(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 806 661 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
06.09.2017 Bulletin 2017/36

(51) Int Cl.:
H04R 25/00 *(2006.01)* *H04S 7/00* *(2006.01)*

(21) Application number: **13168917.6**

(22) Date of filing: **23.05.2013**

(54) **A hearing aid with spatial signal enhancement**

Hörgerät mit räumlicher Signalverstärkung

Prothèse auditive avec amélioration spatiale de signal

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(43) Date of publication of application:
26.11.2014 Bulletin 2014/48

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Description

[0001] A new binaural hearing aid system is provided that is configured to impart perceived spatial separation on monaural signal sources.

[0002] Hearing impaired individuals often experience at least two distinct problems:

1) A hearing loss, which is an increase in hearing threshold level, and

2) A loss of ability to understand speech in noise in comparison with normal hearing individuals. For most hearing impaired patients, the performance in speech-in-noise intelligibility tests is worse than for normal hearing people, even when the audibility of the incoming sounds is restored by amplification. Speech reception threshold (SRT) is a performance measure for the loss of ability to understand speech, and is defined as the signal-to-noise ratio required in a presented signal to achieve 50 percent correct word recognition in a hearing in noise test.

[0003] In order to compensate for hearing loss, today's digital hearing aids typically use multi-channel amplification and compression signal processing to restore audibility of sound for a hearing impaired individual. In this way, the patient's hearing ability is improved by making previously inaudible speech cues audible.

[0004] However, loss of ability to understand speech in noise, including speech in an environment with multiple speakers, remains a significant problem of most hearing aid users.

[0005] One tool available to a hearing aid user in order to increase the signal to noise ratio of speech originating from a specific speaker, is to equip the speaker in question with a microphone, often referred to as a spouse microphone, that picks up speech from the speaker in question with a high signal to noise ratio due to its proximity to the speaker. The spouse microphone converts the speech into a corresponding audio signal with a high signal to noise ratio and transmits the signal, preferably wirelessly, to the hearing aid for hearing loss compensation. In this way, a speech signal is provided to the user with a signal to noise ratio well above the SRT of the user in question.

[0006] Another way of increasing the signal to noise ratio of speech from a speaker that a hearing aid user desires to listen to, such as a speaker addressing a number of people in a public place, e.g. in a church, an auditorium, a theatre, a cinema, etc., or through a public address systems, such as in a railway station, an airport, a shopping mall, etc., is to use a telecoil to magnetically pick up audio signals generated, e.g., by telephones, FM systems (with neck loops), and induction loop systems (also called "hearing loops"). In this way, sound may be transmitted to hearing aids with a high signal to noise ratio well above the SRT of the hearing aid users.

[0007] In all of the above-mentioned examples a monaural audio signal is transmitted to the hearing aid.

[0008] However, in a situation in which a user of a conventional binaural hearing aid system desires to listen to more than one of the above-mentioned audio signal sources simultaneously, the user will find it difficult to separate one signal source from another. US 8,208,642 B2 discloses a method and an apparatus for a binaural hearing aid in which sound from a single monaural signal source is presented to both ears of a user wearing the binaural hearing aid in order to obtain benefits of binaural hearing when listening to the monaural signal source. The sound presented to one ear is phase shifted relative to the sound presented to the other ear, and additionally, the sound presented to one ear may be set to a different level relative to the sound presented to the other ear. In this way, lateralization and volume of the monaural signal are controlled. For example, a telephone signal may be presented to both ears in order to benefit from binaural reception of a telephone call, e.g. by relaying of the caller's voice to the ear without the telephone against it, albeit at the proper phase and level to properly lateralize the sound of the caller's voice.

[0009] WO 2010/043223 discloses a binaural hearing aid system capable of delivering binaural stereo signals such that the user perceives the stereo image as being wider and more natural. Hearing aids typically reproduce sound in such a way that the user perceives sound sources to be localized inside the head. The sound is said to be internalized rather than being externalized. A common complaint for hearing aid users when referring to the "hearing speech in noise problem" is that it is very hard to follow anything that is being said even though the signal to noise ratio (SNR) should be sufficient to provide the required speech intelligibility. A significant contributor to this fact is that the hearing aid reproduces an internalized sound field. This adds to the cognitive loading of the hearing aid user and may result in listening fatigue and ultimately that the user removes the hearing aid(s).

[0010] Thus, there is a need for a new binaural hearing aid system with improved localization of sound sources, i.e. there is a need for a new binaural hearing aid system capable of imparting perceived spatial information of direction and possibly distance of a respective sound source with relation to the orientation of the head of the wearer of the binaural hearing aid system.

[0011] Below, an exemplary method is disclosed of enhancement in a hearing aid of a signal that is not received by the microphone accommodated in the hearing aid.

[0012] The new method makes use of the human auditory system's capability of distinguishing sound sources located in different spatial positions in the sound environment, and concentrating on a selected one or more of the spatially separated sound sources.

[0013] A new binaural hearing aid system using the new method is also disclosed.

[0014] According to the new method, signals from different sound sources are presented to the ears of human

in such a way that the human perceives the sound sources to be positioned in different spatial positions in the sound environment of the user. In this way, the user's auditory system's binaural signal processing is utilized to improve the user's capability of separating the signals from the different sound sources and of focussing his or her listening to a desired one of the sound sources, or even to simultaneously listen to and understand more than one of the sound sources.

[0015] It has also been found that if a speech signal is presented in anti-phase, i.e. phase shifted 180° with relation to each other, in the two ears of the human, a specific direction of arrival of the speech signal is not perceived; however, many users find speech signals presented in anti-phase easy to separate from other sound sources and understand. This effect may be obtained with a phase shift ranging from 150° to 210°.

[0016] Human beings detect and localize sound sources in three-dimensional space by means of the human binaural sound localization capability.

[0017] The input to the hearing consists of two signals, namely the sound pressures at each of the eardrums, in the following termed the binaural sound signals. Thus, if sound pressures at the eardrums that would have been generated by a given spatial sound field are accurately reproduced at the eardrums, the human auditory system will not be able to distinguish the reproduced sound from the actual sound generated by the spatial sound field itself.

[0018] The transmission of a sound wave from a sound source positioned at a given direction and distance in relation to the left and right ears of the listener is described in terms of two transfer functions, one for the left ear and one for the right ear, that include any linear distortion, such as coloration, interaural time differences and interaural spectral differences. Such a set of two transfer functions, one for the left ear and one for the right ear, is called a Head-Related Transfer Function (HRTF). Each transfer function of the HRTF is defined as the ratio between a sound pressure p generated by a plane wave at a specific point in or close to the appertaining ear canal (p_L in the left ear canal and p_R in the right ear canal) in relation to a reference. The reference traditionally chosen is the sound pressure p_I that would have been generated by a plane wave at a position right in the middle of the head with the listener absent.

[0019] The HRTF contains all information relating to the sound transmission to the ears of the listener, including diffraction around the head, reflections from shoulders, reflections in the ear canal, etc., and therefore, the HRTF varies from individual to individual.

[0020] In the following, one of the transfer functions of the HRTF will also be termed the HRTF for convenience.

[0021] The HRTF changes with direction and distance of the sound source in relation to the ears of the listener. It is possible to measure the HRTF for any direction and distance and simulate the HRTF, e.g. electronically, e.g. by filters. If such filters are inserted in the signal path between a audio signal source, such as a microphone, and headphones used by a listener, the listener will achieve the perception that the sounds generated by the headphones originate from a sound source positioned at the distance and in the direction as defined by the transfer functions of the filters simulating the HRTF in question, because of the true reproduction of the sound pressures in the ears.

[0022] Binaural processing by the brain, when interpreting the spatially encoded information, results in several positive effects, namely better signal source segregation ; direction of arrival (DOA) estimation; and depth/distance perception.

[0023] It is not fully known how the human auditory system extracts information about distance and direction to a sound source, but it is known that the human auditory system uses a number of cues in this determination. Among the cues are spectral cues, reverberation cues, interaural time differences (ITD), interaural phase differences (IPD) and interaural level differences (ILD).

[0024] The most important cues in binaural processing are the interaural time differences (ITD) and the interaural level differences (ILD). The ITD results from the difference in distance from the source to the two ears. This cue is primarily useful up till approximately 1.5 kHz and above this frequency the auditory system can no longer resolve the ITD cue.

[0025] The level difference is a result of diffraction and is determined by the relative position of the ears compared to the source. This cue is dominant above 2 kHz but the auditory system is equally sensitive to changes in ILD over the entire spectrum.

[0026] It has been argued that hearing impaired subjects benefit the most from the ITD cue since the hearing loss tends to be less severe in the lower frequencies.

[0027] In accordance with the new method, a first monaural audio signal in a binaural hearing aid system originating from a first sound source, such as a first monaural signal received from a first spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., is filtered with a first binaural filter in such a way that the user perceives the received first monaural audio signal to be emitted by the first sound source positioned in a first position and/or arriving from a first direction in space.

[0028] Further, a second monaural audio signal in the binaural hearing aid system originating from a second sound source, such as a second monaural signal received from a second spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., may be conventionally hearing loss compensated in the binaural hearing aid system whereby the second monaural signal is perceived to be emitted by the second sound source positioned at the centre of the head of the user of the binaural hearing aid system.

[0029] The perceived spatial separation of the first and second signal sources assists the user in understanding

speech in the first and second monaural audio signals, and in focussing the user's listening to a desired one of the first and second monaural audio signals.

[0030] For example, the first binaural filter may be configured to output signals intended for the right ear and left ear of the user of the binaural hearing aid system that are phase shifted with relation to each other in order to introduce a first interaural time difference whereby the perceived position of the corresponding sound source is shifted outside the head and laterally with relation to the orientation of the head of the user of the binaural hearing aid system.

[0031] In the event that the output signals intended for the right ear and left ear are phase shifted 180° with relation to each other, sense of direction is lost; however, many users find speech signals phase shifted 180° easy to separate from other signal sources and understand.

[0032] Further separation of sound sources may be obtained by provision of a second binaural filter so that the second monaural signal, such as a second monaural signal received from a second spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., is filtered with the second binaural filter in such a way that the user perceives the received second monaural audio signal to be emitted by a sound source positioned in a second position and/or arriving from a second direction in space different from the first position and first direction.

[0033] For example, the second binaural filter may be configured to output signals intended for the right ear and left ear of the user of the binaural hearing aid system that are phase shifted with relation to each other in order to introduce a second interaural time difference whereby the corresponding position of the second sound source is shifted laterally, preferably in the opposite direction of the first sound source, with relation to the orientation of the head of the user of the binaural hearing aid system.

[0034] Alternatively, or additionally, the first binaural filter may be configured to output signals intended for the right ear and left ear of the user of the binaural hearing aid system that are equal to the first audio input signal multiplied with a first right gain and a first left gain, respectively; in order to obtain a first interaural level difference whereby the perceived position of the corresponding sound source is shifted laterally with relation to the orientation of the head of the user of the binaural hearing aid system.

[0035] Alternatively, or additionally, the second binaural filter may be configured to output signals intended for the right ear and left ear of the user of the binaural hearing aid system that are equal to the second audio input signal multiplied with a second right gain and a second left gain, respectively, in order to obtain a second interaural level difference whereby the perceived position of the corresponding sound source is shifted laterally, preferably in the opposite direction of the other sound source, with relation to the orientation of the head of the user of the binaural hearing aid system.

[0036] In order for the user of the new binaural hearing aid system to perceive the first audio signal source and the second audio signal source to be located in different positions in the surroundings, the pair of first interaural time difference and first interaural level difference must be different from the pair of second interaural time difference and second interaural level difference, i.e. the first and second interaural level differences may be identical provided that the first and second interaural time differences are different and vice versa.

[0037] In accordance with the new method, a first monaural audio signal in a binaural hearing aid, such as a first monaural signal received from a first spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., may be filtered with a selected first HRTF of a given first direction and first distance towards a sound source so that the user perceives the received first monaural audio signal to be emitted by a sound source positioned outside the head and in the first direction and at the first distance of the first HRTF.

[0038] A second monaural audio signal, such as a second monaural signal received from a second spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., may be conventionally hearing loss compensated in the binaural hearing aid system whereby the second monaural signal is perceived to originate from the centre of the head.

[0039] The perceived spatial separation of the perceived signal sources of the first and second monaural audio signals, one of which is perceived to be located outside the head of the user and one of which is perceived to be located inside the head of the user, assists the user in understanding speech in the first and second monaural audio signals, and in focussing the user's listening to a desired one of the first and second monaural audio signals.

[0040] Further separation of sound sources may be obtained by provision of a selected second HRTF so that the second monaural signal, such as a second monaural signal received from a second spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., is filtered with the selected second HRTF different from the first HRTF of a given second direction and second distance towards a sound source so that the user perceives the received second monaural audio signal to be emitted by a sound source positioned in the second direction and at the second distance corresponding to the second HRTF, i.e. the first and second monaural audio signals are perceived to be emitted by sound sources located in different positions in space.

[0041] The perceived spatial separation of the perceived signal sources of the first and second monaural audio signals, both of which are perceived to be located outside the head of the user, assists the user in under-

standing speech in the first and second monaural audio signals, and in focussing the user's listening to a desired one of the first and second monaural audio signals.

[0042] In accordance with the new method, the first and second monaural audio signals may be filtered with approximations to respective HRTFs. For example, HRTFs may be determined using a manikin, such as KEMAR. In this way, an approximation to the individual HRTFs is provided that can be of sufficient accuracy for the hearing aid user to maintain sense of direction when wearing the hearing aid.

[0043] Thus, a new binaural hearing aid system is provided in which signals that are not received by a microphone, such as a spouse microphone, a media player, a hearing loop system, a teleconference system, a radio, a TV, a telephone, a device with an alarm, etc., are filtered with binaural filters in such a way that a user perceives the signals to be emitted by respective sound sources positioned in different spatial positions in the sound environment of the user, whereby improved spatial separation of the different sound sources is facilitated.

[0044] Accordingly, an example, presented for better understanding of the invention, of a new method of binaural signal enhancement in a binaural hearing aid system is provided, the method comprising the steps of, binaurally filtering a first audio input signal into a first right ear signal for the right ear and a first left ear signal for the left ear selected from the group of signal pairs consisting of:

- a first right ear signal and a first left ear signal that are phase shifted with a first phase shift with relation to each other;
- a first right ear signal and a first left ear signal that are equal to the first audio input signal multiplied with a first right gain and a different first left gain, respectively;

a first right ear signal and a first left ear signal that are equal to the first audio input signal multiplied with a first right gain and a different first left gain, respectively, and phase shifted with a first phase shift with relation to each other; providing the first right ear signal and the first left ear signal to the right and left ears, respectively, of a user, and

providing a second audio input signal to both the right and left ears of the user.

[0045] In this way, at least some, users will perceive the first sound source to be spatially separated from the second sound source.

[0046] The method may further comprise the steps of:

binaurally filtering the second audio input signal into a second right ear signal for the right ear and a second left ear signal for the left ear selected from the group of signal pairs consisting of:

- a second right ear signal and a second left ear signal that are phase shifted with a second phase shift different from the first phase shift with relation to each other,
- a second right ear signal and a second left ear signal that are multiplied with a second gain different from the first gain with relation to each other;
- a second right ear signal and a second left ear signal that are phase shifted with a second phase shift different from the first phase shift with relation to each other and multiplied with a second gain different from the first gain with relation to each other, and

providing the second right ear signal and the second left ear signal to the right and left ears, respectively, of a user. According to the present invention, a new binaural hearing aid system is provided, as defined in claim 1.

In this way, at least some, users will perceive the first sound source to be spatially separated from the second sound source.

[0047] Each of the first and second phase shifts and/or each of the first and second interaural level differences may correspond to azimuth directional changes towards the respective one of the first and second sound sources, ranging from - 90° to 90°. Azimuth is the perceived angle of direction towards the sound source projected onto the horizontal plane with reference to the forward looking direction of the user. The forward looking direction is defined by a virtual line drawn through the centre of the user's head and through a centre of the nose of the user. Thus, a sound source located in the forward looking direction has an azimuth value of 0°, and a sound source located directly in the opposite direction has an azimuth value of 180°. A sound source located in the left side of a vertical plane perpendicular to the forward looking direction of the user has an azimuth value of - 90°, while a sound source located in the right side of the vertical plane perpendicular to the forward looking direction of the user has an azimuth value of + 90°.

[0048] Throughout the present disclosure, one signal is said to represent another signal when the one signal is a function of the other signal, for example the one signal may be formed by analogue-to-digital conversion, or digital-to-analogue conversion of the other signal; or, the one signal may be formed by conversion of an acoustic signal into an electronic signal or vice versa; or the one signal may be formed by analogue or digital filtering or mixing of the other signal; or the one signal may be formed by transformation, such as frequency transformation, etc, of the other signal; etc.

[0049] Further, signals that are processed by specific circuitry, e.g. in a signal processor, may be identified by a name that may be used to identify any analogue or digital signal forming part of the signal path of the signal in question from its input of the circuitry in question to its

output of the circuitry. For example an output signal of a microphone, i.e. the microphone audio signal, may be used to identify any analogue or digital signal forming part of the signal path from the output of the microphone to its input to the receiver, including any processed microphone audio signals.

[0050] The new binaural hearing aid system may comprise multi-channel first and/or second hearing aids in which the audio input signals are divided into a plurality of frequency channels for individual processing of at least some of the audio input signals in each of the frequency channels.

[0051] The plurality of frequency channels may include warped frequency channels, for example all of the frequency channels may be warped frequency channels.

[0052] The new binaural hearing aid system may additionally provide circuitry used in accordance with other conventional methods of hearing loss compensation so that the new circuitry or other conventional circuitry can be selected for operation as appropriate in different types of sound environment. The different sound environments may include speech, babble speech, restaurant clatter, music, traffic noise, etc.

[0053] The new binaural hearing aid system may for example comprise a Digital Signal

[0054] Processor (DSP), the processing of which is controlled by selectable signal processing algorithms, each of which having various parameters for adjustment of the actual signal processing performed. The gains in each of the frequency channels of a multi-channel hearing aid are examples of such parameters.

[0055] One of the selectable signal processing algorithms operates in accordance with the new method.

[0056] For example, various algorithms may be provided for conventional noise suppression, i.e. attenuation of undesired signals and amplification of desired signals.

[0057] Microphone audio signals obtained from different sound environments may possess very different characteristics, e.g. average and maximum sound pressure levels (SPLs) and/or frequency content. Therefore, each type of sound environment may be associated with a particular program wherein a particular setting of algorithm parameters of a signal processing algorithm provides processed sound of optimum signal quality in a specific sound environment. A set of such parameters may typically include parameters related to broadband gain, corner frequencies or slopes of frequency-selective filter algorithms and parameters controlling e.g. knee-points and compression ratios of Automatic Gain Control (AGC) algorithms.

[0058] Signal processing characteristics of each of the algorithms may be determined during an initial fitting session in a dispenser's office and programmed into the new binaural hearing aid system in a non-volatile memory area.

[0059] The new binaural hearing aid system may have a user interface, e.g. buttons, toggle switches, etc, of the hearing aid housings, or a remote control, so that the user of the new binaural hearing aid system can select one of the available signal processing algorithms to obtain the desired hearing loss compensation in the sound environment in question.

[0060] The new binaural hearing aid system may be capable of automatically classifying the user's sound environment into one of a number of sound environment categories, such as speech, babble speech, restaurant clatter, music, traffic noise, etc, and may automatically select the appropriate signal processing algorithm accordingly as known in the art.

[0061] In the following, preferred embodiments of the invention is explained in more detail with reference to the drawing, wherein

- Fig. 1 schematically illustrates an exemplary new binaural hearing aid system,
- Fig. 2 schematically illustrates an exemplary new binaural hearing aid system,
- Fig. 3 schematically illustrates an exemplary new binaural hearing aid system,
- Fig. 4 schematically illustrates an exemplary new binaural hearing aid system, and
- Fig. 5 schematically illustrates an exemplary new binaural hearing aid system.

[0062] The new method and binaural hearing aid system will now be described more fully hereinafter with reference to the accompanying drawings, in which various examples of the new binaural hearing aid system are shown. The new method and binaural hearing aid system may, however, be embodied in different forms and should not be construed as limited to the examples set forth herein. Rather, these examples are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0063] It should be noted that the accompanying drawings are schematic and simplified for clarity, and they merely show details which are essential to the understanding of the invention, while other details have been left out.

[0064] Like reference numerals refer to like elements throughout. Like elements will, thus, not be described in detail with respect to the description of each figure.

[0065] Fig. 1 schematically illustrates an example of the new binaural hearing aid system 10.

[0066] The new binaural hearing aid system 10 has first and second hearing aids 10A, 10B.

[0067] The first hearing aid 10A comprises a first microphone 12A for provision of first microphone audio signal 14A in response to sound received at the first microphone 12A. The microphone audio signal 14A may be pre-filtered in a first pre-filter 16A well-known in the art, and input to a signal processor 18.

[0068] The first microphone 12A may include two or more microphones with signal processing circuitry for combining the microphone signals into the microphone audio signal 14A. For example, the first hearing aid 10A

may have two microphones and a beamformer for combining the microphone signals into a microphone audio signal 14A with a desired directivity pattern as is well-known in the art of hearing aids.

[0069] The first hearing aid 10A also comprises a first input 20A for provision of a first audio input signal 24A representing sound output by a first sound source (not shown) and received at the first input 20A that is not a microphone input.

[0070] The first sound source may be a spouse microphone (not shown) carried by a person the hearing aid user desires to listen to. The output signal of the spouse microphone is encoded for transmission to the first hearing aid 10A using wireless or wired data transmission. The transmitted data representing the spouse microphone audio signal are received by a receiver and decoder 22A for decoding into the first audio input signal 24A.

[0071] The second hearing aid 10B comprises a second microphone 12B for provision of second microphone audio signal 14B in response to sound received at the second microphone 12B. The microphone audio signal 14B may be pre-filtered in a second pre-filter 16B well-known in the art, and input to signal processor 18.

[0072] The second microphone 12B may include two or more microphones with signal processing circuitry for combining the microphone signals into the microphone audio signal 14B. For example, the second hearing aid 10B may have two microphones and a beamformer for combining the microphone signals into a microphone audio signal 14B with a desired directivity pattern as is well-known in the art of hearing aids.

[0073] The binaural hearing aid system 10 also comprises a second input 26 for provision of a second audio input signal 30 representing sound output by a second sound source (not shown) and received at the second input 26.

[0074] The second sound source may be a second spouse microphone (not shown) carried by a second person the hearing aid user desires to listen to. The output signal of the second spouse microphone is encoded for transmission to the binaural hearing aid system 10 using wireless or wired data transmission. The transmitted data representing the spouse microphone audio signal are received by a receiver and decoder 28 for decoding into the second audio input signal 30.

[0075] The second input 26 and receiver and decoder 28 may be accommodated in the first hearing aid 10A or in the second hearing aid 10B.

[0076] In the event that the first and second audio input signal 24A, 30 are presented to the ears of the user as monaural signals, i.e. the same signal is presented to both ears of the user, and both signals will be perceived to originate from the centre of the head of the user of the binaural hearing aid system.

[0077] Although the signals are compensated for hearing loss, as is well-known in the art of hearing aids, a user with hearing loss will have difficulties in understanding more than one monaural audio input signal at the time due to lack of perceived spatial separation of the signal sources.

[0078] Therefore at least one of the first and second audio input signals 24A, 30 is filtered in such a way that the user of the binaural hearing aid system 10 perceives the corresponding signal source to be moved away from the centre of the head of the user.

[0079] The resulting perceived spatial separation of the sound sources facilitates that the user's auditory system's binaural signal processing is utilized to improve the user's capability of separating the signals from the sound sources and of focussing his or her listening to a desired one of the sound sources, or even to simultaneously listen to and understand more than one of the sound sources.

[0080] It has also been found that if a speech signal is presented in anti-phase, i.e. phase shifted 180° with relation to each other, in the two ears of the human, a specific direction of arrival of the speech signal is not perceived; however, many users find the speech signal presented in anti-phase easy to separate from other signal sources and understand.

[0081] In the illustrated new binaural hearing aid system 10, a set of two filters 32A-R, 32A-L, 34-R, 34-L is provided with inputs connected to the respective outputs 24A, 30 of each of the respective receivers and decoders 22A, 28 and with outputs 36A-R, 36A-L, 38-R, 38-L, one of which 36A-R, 38-R provides an output signal to the right ear and the other 36A-L, 38-L provides an output signal to the left ear. The sets of two filters 32A-R, 32A-L, 34-R, 34-L have transfer functions of respective HRTFs 32A, 34 imparting selected directions of arrival to the first and second sound sources. In one example of the system of Fig. 1, the HRTF 32A imparts a perceived direction of arrival to the first sound source having a direction of arrival with -45° azimuth, while the HRTF 34 imparts a perceived direction of arrival to the second sound source having a direction of arrival with + 45° azimuth.

[0082] The first hearing aid 10A and the second hearing aid 10B may be configured for hearing loss compensation of the right ear and the left ear of the user, respectively; or, vice versa. For ease of description, in the following, the first hearing aid 10A is assumed to be configured for hearing loss compensation of the right ear; however, the operating principles of the new binaural hearing aid system and method do not depend on for which of the right and left ears, the first and second hearing aids perform hearing loss compensation.

[0083] The output of the filters 32A-R, 32A-L, 34-R, 34-L, are processed in signal processor 18 for hearing loss compensation and the processor output signal 40A intended to be transmitted towards the right ear is connected to a first receiver 42A of the first hearing aid 10A for conversion into an acoustic signal for transmission towards an eardrum of the right ear of a user of the binaural hearing aid system 10, and the processor output signal 40B intended to be transmitted towards the left ear is

connected to a second receiver 42B of the second hearing aid 10B for conversion into an acoustic signal for transmission towards an eardrum of the left ear of the user of the binaural hearing aid system 10.

[0084] The HRTFs 32A, 34 may be individually determined for the user of the binaural hearing aid system, whereby the user's perceived externalization of and sense of direction towards the first and second sound sources will be distinct since the HRTFs will contain all information relating to the sound transmission to the ears of the user, including diffraction around the head, reflections from shoulders, reflections in the ear canal, etc., which cause variations of HRTFs of different users.

[0085] Good sense of directions may also be obtained by approximations to individually determined HRTFs, such as HRTFs determined on a manikin, such as a KEMAR head, provided that the approximation to the individual HRTF is sufficiently accurate for the hearing aid user to maintain sense of direction towards the first and second sound sources. Likewise, approximations may be constituted by HRTFs determined as averages of individual HRTFs of humans in a selected group of humans with certain physical similarities leading to corresponding similarities of the individual HRTFs, e.g. humans of the same age or in the same age range, humans of the same race, humans with similar sizes of pinnas, etc.

[0086] Fig. 2 shows an example of the new binaural hearing aid system 10 similar to the example shown in Fig. 1 except for the fact that sufficient perceived spatial separation between the first and second sound sources is obtained by introducing a delay equal to the ITD of a desired azimuth direction of arrival in the signal path from the first receiver and decoder 22A to one of the ears of the user. In the illustrated example, the filter 32A-R introduces a time delay between its input signal 24A and output signal 36A-R intended for the right ear of the user, while the filter 32A-L shown in Fig. 1 is constituted by a direct connection between input 24A and output 36A-L.

[0087] In this way, the perceived azimuth of the direction of arrival of the first sound source is shifted, e.g. to - 45°, while the signal from the second sound source is presented monaurally to the ears of the user, i.e. the output 30 of the receiver and decoder 28 is input as a monaural signal to the signal processor 18 and output to both ears of the user. Thus, perceived spatial separation of the first and second sound sources is obtained, since the first sound source is perceived to be position in a direction determined by the delay 32A-R, e.g. 45° azimuth, while the second sound source is perceived to be positioned at the centre inside the head of the user.

[0088] Fig. 3 shows an example of the new binaural hearing aid system 10 similar to the example shown in Fig. 2 except for the fact that improved perceived spatial separation between the first and second sound sources is obtained by introducing an additional delay equal to the ITD of a desired second azimuth direction of arrival in the signal path from the second receiver and decoder 28 to one of the ears of the user. For example, the filter 34-L may introduce a time delay between its input signal 30 and output signal 38-L intended for the left ear of the user, while the filter 34-R shown in Fig. 1 is constituted by a short-circuit between input 30 and output 38-R.

[0089] In this way, the perceived azimuth of the direction of arrival of the second sound source is shifted, e.g. to + 45° while the perceived azimuth of the direction of arrival of the first sound source remains shifted, e.g. to - 45 °. Thus, improved perceived spatial separation of the first and second sound sources is obtained, since the first sound source is perceived to be position in a direction determined by the delay 32A-R, e.g. at - 45° azimuth, while the second sound source is perceived to be positioned in a direction determined by the delay 34-L, e.g. at +45° azimuth.

[0090] In Figs. 1, 2, and 3, the dashed lines indicate the housings of the first and second hearing aids 10A, 10B accommodating the components of the binaural hearing aid system 10. Each of the housings accommodates the one or more microphones 12A, 12B for reception of sound at the respective ear of the user for which the respective hearing aid 10A, 10B is intended for performing hearing loss compensation, and the respective receiver 42A, 42B for conversion of the respective output signal 40A, 40B of the signal processor 18 into acoustic signals for transmission towards eardrum of the respective one of the right and left ears of the user. The remaining circuitry may be distributed in arbitrary ways between the two hearing aid housings in accordance with design choices made by the designer of the binaural hearing aid system. Each of the signals in the binaural hearing aid system shown in Figs. 1, 2 and 3 may be transmitted by wired or wireless transmission between the hearing aids 10A, 10B in a way well-known in the art of signal transmission.

[0091] Fig. 4 shows an example of the new binaural hearing aid system 10 shown in Fig. 1, wherein the second hearing aid 10B does not have a signal processor 18 and does not have inputs for provision of first and second audio input signals representing sound from respective first and second sound sources. The second hearing aid 10B only has the one or more second microphone 12B and the second receiver 42B and the required encoder and transmitter (not shown) for transmission of the microphone audio signal 14B for signal processing in the first hearing aid 10A, and receiver and decoder (not shown) for reception of the output signal 40B of the signal processor 18A. The remaining circuitry shown in Fig. 1 is accommodated in the housing of the first hearing aid 10A.

[0092] Fig. 5 shows an example of the new binaural hearing aid system 10 shown in Fig. 1, wherein the first and second hearing aids 10A, 10B both comprise a microphone, and a receiver, and a hearing aid processor.

[0093] Thus, the illustrated new binaural hearing aid system comprises,

[0094] A first hearing aid 10A comprising

a first input 20A for provision of a first audio input signal 24A representing sound output by a first sound source and received at the first input 20A,

a first binaural filter 32A-R, 32A-L for filtering the first audio input signal 24A and configured to output a first right ear signal 36A-R for the right ear and a first left ear signal 36A-L for the left ear that are that are equal to the first audio input signal multiplied with a first right gain and a different first left gain, respectively, and/or phase shifted with a first phase shift with relation to each other, a first ear receiver 42A for conversion of a first ear receiver input signal 40A into an acoustic signal for transmission towards an eardrum of the first ear of a user of the binaural hearing aid system 10, and

a second input 26B for provision of a second audio input signal 30B representing sound output by a second sound source and received at the second input 26B,

a second binaural filter 34B-R, 34B-L for filtering the second audio input signal 30B and configured to output a second right ear signal 38B-R for the right ear and a second left ear signal 38B-L for the left ear that are equal to the second audio input signal multiplied with a second right gain and a different second left gain, respectively, and/or that are phase shifted with a second phase shift different from the first phase shift with relation to each other, and wherein

the first and second right ear signals 36A-R, 38B-R are provided to the first ear receiver input 40A, and

the first and second left ear signals 36A-L, 38B-L are provided to the second ear receiver input 40B.

Claims

1. A binaural hearing aid system (10) comprising
a first hearing aid (10A),
a second hearing aid (10B),
a first spouse microphone for picking up speech from a speaker equipped with the first spouse microphone and converting the speech into a first monaural audio signal (24A) for transmission to the first hearing aid (10A), and
a second spouse microphone for picking up speech from a speaker equipped with the second spouse microphone and converting the speech into a second monaural audio signal (30) for transmission to one of the first hearing aid (10A) and the second hearing aid (10B), wherein
the first hearing aid (10A) comprises

a first input (20A) for provision of the first monaural audio input signal (24A) representing speech and output by the first spouse microphone and received at the first input (20A),

one of the first hearing aid (10A) and the second hearing aid (10B) comprises

a second input (26) for provision of a second monaural audio input signal (30) representing speech and output by the second spouse microphone and received at the second input (26),

the first hearing aid (10A) comprises

a first binaural filter (32A-R, 32A-L) for filtering the first monaural audio input signal (24A) and configured to output a first right ear signal (36A-R) for a right ear of a user of the binaural hearing aid system (10) and a first left ear signal (36A-L) for a left ear of the user, selected from the group of signal pairs consisting of:

a first right ear signal (36A-R) and a first left ear signal (36A-L) that are phase shifted with a first phase shift with relation to each other;
a first right ear signal (36A-R) and a first left ear signal (36A-L) that are equal to the first monaural audio input signal (24A) multiplied with a first right gain and a different first left gain, respectively;
a first right ear signal (36A-R) and a first left ear signal (36A-L) that are equal to the first monaural audio input signal (24A) multiplied with a first right gain and a different first left gain, respectively, and phase shifted with a first phase shift with relation to each other,

one of the first hearing aid (10A) and the second hearing aid (10B) comprises

a second binaural filter (34B-R, 34B-L) for filtering the second monaural audio input signal (30) and configured to output a second right ear signal (38B-R) for the right ear and a second left ear signal (38B-L) for the left ear selected from the group of signal pairs consisting of:

a second right ear signal (38B-R) and a second left ear signal (38B-L) that are phase shifted with a second phase shift different from the first phase shift with relation to each other;
a second right ear signal (38B-R) and a second left ear signal (38B-L) that are equal to the second monaural audio input signal (30) multiplied with a second right gain and a different second left gain, respectively;

a second right ear signal (38B-R) and a second left ear signal (38B-L) that are equal to the second monaural audio input signal (30) multiplied with a second right gain and a different second left gain, respectively, and phase shifted with a second phase shift with relation to each other,

the first hearing aid (10A) comprises

a first ear receiver (42A) for conversion of a first ear receiver input signal (40A) into an acoustic signal for transmission towards an eardrum of the first ear of the user of the binaural hearing aid system (10), and

the second hearing aid (10B) comprises
a second ear receiver (42B) for conversion of a second ear receiver input signal (40B) into an acoustic signal for transmission towards an eardrum of the second ear of the user of the binaural hearing aid system (10), and wherein
the first right ear signal (36A-R) and the second right ear signal (38B-R) are provided to one of the first ear receiver input (40A) and the second ear receiver input (40B), and the first left ear signal (36A-L) and the second left ear signal (38B-L) are provided to the other one of the first ear receiver input (40A) and the second ear receiver input (40B), whereby
the user perceives the first monaural audio input signal (24A) from the first spouse microphone to arrive from a first direction in space and the second monaural audio input signal (30) from the second spouse microphone to arrive from a second direction in space different from the first direction thereby assisting the user in understanding speech in the first and second monaural audio signals, and in focussing the user's listening to a desired one of the first and second monaural audio signals.

2. A binaural hearing aid system (10) according to claim 1, wherein the first phase shift ranges from 150° to 210°.

3. A binaural hearing aid system (10) according to claim 1, wherein the first phase shift corresponds to azimuth directional changes ranging from - 90° to 90°.

4. A binaural hearing aid system (10) according to any of the preceding claims, wherein one of the first right ear signal (36A-R) and the first left ear signal (36A-L) is phase shifted with relation to the first monaural audio input signal (24A), and the other one of the first right ear signal (36A-R) and the first left ear signal (36A-L) is the first monaural audio input signal (24A).

5. A binaural hearing aid system (10) according to any of the previous claims, wherein the first hearing aid (10A) comprises

the second input (26), and
the second binaural filter (34B-R, 34B-L).

6. A binaural hearing aid system (10) according to any of claims 1 - 4, wherein
the second hearing aid (10B) comprises

the second input (26), and
the second binaural filter (34B-R, 34B-L).

7. A binaural hearing aid system (10) according to any of the preceding claims, wherein the first binaural filter (32A-R, 32A-L) is a HRTF filter.

8. A binaural hearing aid system (10) according to any of the preceding claims, wherein the second binaural filter (34B-R, 34B-L) is a HRTF filter.

Patentansprüche

1. Binaurales Hörgerätesystem (10), das umfasst:

ein erstes Hörgerät (10A),
ein zweites Hörgerät (10B),
ein erstes Partnermikrofon zum Aufnehmen von Sprache von einem mit dem ersten Partnermikrofon ausgestatteten Lautsprecher und zum Umwandeln der Sprache in ein erstes monaurales Audiosignal (24A) zur Übertragung an das erste Hörgerät (10A), und
ein zweites Partnermikrofon zum Aufnehmen von Sprache von einem mit dem zweiten Partnermikrofon ausgestatteten Lautsprecher und zum Umwandeln der Sprache in ein zweites monaurales Audiosignal (30) zur Übertragung an eines von dem ersten Hörgerät (10A) und dem zweiten Hörgerät (10B), wobei
das erste Hörgerät (10A)
einen ersten Eingang (20A) zum Bereitstellen des ersten monauralen Audioeingangssignals (24A) umfasst, das eine Sprache repräsentiert und von dem ersten Partnermikrofon ausgegeben wird und an dem ersten Eingang (20A) empfangen wird,
eines von dem ersten Hörgerät (10A) und dem zweiten Hörgerät (10B)
einen zweiten Eingang (26) zum Bereitstellen eines zweiten monauralen Audioeingangssignals (30) umfasst, das eine Sprache repräsentiert und von dem zweiten Partnermikrofon ausgegeben wird und an dem zweiten Eingang (26) empfangen wird,
das erste Hörgerät (10A)
einen ersten binauralen Filter (32A-R, 32A-L)

zum Filtern des ersten monauralen Audioeingangssignals (24A) umfasst, der konfiguriert ist, um ein erstes rechtes Ohrsignal (36A-R) für ein rechtes Ohr eines Benutzers des binauralen Hörgerätesystems (10) und ein erstes linkes Ohrsignal (36A-L) für ein linkes Ohr des Benutzers auszugeben, die aus der Gruppe von Signalpaaren ausgewählt sind, die besteht aus:

einem ersten rechten Ohrsignal (36A-R) und einem ersten linken Ohrsignal (36A-L), die um eine erste Phasenverschiebung in Beziehung zueinander phasenverschoben sind;
einem ersten rechten Ohrsignal (36A-R) und einem erstem linken Ohrsignal (36A-L), die gleich dem ersten monauralen Audioeingangssignal (24A) sind, das mit einer ersten rechten Verstärkung bzw. einer unterschiedlichen ersten linken Verstärkung multipliziert ist;
einem ersten rechten Ohrsignal (36A-R) und einem ersten linken Ohrsignal (36A-L), die gleich dem ersten monauralen Audioeingangssignal (24A) sind, das mit einer ersten rechten Verstärkung bzw. einer unterschiedlichen ersten linken Verstärkung multipliziert sind und um eine erste Phasenverschiebung in Beziehung zueinander phasenverschoben sind,
eines von dem ersten Hörgerät (10A) und dem zweiten Hörgerät (10B)
einen zweiten binauralen Filter (34B-R, 34B-L) zum Filtern des zweiten monauralen Audioeingangssignals (30) umfasst, der konfiguriert ist, um ein zweites rechtes Ohrsignal (38B-R) für das rechte Ohr und ein zweites linkes Ohrsignal (38B-L) für das linke Ohr auszugeben, die aus der Gruppe von Signalpaaren ausgewählt sind, die besteht aus:

einem zweiten rechten Ohrsignal (38B-R) und einem zweiten linken Ohrsignal (38B-L), die um eine zweite Phasenverschiebung, die sich von der ersten Phasenverschiebung unterscheidet, in Beziehung zueinander phasenverschoben sind;
einem zweiten rechten Ohrsignal (38B-R) und einem zweiten linken Ohrsignal (38B-L), die gleich dem zweiten monauralen Audioeingangssignal (30) sind, das mit einer zweiten rechten Verstärkung bzw. einer unterschiedlichen zweiten linken Verstärkung multipliziert ist;
einem zweiten rechten Ohrsignal (38B-R) und einem zweiten linken Ohrsignal (38B-L), die gleich dem zweiten monauralen Audioeingangssignal (30) sind, das mit einer zweiten rechten Verstärkung bzw. einer unterschiedlichen zweiten linken Verstärkung multipliziert ist, und mit einer zweiten Phasenverschiebung in Beziehung zueinander phasenverschoben sind,

wobei das erste Hörgerät (10A)
einen ersten Ohrempfänger (42A) zur Umwandlung eines Eingangssignals (40A) des ersten Ohrempfängers in ein akustisches Signal zur Übertragung zu einem Trommelfell des ersten Ohrs des Benutzers des binauralen Hörgerätesystems (10) umfasst, und
das zweite Hörgerät (10B)
einen zweiten Ohrempfänger (42B) zur Umwandlung eines Eingangssignals (40B) des zweiten Ohrhörers in ein akustisches Signal zur Übertragung zu einem Trommelfell des zweiten Ohrs des Benutzers des binauralen Hörgerätesystems (10) umfasst, und wobei das erste rechte Ohrsignal (36A-R) und das zweite rechte Ohrsignal (38B-R) an einem von dem ersten Ohrempfängereingang (40A) und dem zweiten Ohrempfängereingang (40B) bereitgestellt werden, und das erste linke Ohrsignal (36A-L) und das zweite linke Ohrsignal (38B-L) an dem anderen von dem ersten Ohrempfängereingang (40A) und dem zweiten Ohrempfängereingang (40B) bereitgestellt werden, wobei
der Benutzer wahrnimmt, dass das erste monaurale Audioeingangssignal (24A) von dem ersten Partnermikrofon aus einer ersten Richtung im Raum ankommt, und dass das zweite monaurale Audioeingangssignal (30) von dem zweiten Partnermikrofon von einer zweiten Richtung im Raum ankommt, die von der ersten Richtung im Raum unterschiedlich ist, wodurch der Benutzer dabei unterstützt wird, die Sprache in dem ersten und dem zweiten monauralen Audiosignal zu verstehen, und das Hören des Benutzers auf ein gewünschtes von dem ersten und dem zweiten monauralen Audiosignal zu fokussieren.

2. Binaurales Hörgerätesystem (10) nach Anspruch 1, wobei die erste Phasenverschiebung von 150° bis 210° reicht.

3. Binaurales Hörgerätesystem (10) nach Anspruch 1, wobei die erste Phasenverschiebung Azimutrichtungsänderungen entspricht, die von - 90° bis 90°

reichen.

4. Binaurales Hörgerätesystem (10) nach einem der vorhergehenden Ansprüche, wobei eines von dem ersten rechten Ohrsignal (36A-R) und dem ersten linken Ohrsignal (36A-L) in Bezug auf das erste monaurale Audioeingangssignal (24A) phasenverschoben ist, und das andere von dem ersten rechten Ohrsignal (36A-R) und dem ersten linken Ohrsignal (36A-L) das erste monaurale Audioeingangssignal (24A) ist.

5. Binaurales Hörgerätesystem (10) nach einem der vorhergehenden Ansprüche, wobei das erste Hörgerät (10A) umfasst

den zweiten Eingang (26) und
den zweiten binauralen Filter (34B-R, 34B-L).

6. Binaurales Hörgerätesystem (10) nach einem der Ansprüche 1 bis 4, wobei das zweite Hörgerät (10B) umfasst

den zweiten Eingang (26) und
den zweiten binauralen Filter (34B-R, 34B-L).

7. Binaurales Hörgerätesystem (10) nach einem der vorhergehenden Ansprüche, wobei der erste binaurale Filter (32A-R, 32A-L) ein HRTF-Filter ist.

8. Binaurales Hörgerätesystem (10) nach einem der vorhergehenden Ansprüche, wobei der zweite binaurale Filter (34B-R, 34B-L) ein HRTF-Filter ist.

Revendications

1. Système de prothèse auditive binauriculaire (10) comprenant :

une première prothèse auditive (10A),
une seconde prothèse auditive (10B),
un premier microphone conjoint pour capter la parole d'un locuteur équipé du premier microphone conjoint et convertir la parole en un premier signal audio monauriculaire (24A) pour une transmission à la première prothèse auditive (10A), et
un second microphone conjoint pour capter la parole d'un locuteur équipé du second microphone conjoint et convertir la parole en un second signal audio monauriculaire (30) pour une transmission à l'une de la première prothèse auditive (10A) et de la seconde prothèse auditive (10B), dans lequel :

la première prothèse auditive (10A) comprend :

une première entrée (20A) pour fournir le premier signal d'entrée audio monauriculaire (24A) représentant la parole et délivré par le premier microphone conjoint et reçu à la première entrée (20A),
l'une de la première prothèse auditive (10A) et de la seconde prothèse auditive (10B) comprend :

une seconde entrée (26) pour fournir un second signal d'entrée audio monauriculaire (30) représentant la parole et délivré par le second microphone conjoint et reçu à la seconde entrée (26),

la première prothèse auditive (10A) comprend :

un premier filtre binauriculaire (32A-R, 32A-L) pour filtrer le premier signal d'entrée audio monauriculaire (24A) et configuré pour délivrer un premier signal d'oreille droite (36A-R) pour l'oreille droite d'un utilisateur du système de prothèse auditive binauriculaire (10) et un premier signal d'oreille gauche (36A-L) pour l'oreille gauche de l'utilisateur, choisis dans le groupe de paires de signaux constituées des suivantes :

un premier signal d'oreille droite (36A-R) et un premier signal d'oreille gauche (36A-L) qui sont décalés en phase avec un premier décalage de phase l'un par rapport à l'autre ;
un premier signal d'oreille droite (36A-R) et un premier signal d'oreille gauche (36A-L) qui sont égaux au premier signal d'entrée audio monauriculaire (24A) multiplié par un premier gain de droite et un premier gain de gauche différent, respectivement ;
un premier signal d'oreille droite (36A-R) et un premier signal d'oreille gauche (36A-L) qui sont égaux au premier signal d'entrée audio monauriculaire (24A) multiplié par un premier gain de droite et un premier gain de gauche différent, respectivement, et décalés en phase avec un premier décalage de phase l'un par rapport à l'autre,

l'une de la première prothèse auditive (10A) et de la seconde prothèse auditive (10B) comprend :

un second filtre binauriculaire (34B-R, 34B-L) pour filtrer le second signal audio monauriculaire (30) et configuré pour délivrer un second signal d'oreille droite (38B-R) pour l'oreille droite et un second signal d'oreille gauche (38B-L) pour l'oreille gauche choisis parmi le groupe de paires de signaux constituées des suivantes :

un second signal d'oreille droite (38B-R) et un second signal d'oreille gauche (38B-L) qui sont décalés en phase avec un second décalage de phase différent du premier décalage de phase l'un par rapport à l'autre ;
un second signal d'oreille droite (38B-R) et un second signal d'oreille gauche (38B-L) qui sont égaux au second signal d'entrée audio monauriculaire (30) multiplié par un second gain de droite et un second gain de gauche différent, respectivement ;
un second signal d'oreille droite (38B-R) et un second signal d'oreille gauche (38B-L) qui sont égaux au second signal d'entrée audio monauriculaire (30) multiplié par un second gain de droite et un second gain de gauche différent, respectivement, et décalés en phase avec un second décalage de phase l'un par rapport à l'autre,

la première prothèse auditive (10A) comprend :

un premier récepteur d'oreille (42A) pour la conversion d'un premier signal d'entrée de récepteur d'oreille (40A) en un signal acoustique pour une transmission vers une caisse du tympan de la première oreille de l'utilisateur du système de prothèse auditive binauriculaire (10) et

la seconde prothèse auditive (10B) comprend :

un second récepteur d'oreille (42B) pour la conversion d'un second signal d'entrée de récepteur d'oreille (40B) en un signal acoustique pour une transmission vers une caisse du tympan de la seconde oreille de l'utilisateur du système de prothèse auditive binauriculaire (10), et dans lequel :

le premier signal d'oreille droite (36A-R) et le second signal d'oreille droite (38B-R) sont fournis à l'une de la première entrée (40A) du récepteur d'oreille et de la seconde entrée (40B) du récepteur d'oreille et le premier signal d'oreille gauche (36A-L) et le second signal de l'oreille gauche (38B-L) sont fournis à l'autre de la première entrée (40A) du récepteur d'oreille et de la seconde entrée (40B) du récepteur d'oreille, dans lequel l'utilisateur perçoit le premier signal d'entrée audio monauriculaire (24A) du premier microphone conjoint comme arrivant d'une première direction de l'espace et le second signal d'entrée audio monauriculaire (30) du second microphone conjoint comme arrivant d'une seconde direction de l'espace différente de la première direction, aidant de la sorte l'utilisateur à comprendre la parole des premier et second signaux audio monauriculaires et à focaliser l'écoute de l'utilisateur à l'un souhaité des premier et second signaux audio monauriculaires.

2. Système de prothèse auditive binauriculaire (10) selon la revendication 1, dans lequel le premier décalage de phase se situe dans une plage de 150° à 210°.

3. Système de prothèse auditive binauriculaire (10) selon la revendication 1, dans lequel le premier décalage de phase correspond à des changements directionnels d'azimut allant de -90° à 90°.

4. Système de prothèse auditive binauriculaire (10) selon l'une quelconque des revendications précédentes, dans lequel l'un du premier signal d'oreille droite (36A-R) et du premier signal d'oreille gauche (36A-L) est décalé en phase par rapport au premier signal d'entrée audio monauriculaire (24A) et l'autre du premier signal d'oreille droite (36A-R) et du premier signal d'oreille gauche (36A-L) est le premier signal d'entrée audio monauriculaire (24A).

5. Système de prothèse auditive binauriculaire (10) se-

lon l'une quelconque des revendications précédentes, dans lequel la première prothèse auditive (10A) comprend :

la seconde entrée (26) et
le second filtre binauriculaire (34B-R, 34B-L).

6. Système de prothèse auditive binauriculaire (10) selon l'une quelconque des revendications 1 à 4, dans lequel la seconde prothèse auditive (10B) comprend :

la seconde entrée (26) et
le second filtre binauriculaire (34B-R, 34B-L).

7. Système de prothèse auditive binauriculaire (10) selon l'une quelconque des revendications précédentes, dans lequel le premier filtre binauriculaire (32A-R, 32A-L) est un filtre HRTF.

8. Système de prothèse auditive binauriculaire (10) selon l'une quelconque des revendications précédentes, dans lequel le second filtre binauriculaire (34B-R, 34B-L) est un filtre HRTF.

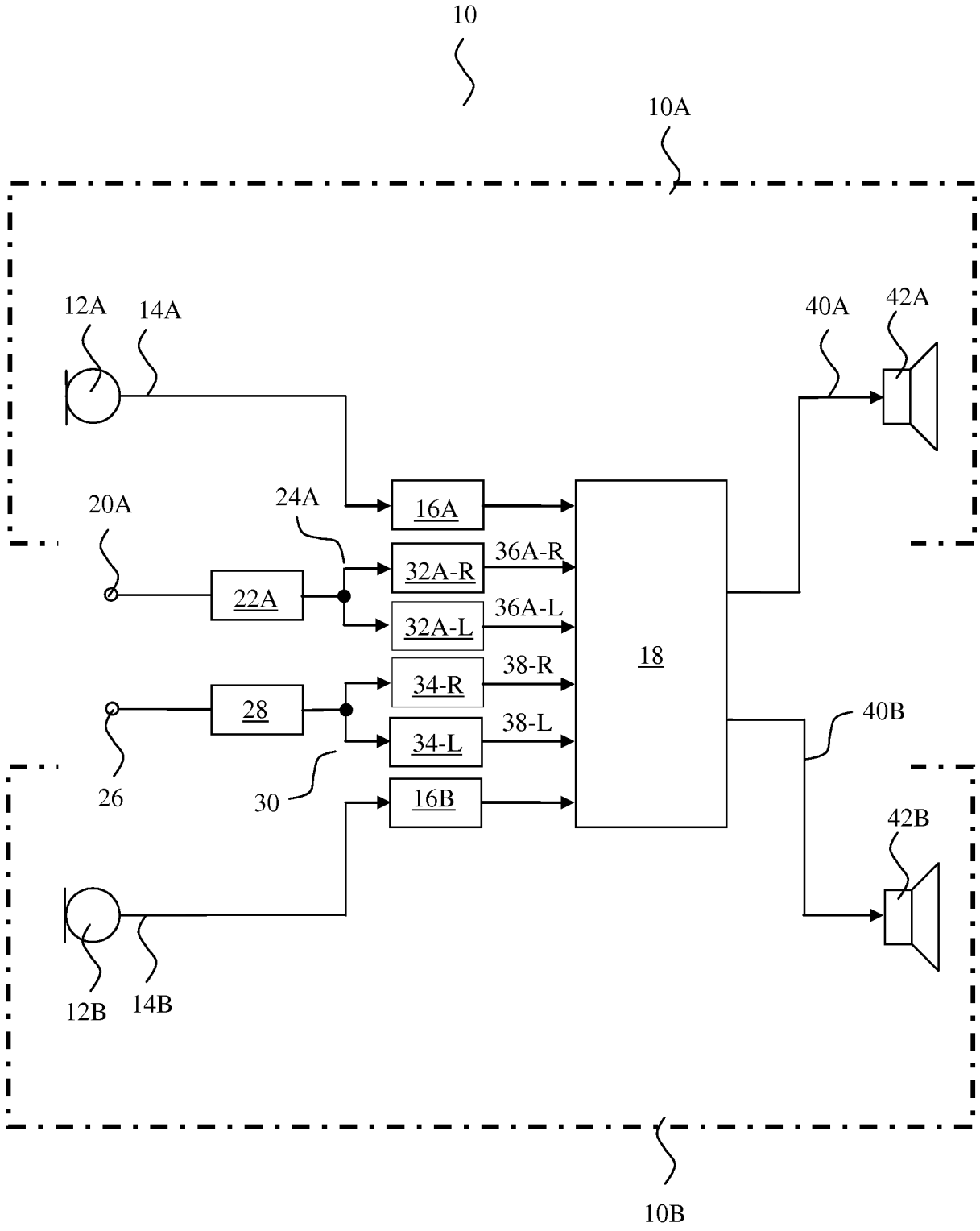

10
10A
12A
14A
40A
42A
20A
24A
16A
32A-R
36A-R
22A
32A-L
36A-L
18
34-R
38-R
28
34-L
38-L
40B
26
30
16B
42B
12B
14B
10B

Fig. 1

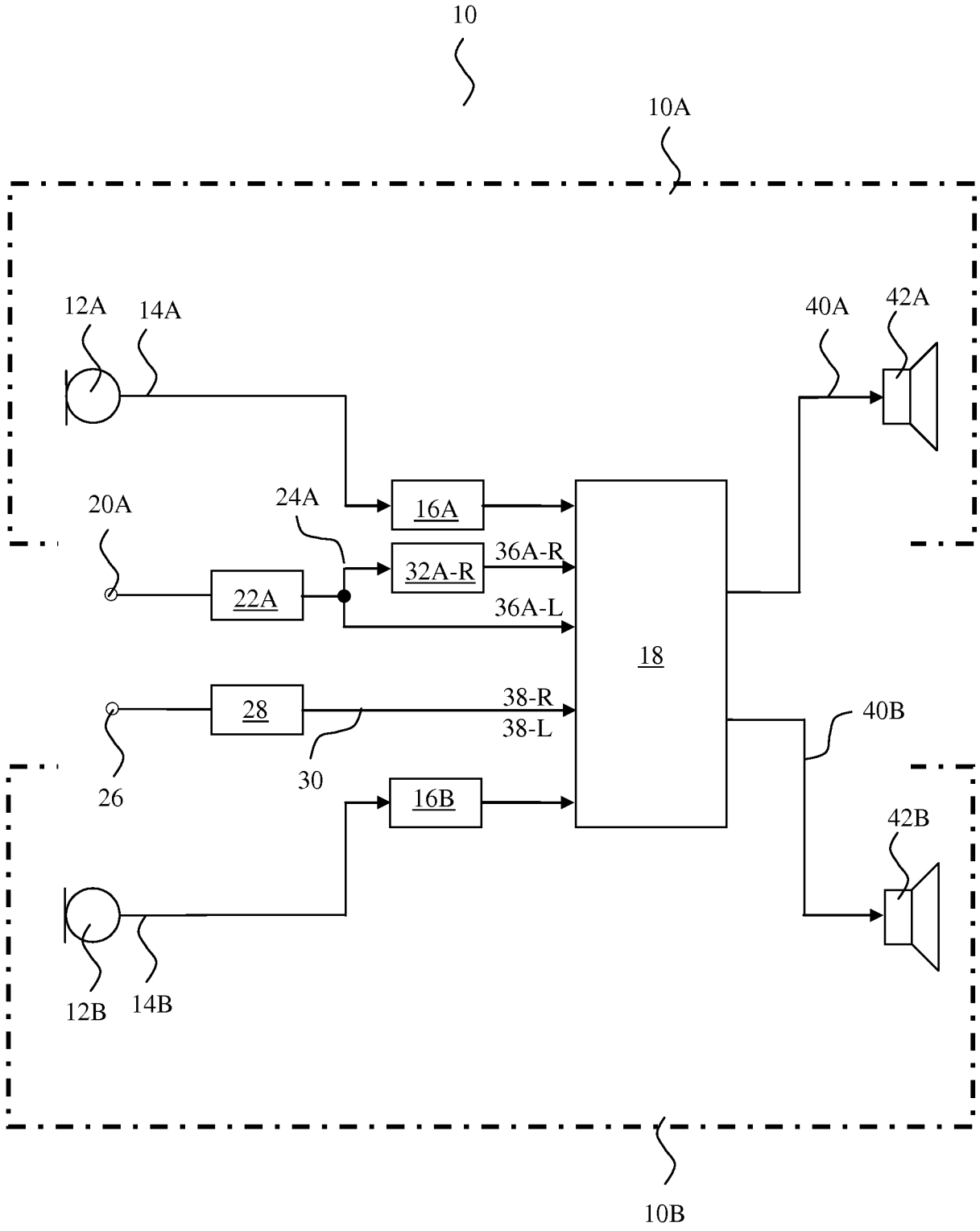

10
10A
12A
14A
40A
42A
20A
24A
16A
32A-R
36A-R
22A
36A-L
18
28
38-R
38-L
40B
26
30
16B
42B
12B
14B
10B

Fig. 2

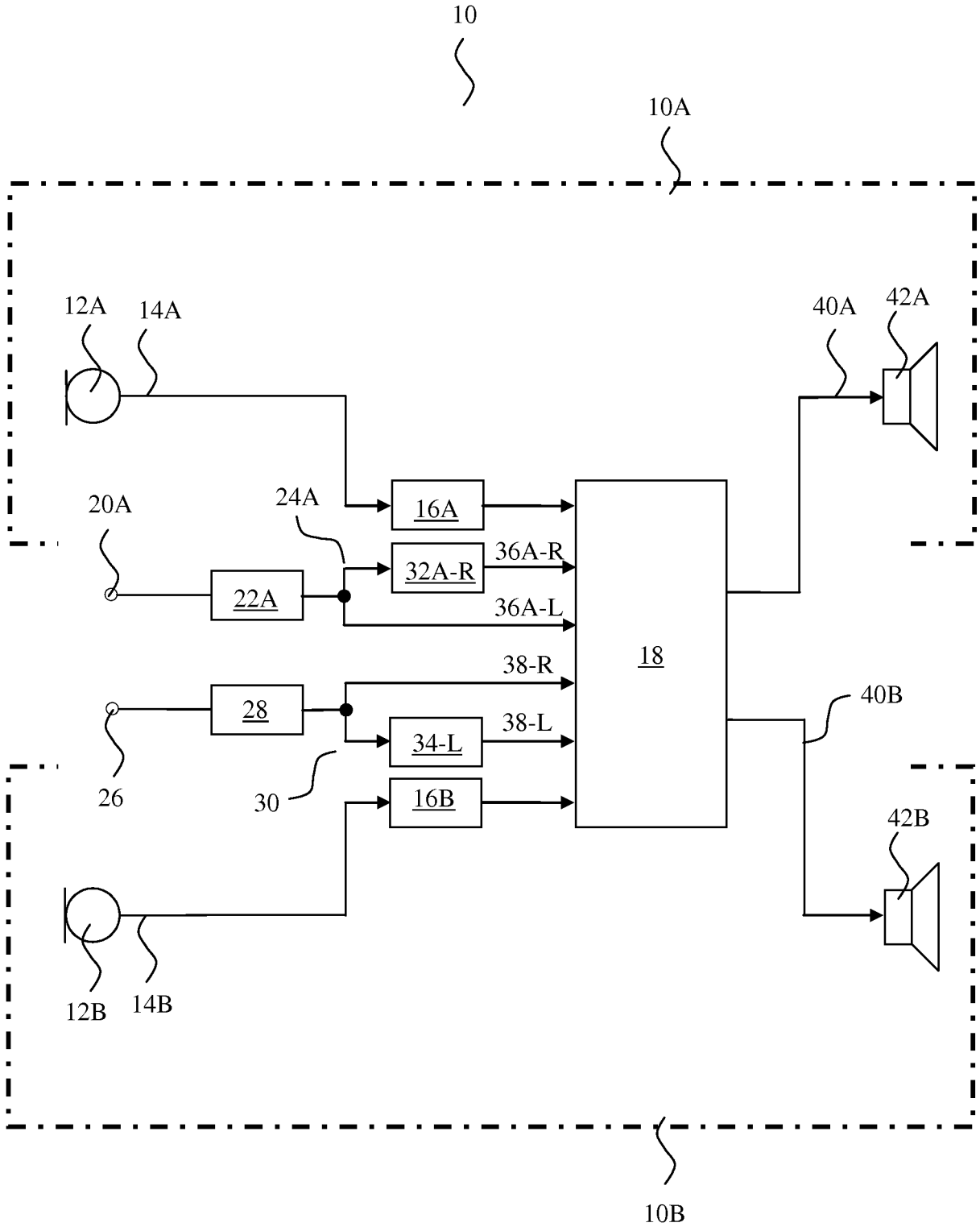

10
10A
12A
14A
40A
42A
20A
24A
16A
32A-R
36A-R
22A
36A-L
18
38-R
28
40B
38-L
34-L
26
30
16B
42B
12B
14B
10B

Fig. 3

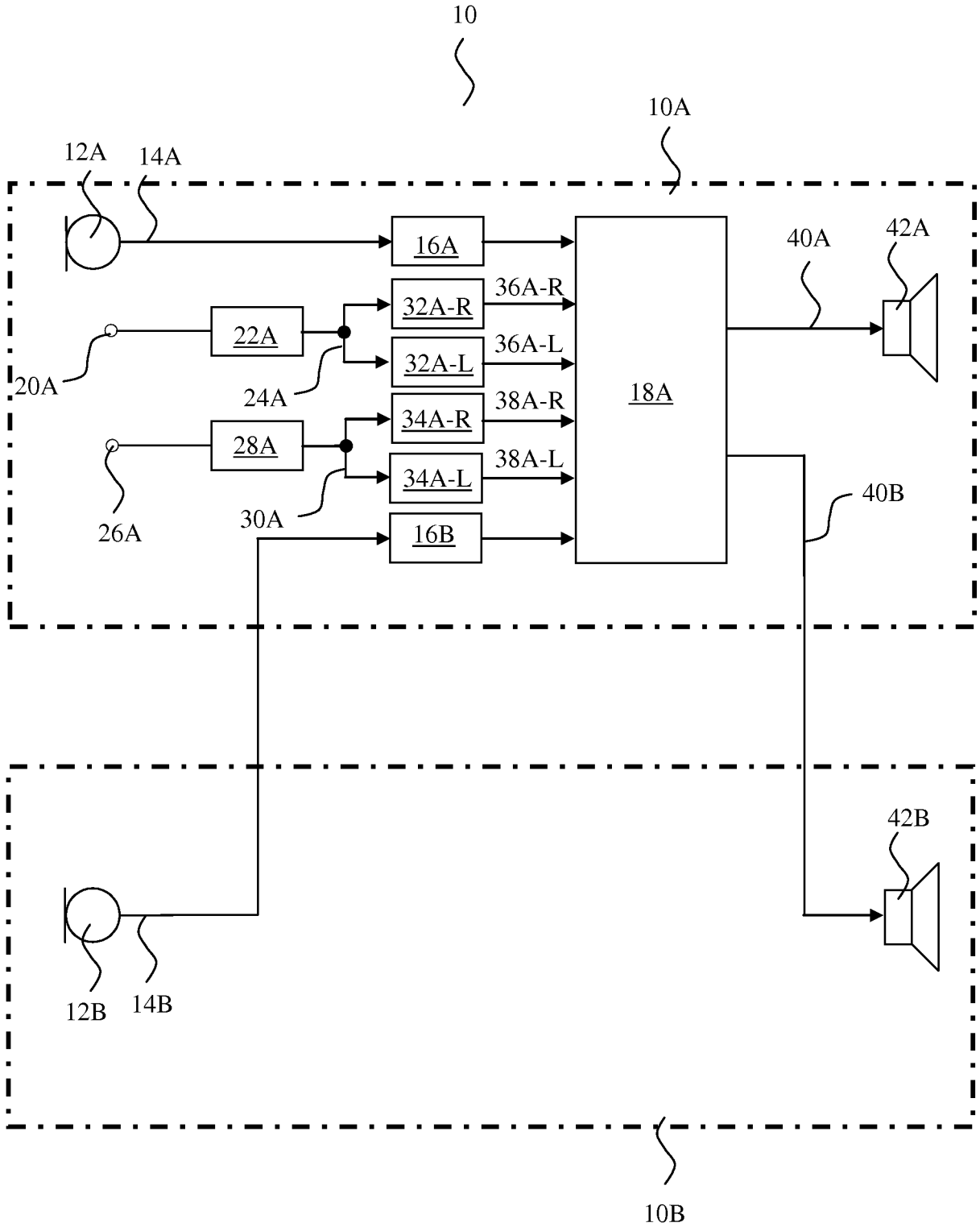

10
10A
12A
14A
16A
32A-R
36A-R
32A-L
36A-L
22A
20A
24A
34A-R
38A-R
34A-L
38A-L
28A
26A
30A
16B
18A
40A
42A
40B
42B
12B
14B
10B

Fig. 4

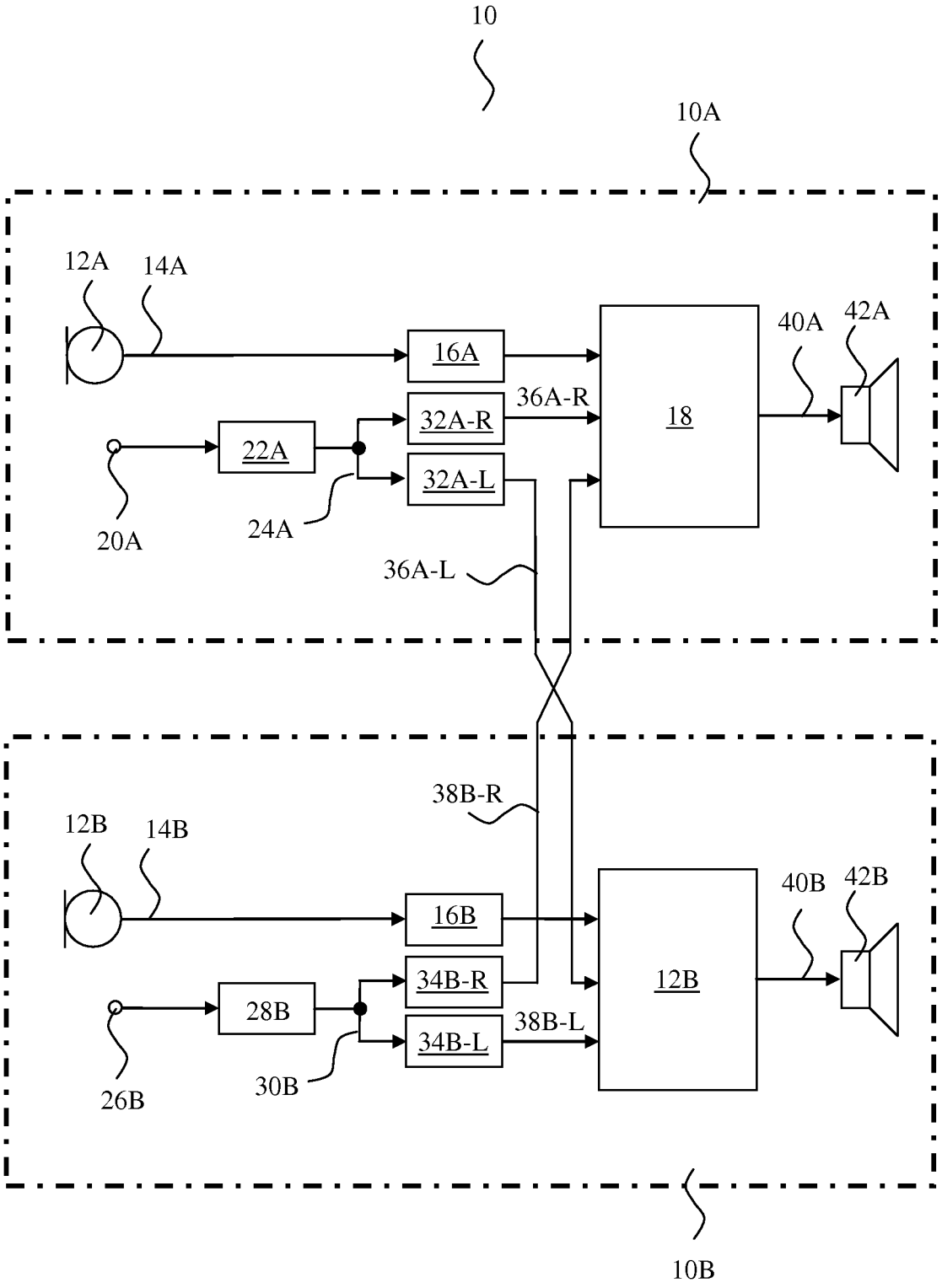

10
10A
12A
14A
16A
32A-R
36A-R
18
40A
42A
22A
32A-L
20A
24A
36A-L
38B-R
12B
14B
16B
34B-R
12B
40B
42B
28B
38B-L
34B-L
26B
30B
10B

Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 8208642 B2 **[0008]**
- WO 2010043223 A **[0009]**