphone or microphones from the other side, allows for a better beamforming, i.e., a narrower directionality if required or a better signal-to-noise-ratio in beamforming noise reduction. In particular, the third microphone is located within the first hearing aid slightly apart from the first microphone in order to be able to detect small time shifts with respect to the first reference microphone when a propagating sound signal impinges on the first hearing aid. Similar considerations may hold for the fourth microphone and its location within the second hearing aid.

[0026] Hereby, it is of particular advantage to take into account the first supplementary signal and the second supplementary signal in order to determine the common gain, as all possible spatial information available can be used to determine the common gain, such allowing for the best possible spatial resolution.

[0027] Preferably, at least for a number of frequency bands the second binaural beamformer signal is compared with the second common gain signal for classification with respect to a noise reduction, and the second binaural beamformer signal and the second common gain signal are mixed in dependence of said classification in order to obtain a second output signal. In particular, the first output signal may be used to derive a first playback signal which is converted into a first sound signal via a first loudspeaker of the first hearing aid, and preferably, the second output signal may be used to derive a second playback signal which is converted into a second sound signal via a second loudspeaker of the second hearing aid. In particular, the first playback signal may be derived from the first output signal without an additional input of the second output signal into the first playback signal. The notion of a first loudspeaker or a second loudspeaker, respectively, shall comprise any type of sound generator which is set up to and capable to receive an electrical signal and to transduce this electrical signal into an acoustical wave pattern of sound waves.

[0028] Thus, in each hearing aid, at least for a number of frequency bands the playback signal is given by a mixture of the local binaural beamformer signal - containing signal components

from the microphones of the other hearing aid - and the local common gain signal containing only local signal components, the information of the other hearing aid's microphones entering only via the common gain factor. This helps to develop a realistic hearing perception with respect to the binaural cues, as the signals involved are treated as symmetrical as possible,

[0029] Another aspect of the invention is given by a binaural hearing system, comprising a first hearing aid and a second hearing aid, said binaural hearing system comprising means to perform the method described above. The advantages of the proposed method for operating a binaural hearing system and for its preferred embodiments can be transferred to the binaural hearing system itself in a straight forward manner.

[0030] The attributes and properties as well as the advantages of the invention which have been described above are now illustrated with help of a drawing of an embodiment example. In detail,

figure 1

shows a schematical top view of a conversation hearing situation including a user of a state-of-the-art binaural hearing system and five speakers,

figure 2

shows a schematical top view of the conversation hearing situation according to figure 1. as well as the acoustical localization of the speakers as perceived by the user of the binaural hearing system,

figure 3

shows a block diagram of a method for operating a binaural hearing system in order to preserve the perception of binaural cues when noise reduction is active, and

figure 4

shows a schematical top view of conversation hearing situation given in figure 1, as well as the acoustical localization of the speakers as perceived by the user of the binaural hearing system when applying the method according to figure 3.

[0031] Parts and variables corresponding to one another are provided with In each case the same reference numerals in all figures.

[0032] In figure 1, a schematical top view of a hearing situation 1 corresponding to a conversation is shown. A user 2 of a state-of-the-art binaural hearing system (not shown) is surrounded by his conversational partners, given by the speakers 4, 6, 8, 10, 12, while directing his view towards the target speaker 4 for a given moment.

[0033] If the state-of-the-art binaural hearing system is applying a noise reduction in which noise from directions other than the one of the target speaker 4, at least partially, is aimed to be reduced via the binaural beamforming of the binaural beamforming system, the target speaker 4 will be perceived by the user 2 in the proper direction. However, the other, non-target speakers 6, 8, 10, 12, apart from having an attenuated signal volume in the output

signal of the binaural beamforming hearing aid as perceived by the user 2, due to the binaural beamforming may show their binaural cues distorted when talking to the user 2 which is focused on the target speaker 4, leading to an improper perception of the acoustical localization of the non-target speakers 6, 8, 10, 12 in the perception of the user 2.

[0034] This is displayed schematically in figure 2. The attenuation of the signal volume of - possibly occasional - conversational contributions of the non-target speakers 6, 8, 10, 12 with respect to the signal volume of the contributions of the target speaker 4 in the output signal of the binaural hearing system is displayed by a miniaturization of the non-target speakers 6, 8, 10, 12 compared to figure 1. The loss of the binaural cues may lead to a wrong acoustical perception of the positions of the non-target speakers 6, 8, 10, 12 by the user 2. This means, the user 2 can see the actual positions of two intervening non-target speakers 6, 12 as spatially well separated from the target speaker 4, but due to the state-of-the-art binaural beamforming, displayed by the beam 14, and the loss of binaural cues of the non-target speakers 6, 12 caused by the noise reduction processes, the user 2 "hears" contributions from the non-target speakers 6, 12 as if those were located much closer to the target speaker 4.

[0035] In figure 3, a method 18 for operating a binaural hearing system 20 is illustrated by means of a block diagram. The method 18 is particularly useful in order to preserve binaural cues of a sound signal 22 when noise reduction is active in the binaural hearing system 20. The binaural hearing system 20 comprises a first hearing aid 24 and a second hearing aid 26. In the first hearing aid 24, a first reference signal 28 is generated from the sound signal 22 by a first microphone 30, while in the second hearing aid 26, a second reference signal 32 is generated from the sound signal 22 by a second microphone 34. Again in the first hearing aid 24, a first supplementary signal 36 is generated from the sound signal 22 by a third microphone 38, while in the second hearing aid 26 a second supplementary signal 40 is generated from the sound signal 22 by a fourth microphone 42.

[0036] The second reference signal 32 and the second supplementary signal 40 are transmitted from the second hearing aid 26 to the first hearing aid 24. There, the first reference signal 28, the second reference signal 32, the first supplementary signal 36 and the second supplementary signal 42 are transformed into the time-frequency domain by a filter bank 44. After transformation, the signal components of the first and second reference and supplementary signals 28, 32, 36, 40 in each frequency band are used to form a first binaural beamformer signal 46. The binaural information in the binaural beamformer signal 46 together with the first reference signal 28 and the second reference signal 32 are used to determine a common gain 48 in each frequency band given by the filter bank 40. The first binaural beamformer signal 46 is used to derive the common gain 48 in order to include all possible acoustical information, i.e., also time or level differences that are only measurable with the help of the first and the second supplementary signal 36, 40. The information content of these two signals is introduced into the common gain 48 by the first binaural beamformer signal 46.

[0037] The common gain 48 is applied to the first reference signal 28 by a mere scalar multiplication to obtain the first common gain signal 50. To the first binaural beamformer signal

46, a decomposition 52 is applied in order to decompose the first binaural beamformer signal 46 into its magnitude and phase components. To the first common gain signal 50, a decomposition 54 is applied in order to decompose the first common gain signal 50 into at least its magnitude component. If the phase component of the first common gain signal 50 is not further taken into account, the decomposition 54 can be achieved by merely taking the absolute value of the first common gain signal 50.

[0038] The first binaural beam former signal 46 and the first common gain signal 50 are now compared in a way still to be described. The result of the comparison is a hierarchical classification 56 with respect to noise reduction, i.e., from the classification 56 quantitative information on whether or not a strong noise reduction is present in the first binaural beamformer signal 46 can be obtained. According to the classification 56, the magnitudes of the first binaural beamformer signal 46 and the first common gain signal 50 are mixed in order to derive a first output signal 58. The phase of the first output signal 58 is taken to be the phase 60 of the first reference signal 28 or the phase of the first binaural beamformer signal 46 according to the classification 56. The first output signal 58 may be further processes (not shown in figure 3) to derive a first playback signal 62 which is converted into a sound signal 64 by a first loudspeaker 66 of the first hearing aid 24.

[0039] The magnitude of the first output signal 58 in a given frequency band and to a time-frequency frame may be taken as a linear mixture

$$|1stOut| = a \cdot |1stBinBF| + (1-a) \cdot |1stComG|,$$

where 1 stOut indicates the first output signal 58, 1stBinBF the first binaural beamformer signal 46, and 1 stComG the first common gain signal 50, and $|\cdot|$ denotes the absolute value.

[0040] For the classification, if taking signal power as the variable to compare, the mixing factor a may depend on the classification of $\text{pow}(1stBinBF)$ and $\text{pow}(1stComG)$, where $\text{pow}(\cdot)$ denotes the signal power of the argument. E.g., one might take

$$a = 0.7 \text{ for } \text{pow}(1stBinBF) < \text{pow}(1stComG);$$

and

$$a = 0.3 \text{ otherwise.}$$

[0041] If taking the power difference of the first common gain signal 50 and the first binaural beamformer signal 46 as the relevant variable for the classification 56, one might establish a hierarchy by taking as the upper and lower limit for the power difference diff the maximum and minimum values $\text{max}(\text{diff})$, $\text{min}(\text{diff})$ over the given time window (e.g., a frame or a sequence of frames) as well as the temporal mean value $\text{mean}(\text{diff})$ of the power difference over the time window. For each time window, the power difference diff may attain a value which falls into one of the following four intervals:

$$1: [\text{max}(\text{diff}), \text{max}(\text{diff})/2 + \text{mean}(\text{diff})/2],$$

$$2: [\text{max}(\text{diff})/2 + \text{mean}(\text{diff})/2, \text{mean}(\text{diff})],$$

$$3: [\text{mean}(\text{diff}), \text{mean}(\text{diff})/2 + \text{min}(\text{diff})/2],$$

4: $[\text{mean}(\text{diff})/2 + \text{min}(\text{diff})/2, \text{min}(\text{diff})]$.

[0042] To each interval, a different value is assigned to the scalar a in the equation given above for the linear mixture, with the hierarchy $a(1) > a(2) > a(3) > a(4)$.

[0043] The phase of the first output signal 58 in these examples each time may be given by the phase 60 of the first reference signal 28 for lower frequency bands (up to 1.5 kHz or 2 kHz) and by the phase of the first binaural beamformer signal 46 otherwise.

[0044] If the complex coherence C is taken as the variable, a threshold T may be taken as the temporal mean of C over the time window. Then, for low frequency bands up to 2 kHz, the magnitude of the first output signal 58 may be determined according to $a = 1$ for $C < T$, $a = 0.3$ otherwise. For higher frequencies, one might take $a = 0.7$ for $C < T$ and $a = 0.3$ otherwise. Other settings for a different from the given examples are possible. In this embodiment, the main idea is that when the condition $C < T$ is met, more magnitude content of the first binaural beamformer signal 46 in the lower frequency bands than in the higher frequency bands is processed into the first output signal 58.

[0045] This approach reflects the fact that most speech energy is concentrated at lower frequencies, so that the spatial perception of an acoustical environment such as hearing situation 1 is typically dominated by the content in the lower frequency bands. Thus, in case the complex coherence C between the first binaural beamformer signal 46 and the first common gain signal 50 is below a temporal mean value, one may infer that for the short time slot to which the complex coherence is taken, the first binaural beamformer signal 46 - which also indicates the degree of noise reduction by the spatial characteristics of the beam in the given frequency band - differs "more than normal" from the first common gain signal 50. The first common gain signal 50 can be interpreted as a reference of the total signal level at both the first hearing aid 24 and the second hearing aid 26 in each particular frequency band for the degree of noise reduction present in the first binaural beamformer signal 46, while the reference is taken into account via the comparison of C with respect to its temporal mean T . So an instantaneously "more than normal"-deviation of the first binaural beamformer signal 46 from the first common gain signal 50 indicates a higher degree of binaural noise reduction in the former.

[0046] In this embodiment, the phase of the first output signal 58 in this example may be given for lower frequency bands (up to 1.5 kHz or 2 kHz) by the phase 60 of the first reference signal 28 or by the phase of the first binaural beamformer signal 46, depending on the phase angle of C , and only by the phase of the first binaural beamformer signal 46 for higher frequencies.

[0047] A noise reduction process which is based on a binaural beamforming process suppressing sounds from sound sources located in different directions than the target sound source may distort the binaural cues of non-target sound signals, i.e., sound signal components whose source is not located in the target direction. Even though these sound

signals are suppressed by the binaural beamforming anyway, and might not be perceived as "conversationally relevant", they still might have an important impact on the user's 2 perception of the acoustical scene in his hearing environment. Distorted binaural cues of these non-target sound signals then may lead to a mismatch of the acoustical perception of the non-target sound sources and their actual positions as seen by the user. The mixing of the "cues-distorted" first binaural beamformer signal with the "low-noise-reduction" first common gain signal according to the noise reduction present as well as the phase information taken from one hearing aid as the phase in that hearing aid's output signal allows the user 2 to perceive better level differences, temporal shiftings and delays in order to restore binaural cues.

[0048] Thus, as schematically shown in figure 4 in a top view of the hearing situation 1 given in figure 1, the user 2 now acoustically locates the non-target speakers 6, 12 in the same position with respect to the target speaker 4 as he sees them.

[0049] Even though the invention has been illustrated and described in detail with help of a preferred embodiment example, the invention is not restricted by this example. Other variations can be derived by a person skilled in the art without leaving the extent of protection of this invention.

Reference numeral**[0050]**

- 1 hearing situation
- 2 user (of a binaural hearing system)
- 4 target speaker
- 6-12 non-target speakers
- 14 beam
- 18 method for operating a binaural hearing system
- 20 binaural hearing system
- 22 sound signal
- 24 first hearing aid
- 26 second hearing aid

28	first reference signal
30	first microphone
32	second reference signal
34	second microphone
36	first supplementary signal
38	third microphone
40	second supplementary signal
42	fourth microphone
44	filter bank
46	first binaural beamformer signal
48	common gain
50	first common gain signal
52-54	decomposition
56	classification
58	first output signal
60	phase of first reference signal
62	first playback signal
64	sound signal
66	first loudspeaker

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US20040252852A1 [0004]

Patentkrav

1. Fremgangsmåde (18) til brug af et binauralt høresystem (20), hvilket binaurale høresystem (20) omfatter et første høreapparat (24) og et andet høreapparat (26),
5 hvorved det første høreapparat (24) genererer et første referencesignal (28) fra et lydsignal (22) ved hjælp af en første mikrofon (30),
hvorved det andet høreapparat (26) genererer et andet referencesignal (32) fra et lydsignal (22) ved hjælp af en anden mikrofon (34),
10 hvorved det første referencesignal (28) og det andet referencesignal (32) begge anvendes til at opnå et første binauralt stråledannelsessignal (46) og et andet binauralt stråledannelsessignal,
hvorved det første referencesignal (28) og det andet referencesignal (32) anvendes til at bestemme en fælles forstærkning (48), og fra det første referencesignal
15 (28) og den fælles forstærkning (48) opnås et første fælles forstærkningssignal (50),

kendetegnet ved, at

- i det mindste for et antal af frekvensbånd
- 20 - sammenlignes det første binaurale stråledannelsessignal (46) med det første fælles forstærkningssignal (50) til klassifikation (56) med hensyn til en mængde, som er en funktion af en grad af støjreduktion, og
- blandes det første binaurale stråledannelsessignal (46) og det første fælles forstærkningssignal (50) i afhængighed af klassifikationen (56) med henblik
25 på at opnå et første outputsignal (58).

2. Fremgangsmåde (18) ifølge krav 1,
hvorved det første binaurale stråledannelsessignal (46) sammenlignes med det første fælles forstærkningssignal (50) i et tids-frekvens-domæne, og
30 hvorved det første outputsignal (58) opnås i tids-frekvens-domænet.

3. Fremgangsmåde (18) ifølge krav 1 eller 2,

hvorved der til klassifikationen (56) af det første binaurale stråledannelsessignal (46) og det første fælles forstærkningssignal (50) tages hensyn til i det mindste en af de variables signalydelse og/eller den gennemsnitlige signalydelse og/eller den komplekse kohærensfunction.

5

4. Fremgangsmåde (18) ifølge et af de foregående krav, hvorved i det mindste for et antal af frekvensbånd,

10 - bestemmes den fælles forstærkning (48) i hvert frekvensbånd ud af antallet af frekvensbånd fra det første referencesignal (28) i frekvensbåndet og det andet referencesignal (32) i frekvensbåndet,

- opnås det første fælles forstærkningssignal (50) i frekvensbåndet fra den fælles forstærkning (48) i frekvensbåndet og det første referencesignal (28) i frekvensbåndet, og

15 - opnås et andet fælles forstærkningssignal i frekvensbåndet fra den fælles forstærkning (48) i frekvensbåndet og det andet referencesignal i frekvensbåndet.

5. Fremgangsmåde (18) ifølge et af de foregående krav, hvorved i i det mindste et frekvensbånd under 2 kHz opnås en fase af det første outputsignal (58) fra en fase (60) af det første referencesignal (28).

6. Fremgangsmåde ifølge et af de foregående krav, hvorved i i et mindste et frekvensbånd en fase af det første outputsignal (58) opnås fra en fase af det første binaurale stråledannelsessignal (46).

7. Fremgangsmåde (18) ifølge et af de foregående krav, hvorved for antallet af frekvensbånd,

30 - opløses det første binaurale stråledannelsessignal (46) og det første fælles forstærkningssignal (50) hver i en størrelseskomponent og en fasekomponent, og

- blandes det første binaurale stråledannelsessignals (46) størrelseskomponent og det første fælles forstærkningssignals (50) størrelseskomponent i afhængighed af klassifikationen (56) med henblik på at opnå en størrelseskomponent af det første outputsignal (58).

5

8. Fremgangsmåde (18) ifølge et af de foregående krav, hvorved det første høreapparat (24) genererer et første supplerende signal (36) fra et lydsignal (22) ved hjælp af en tredje mikrofon (38), hvorved det andet høreapparat (26) genererer et andet supplerende signal (40) fra lydsignalet (22) ved hjælp af en fjerde mikrofon (42), og hvorved der både tages hensyn til det første supplerende signal (36) og det andet supplerende signal (40) for at opnå det første binaurale stråledannelsessignal (46) og det andet binaurale stråledannelsessignal.

15 9. Fremgangsmåde (18) ifølge krav 8, hvorved der tages hensyn til det første supplerende signal (36) og det andet supplerende signal (40) med henblik på at bestemme den fælles forstærkning (48).

10. Fremgangsmåde (18) ifølge et af de foregående krav, hvorved der af det andet referencesignal (32) og den fælles forstærkning (48) opnås et andet fælles forstærkningssignal, og hvorved i det mindste for et antal af frekvensbånd,

25 - sammenlignes det andet binaurale stråledannelsessignal med det andet fælles forstærkningssignal til klassifikation med hensyn til en mængde, som er en funktion af en grad af støjreduktion, og
- blandes det andet binaurale stråledannelsessignal og det andet fælles forstærkningssignal i afhængighed af klassifikationen med henblik på at opnå et andet outputsignal.

30

11. Fremgangsmåde ifølge krav 10,

hvorved der opnås et første playbacksignal (62) fra det første outputsignal (58) uden et yderligere input af det andet outputsignal til det første playbacksignal (62), og

5 hvorved det første playbacksignal (62) omdannes til et lydsignal (64) ved hjælp af en højttaler (66) i det første høreapparat (24).

12. Binauralt høresystem (20) omfattende et første høreapparat (24) og et andet høreapparat (26), hvilket binaurale høresystem (20) omfatter midler til at udøve fremgangsmåden (18) ifølge et af de foregående krav.

DRAWINGS

FIG 1

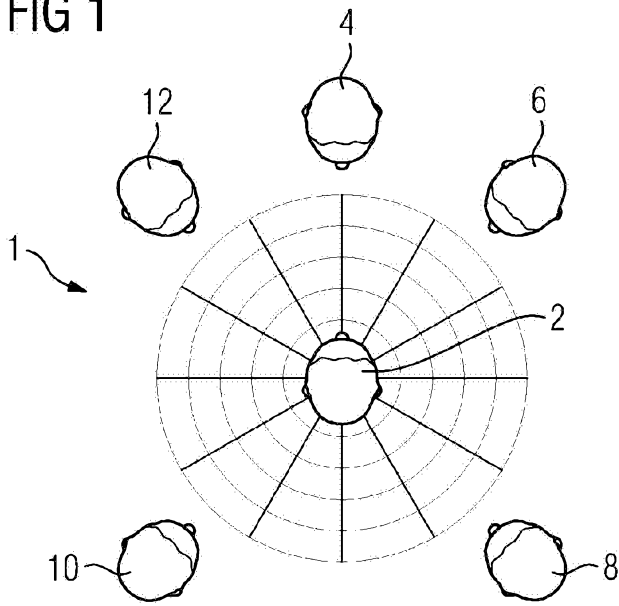


FIG 2

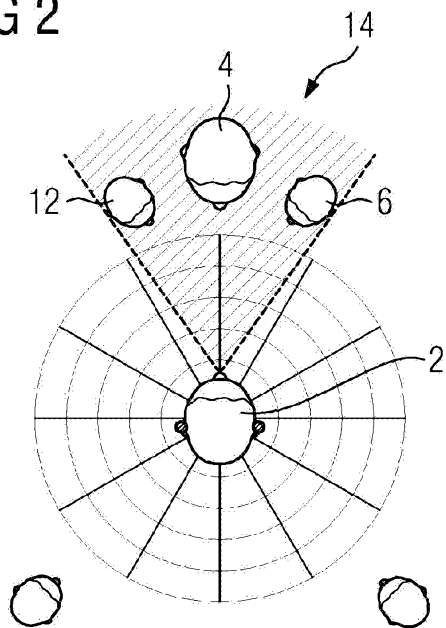


FIG 4

