



(11) **EP 2 107 826 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.10.2009 Bulletin 2009/41

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

(21) Application number: **08103217.9**

(22) Date of filing: **31.03.2008**

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

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(54) **A directional hearing aid system**

(57) The invention relates to a hearing aid system comprising a body worn part comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position. The invention further relates to a method and use. The object of the present invention is to provide a hearing aid system enabling backwards directed directionality. The problem is solved in that the system further comprises a. One or more processing units, which deduct a backward, or omni-directional and a front oriented signal from the electrical input signals from the microphones; b. A weighting unit, which sets the front and the backward signal in relation and determine the importance of one signal over the other; c. A transition unit, which switches or gradually changes between front- or omni- or backward orientation of the signal perception. An advantage of the invention is that the hearing aid system is suitable for use in a situation where a source of sound intended for being specifically heard is located to the rear of a wearer of the hearing aid system. The invention may e.g. be of importance in a hearing aid for use in situations where the wearer of the hearing aid faces away from an acoustic source intended for being received by the wearer.

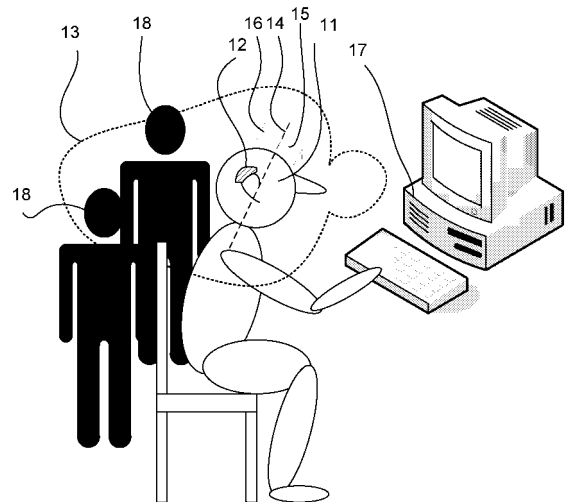


FIG. 1

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DescriptionTECHNICAL FIELD

[0001] The invention relates to hearing aids comprising a directionality system. The invention relates specifically to a hearing aid system comprising a body worn part comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position.

[0002] The invention furthermore relates to a method of controlling the directionality of a hearing aid system comprising a multitude of microphones. The invention furthermore relates to use of a hearing aid system.

[0003] The invention may e.g. be useful in a hearing aid for use in situations where the wearer of the hearing aid faces away from an acoustic source intended for being received by the wearer.

BACKGROUND ART

[0004] The currently known implementations of directionality in hearing systems focus on the perception of front signals. The commonly known ELKO algorithm would suppress all backward sound, even if there is no front sound present at all (cf. e.g. EP 0 869 697 or "A simple first-order adaptive differential microphone" by Gary W. Elko and Anh-Tho Nguyen Pong in proceedings of IEEE ASSP Workshop on Applications of Signal Processing to Audio and Acoustics, 1995, 15-18 Oct. 1995, pp. 169-172).

[0005] In some situations, the exact opposite behaviour would be advantageous, however, e.g.

- Where a teacher wearing a hearing aid writes onto a blackboard, or
- Where a listener wearing a hearing aid in an auditorium wants to hear a person asking a question from behind, or
- Where a person wearing a hearing aid looking into a display-window, of a computer e.g., wants to hear the scene behind him/her.

[0006] In these cases - when the rear signal is more prominent or more important than the front information - the directional characteristic should move to the rear and emphasize the rear sound.

[0007] WO 2007/098768 analyzes signals arriving at the two ears of a wearer of a pair of hearing instruments based on an evaluation of spectral and temporal modulations of the input signals at the two ears by calculation of an evaluation index of speech intelligibility of the two signals. Based on this analysis a selection between omni and directional mode is decided.

DISCLOSURE OF INVENTION

[0008] An object of the present invention is to provide a hearing aid system enabling backwards directed directionality. It is a further object to provide a hearing aid system that automatically switches to the relevant mode of directionality. It is a still further object to provide an analysing method that decides automatically whether the wearer of a hearing instrument in a given moment is likely to prefer back or front directionality thereby avoiding to be forced to turn around to the source of interest only because he is wearing the instrument in directional mode at the time, but that he can e.g. keep working on the computer or write to the blackboard and still know what is going on behind him.

[0009] Objects of the invention are achieved by the invention described in the accompanying claims and as described in the following.

[0010] An object of the invention is achieved by A hearing aid system comprising a body worn part comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position, and further comprising

- a. One or more processing units, which deduct a backward, or omni-directional and a front oriented signal from the electrical input signals from the microphones;
- b. A weighting unit, which sets the front and the backward signal in relation and determine the importance of one signal over the other;
- c. A transition unit, which switches or gradually changes between front- or omni- or backward orientation of the signal perception.

[0011] This new kind of processing overcomes the weaknesses of the currently known directional signal processing patterns, which do not account for backward signals in directional settings having major importance for the listener (wearer of the hearing instrument). The new method will help listeners in variable environments to hear the dominant signals better, than non-dominant, while the level of dominance between front and backwards sound would be adjustable by a distinct algorithm. Such an algorithm could e.g. be based on a comparison of relevant parameters of front and rear microphone signals.

[0012] An advantage of the invention is that the hearing aid system is suitable for use in a situation where a source of sound intended for being specifically heard is located to the rear of a wearer of the hearing aid system. A wearer of a hearing aid may be put in situations, where a person speaking and intended for being heard by the person wearing a hearing aid can be sometimes located in front of and sometimes to the rear of the person wearing a

hearing aid, e.g. if a teacher wearing a hearing aid walks around in a classroom and discusses with the pupils. A hearing aid according to the present invention is useful in such situations.

[0013] The term a multitude of microphones is in the present context taken to mean more than one, such as two or more. In an embodiment, the multitude of microphones comprises an array of microphones that are arranged to optimize the extraction of directional information from acoustic sources in the environment of the hearing aids system, including to the rear of a wearer of the hearing aid system when worn in an operational position.

[0014] In an embodiment, the transition unit is adapted to switch (abruptly) or gradually change (fade) between front- and backward orientation of the signal perception.

[0015] In an embodiment, the hearing aid system is adapted to be fully or partially body worn, e.g. head-worn. In an embodiment, first and second microphones and an output transducer of the hearing aid system are located in the same physical body. In an embodiment, the listening system comprises at least two (first and second) physically separate bodies, which are capable of being in communication with each other by wired or wireless transmission (be it acoustic, ultrasonic, electrical or optical). In an embodiment, a first microphone is located in a first body and a second microphone in a second body of the listening system. In an embodiment, a first microphone is located in a first body together with an output transducer and a second microphone is located in a second body. In an embodiment, first and second microphones are located in a first body and an output transducer is located in a second body. The term 'two physically separate bodies' is in the present context taken to mean two bodies that have separate physical housings, possibly not mechanically connected or alternatively only connected by one or more guides for acoustical, electrical or optical propagation of signals.

[0016] In an embodiment, the hearing aid system comprises two or more microphones, e.g. three microphones or more. In an embodiment, the hearing aid system comprises more than four microphones arranged in a regular array.

[0017] In an embodiment, the multitude of microphones are arranged to at least be able to differentiate between a sound signal originating from a location, respectively, to the front of and to the rear of the person wearing the hearing aid.

[0018] In an embodiment, the hearing aid system comprises a multitude of detectors, which compare a front and a rear sound signal, front and rear being defined relative to a wearer's head, when the hearing aid system is in use by the wearer.

[0019] In an embodiment, the hearing aid system is adapted to provide that the comparison of front and rear signals to determine the importance of one signal over the other is based on one or more of the following parameters of a front and a rear signal:

- Spectral contents,
- Degree of synchrony (simultaneous occurrence)
- Levels,
- Modulation,
- Long term fluctuation,
- Correlation (to detect reflections, e.g. at windows, walls, plain surfaces).

[0020] In an embodiment, the transition unit is adapted to implement some kind of fading when switching between front and rear perception. The fading time is in this context defined as the time from a change of directionality has been detected to its implementation in the hearing aid (i.e. until the switching has been performed). This has the advantage that short time sounds (e.g. noise) will not immediately change the directionality of the system. In an embodiment, the time constants of the fading can be adapted according to the current needs of the situation, either automatically based on the noise level of the acoustic environment or manually by a user operable input to the system (e.g. via a button or a remote control). In an embodiment, the fading involves time constants in the ms to s range, e.g. in the range from 100 ms to 2 s, such as from 200 ms to 800 ms, e.g. around 500 ms.

[0021] It is intended that the features of the system described above, in the detailed description describing modes for carrying out the invention and in the claims can be combined with the method as described below. The method and its embodiments have the same advantages as the corresponding system described above.

[0022] A method of controlling the directionality of a hearing aid system is further more provided, the hearing aid system comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position. The method comprises

- a. deducting a backward, or omni-directional and a front oriented signal from the electrical input signals from the microphones;
- b. setting the front and the backward signal in relation and determine the importance of one signal over the other;
- c. switching or gradually changing between front- or omni- or backward orientation of the signal perception.

[0023] The method has the same advantages as the hearing aid system described above

[0024] In an embodiment, the comparison of front and rear signals to determine the importance of one signal over the other is based on one or more of the following parameters of a front and a rear signal:

- Spectral contents,

- Degree of synchrony
- Levels,
- Modulation,
- Long term fluctuation,
- Correlation.

[0025] In an embodiment, fading is used when switching between front and rear perception.

[0026] Use of a hearing aid system as described above, in the detailed description and in the claims is furthermore provided.

[0027] A software program for running on a digital signal processor of a hearing aid system as described above, in the detailed description and in the claims and implementing at least some of the steps of the method as described above, in the detailed description and in the claims when executed on the digital signal processor.

[0028] Further objects of the invention are achieved by the embodiments defined in the dependent claims and in the detailed description of the invention.

[0029] As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless expressly stated otherwise. It will be further understood that the terms "includes," "comprises," "including," and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements maybe present. Furthermore, "connected" or "coupled" as used herein may include wirelessly connected or coupled. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

BRIEF DESCRIPTION OF DRAWINGS

[0030] The invention will be explained more fully below in connection with a preferred embodiment and with reference to the drawings in which:

FIG. 1 shows a wearer of a hearing aid in a situation where backward directionality of the hearing aid is of interest, and

FIG. 2 shows a block diagram of an embodiment of a hearing aid system according to the invention.

[0031] The figures are schematic and simplified for clarity, and they just show details which are essential to the understanding of the invention, while other details are left out.

[0032] Further scope of applicability of the present invention will become apparent from the detailed descrip-

tion given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

MODE(S) FOR CARRYING OUT THE INVENTION

[0033] FIG. 1 schematically illustrates a situation where an embodiment of a hearing aid system according to the present invention providing backward directionality is advantageous. A first person 11 wearing a listening device 12 (here illustrated as a behind the ear (BTE) hearing instrument) sits at a computer 17 with one or more persons 18 being located behind him (*behind* him as indicated by arrow 16 relative to plane 14 through the ears of the person 11, leaving the face of the person in the *front* half-part of the space thereby defined, as indicated by arrow 15 in FIG. 1) and with whom a conversation is conducted. The microphones and the processing of the picked up signals of the listening device 12 are (in a 'rear-mode' of the hearing aid system, either automatically or manually set) arranged to provide a directionality 13 of the microphones focussing on the rear space (relative to the first person 11) including the persons 18 located behind the person 11 wearing the listening device and thereby improving the processing of the acoustic signals originating from these persons 18.

[0034] FIG. 2 shows a block diagram of an embodiment of a hearing aid system according to the invention.

[0035] A hearing aid system 1 according to the invention incorporates the following functional blocks as shown in FIG. 2:

1. A multitude of microphones (e.g. a microphone array, here two microphones 11, 12 are shown);
2. One or more processing units 20 (*DIR*-part of the block), which deduct the backward (or omni-directional) and the front oriented signal from the input signal 2 applied to the microphones 11, 12;
3. A weighting unit 20 (*W*-part of the block), which sets the front and the backward signal in relation and determines the importance of one signal over the other;
4. A transition unit 23 (*T*-block), which switches or gradually changes between front / omni / backward orientation of the signal perception.

[0036] The multitude of microphones of the hearing aid system here consists of two omni-directional microphones 11, 12, which are combined to produce either an omni-directional or a directional characteristic. Alternatively, three or more microphones can be used. The microphones 11, 12 each convert the acoustic signal 2 at their location to an electrical signal 13, 14, which is fed to respective analogous to digital converters 16, 15

(AD-blocks). The digitized electrical signals 18, 19 are fed to the processing block 20 (*DIR-W*-block) for extracting directional information and decide on the weight between relevant acoustic signals being located in front and to the rear of the wearer of the hearing aid system.

[0037] Directionality of the acoustic input signals provided to the *DIR*-part of processing unit 20 in digitized electrical form can e.g. achieved by application of a delay line at the microphones' output signals (in analogue 13, 14 or digital 18, 19 form), which is adjusted for minimum rear-signal level. The definition of minimum rear level depends on the assumed characteristic of the rear sound. For rear signal minimization, different directional characteristics such as cardioid, hyper-cardioid, or super-cardioid can apply. Different directional patterns (see above) in different frequency bands are state of the art, cf. e.g. EP 1463378. For the detection of the rear sound the same algorithm/means can apply with the exception, that front signals are suppressed instead of rear signals, cf. e.g. WO 2007/147418 or US 5,473,701.

[0038] The weighting unit (*W*-part of the *DIR-W*-block 20 in FIG. 2) preferably includes several detectors, which compare the front sound and rear sound. Examples of sensed parameters that are relevant for the comparison of front and rear signals are:

- Spectral contents of the signals to distinguish between the (speech weighted) importance of the front signal against the rear signal,
- Synchrony of the front and rear signal,
- Level of the front and rear signal,
- Modulation of the front and rear signal,
- Long term fluctuation of front and rear signal,
- Correlation between front and rear signal to detect reflections (at windows, walls, plain surfaces).

[0039] The outputs 21, 22 of the detector part of the *DIR-W*-block 20 can either be simple front-rear detection or a gradually changing value defining a quasi linear measure for the front-rear weighting. The outputs 21, 22 are fed to the transition unit 23 (*T*-block).

[0040] The transition unit 23 is adapted to control the switching between front and rear perception and to incorporate some kind of fading between the modes. It is advantageous to have the transition unit 23 configurable in respect of fading characteristic and fading time, allowing adjusting the perceived behaviour at the wearer's ears more smoothly or aggressively. Apart from the possibility to use the outputs 21, 22 of the detectors of the weighting unit 20 to fade between them to provide an output signal 24 for being processed by a digital signal processor 25 (*HA-DSP*-block), a separate fading unit can be arranged within the processing unit 20 (*DIR-W*-block), which extracts the directional information from the microphones. This will allow to fade gradually between front and rear perception without the danger of producing drops in signal due to unwanted, accidentally met 180°-phase conditions along the fading slope.

[0041] The signal processing unit 25 (*HA-DSP*-block) adapts the directionally adapted input signal 24 to a user's hearing profile and provides a processed output signal 26 to a digital-analogue converter (*DA*-block). The analogue output 28 from the *DA*-converter is fed to an output transducer 29 (e.g. a receiver) producing a corresponding output sound 3.

[0042] The hearing aid system preferably comprises a feedback cancellation system (not shown in FIG. 2) for minimizing or cancelling acoustic feedback from the output transducer 29 to the microphones 11, 12.

[0043] The invention is defined by the features of the independent claim(s). Preferred embodiments are defined in the dependent claims. Any reference numerals in the claims are intended to be non-limiting for their scope.

[0044] Some preferred embodiments have been shown in the foregoing, but it should be stressed that the invention is not limited to these, but may be embodied in other ways within the subject-matter defined in the following claims.

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Claims

1. A hearing aid system comprising a body worn part comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position, the hearing aid system further comprising
 - a. One or more processing units, which deduct a backward, or omni-directional and a front oriented signal from the electrical input signals from the microphones;
 - b. A weighting unit, which sets the front and the backward signal in relation and determine the importance of one signal over the other;
 - c. A transition unit, which switches or gradually

- changes between front- or omni- or backward orientation of the signal perception.
2. A hearing aid system according to claim 1 adapted to be body-worn, e.g. head-worn. 5
3. A hearing aid system according to claim 1 or 2 comprising 2 or more microphones, e.g. 3.
4. A hearing aid system according to any one of claims 1-3 wherein the weighting unit comprises a multitude of detectors, which compare a front and a rear sound signal, front and rear being defined relative to a wearer's head, when the hearing aid system is in use by the wearer. 10
5. A hearing aid system according to claim 4 adapted to provide that the comparison of front and rear signals to determine the importance of one signal over the other is based on one or more of the following parameters of a front and a rear signal: 20
- Spectral content;
 - Degree of synchrony or simultaneous occurrence; 25
 - Levels;
 - Modulation;
 - Long term fluctuation;
 - Correlation, e.g. indicating reflections, e.g. at windows, walls, plain surfaces, etc. 30
6. A hearing aid system according to any one of claims 1-5 wherein the transition unit is adapted to implement some kind of fading when switching between front and rear perception. 35
7. A method of controlling the directionality of a hearing aid system comprising a multitude of microphones, each converting an acoustical signal to an electrical input signal, the microphones being arranged in the system to be able to pick up an acoustical signal from several different directions around a wearer of the body-worn part of the system, when worn in an operational position, 40 comprising 45
- a. deducting a backward, or omni-directional and a front oriented signal from the electrical input signals from the microphones;
 - b. setting the front and the backward signal in relation and determine the importance of one signal over the other; 50
 - c. switching or gradually changing between front- or omni- or backward orientation of the signal perception. 55
8. A method according to claim 7 wherein the comparison of front and rear signals to determine the importance of one signal over the other is based on one or more of the following parameters of a front and a rear signal:
- Spectral contents,
 - Degree of synchrony
 - Levels,
 - Modulation,
 - Long term fluctuation,
 - Correlation.
9. A method according to claim 7 or 8 wherein fading is used when switching between front and rear perception.
10. Use of a hearing aid system according to any one of claims 1-6.
11. A software program for running on a digital signal processor of a hearing aid system according to any one of claims 1-6 and implementing at least some of the steps of the method according to any one of claims 7-9 when executed on the digital signal processor.

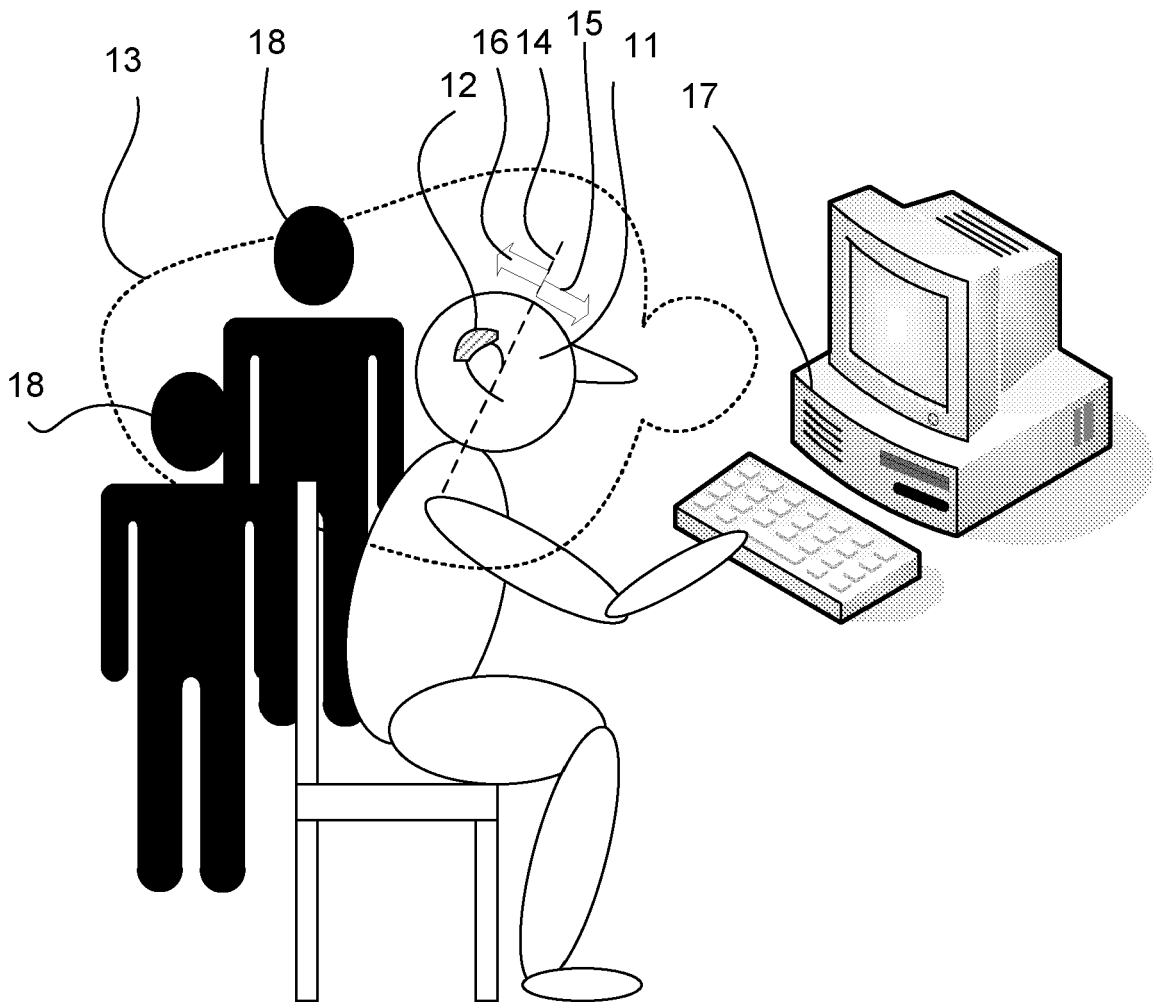


FIG. 1

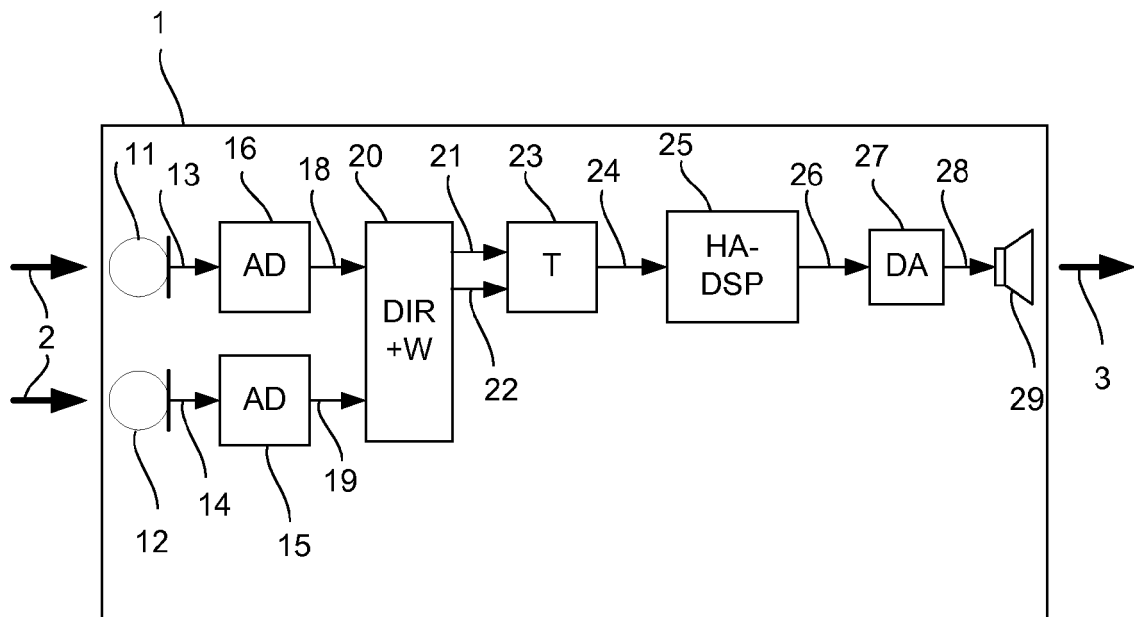


Fig. 2



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
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Place of search		Date of completion of the search	Examiner
The Hague		29 August 2008	Timms, Olegs
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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