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(54) **SYSTEM AND METHOD FOR SEPARATION OF A USER'S VOICE FROM AMBIENT SOUND**

SYSTEM UND VERFAHREN ZUR TRENNUNG DER STIMME EINES BENUTZERS VON UMGEBUNGSGERÄUSCHEN

SYSTÈME ET PROCÉDÉ POUR LA SÉPARATION DE LA VOIX D'UN UTILISATEUR DU SON AMBIANT

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**EP-A1- 1 448 014 EP-A1- 1 509 065**  
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- **SANG MIN LEE ET AL: "New idea of hearing aid algorithm to enhance speech discrimination in a noisy environment and its experimental results" SAN FRANCISCO, CA, USA 1-5 SEPT. 2004, PISCATAWAY, NJ, USA, IEEE, US, 1 September 2004 (2004-09-01), page 978Vol2, XP010774935 ISBN: 0-7803-8439-3**
- **STANACEVIC M ET AL: "Gradient flow adaptive beamforming and signal separation in a miniature microphone array" 2002 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING. PROCEEDINGS. (ICASSP). ORLANDO, FL, MAY 13 - 17, 2002, IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING (ICASSP), NEW YORK, NY : IEEE, US, vol. VOL. 4 OF 4, 13 May 2002 (2002-05-13), pages IV-4016, XP010804511 ISBN: 0-7803-7402-9**

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**EP 1 969 335 B1**

## Description

**[0001]** The present invention relates to a system and a method for separation of a user's voice from ambient sound by using at least one device to be worn at the user's ear or at least partly in the user's ear canal.

**[0002]** For communication purposes, in particular for wireless electronic communication between or from persons exposed to a noisy environment, such as workers in industrial plants, policemen, soldiers, firemen, etc., it is desirable to have a sound pick-up system which is capable at least to some extent to separate the user's voice from ambient noise, or generally ambient sound, in order to improve the intelligibility of the person's speech to the listener, who may be one of the other persons exposed to the noisy environment or who may be a remote person.

**[0003]** A common approach to achieve such separation of a person's voice is the use of a boom microphone, i.e. a microphone which is placed close to the mouth, carried by a headset, helmet or any other device worn by the person. Such microphone selectively emphasizes the near field around the mouth.

**[0004]** Other approaches are vibration pick-up devices which are in direct contact with the throat, picking up the vibrations of the vocal chord, or which are in direct contact with the meatus wall or the outer ear canal, picking up the vibrations of the head tissue (i.e. "bone conduction" microphones) or which are in direct contact with the cheek-bone.

**[0005]** Devices of these types are either fairly sensitive to acoustic noise masking the speech or certain speech sounds are poorly transmitted, especially the high frequency consonant sounds necessary for good intelligibility. Furthermore, for industrial applications boom microphones have the drawbacks that they limit the freedom of movement of the user and that, when combined with a hearing protection device, they will affect the stability and hence the attenuation of the hearing protection device. Bone-conduction microphones have the drawbacks that they have a very limited audio bandwidth which limits the intelligibility of the speech and that they often have to be pressed fairly hard which causes discomfort to the user. US 6,661,901 B1 relates to an active hearing protection system comprising an earplug with an outer microphone for picking up ambient sound and an inner microphone which is sealed with respect to ambient sound but is open towards the inner part of the user's ear canal. In an operation mode in which separation of the user's voice from ambient noise is desired only the inner microphone is activated while the outer microphone is not, with the signal from the inner microphone being processed by an electronics unit integrated within the earplug in order to make the user's voice highly natural and intelligible, either for the user himself or his external communication partners.

**[0006]** Another approach is based on a so-called "blind source separation" (BSS) algorithm in order to separate

a person's voice from background noise by corresponding audio signal processing. In this respect, US 2003/0055535 A1 relates to the use of a BSS algorithm for separating the voice of an operator of a vehicle wheel alignment system with a voice audio interface from background noise by using a microphone array in order to avoid the necessity to use a headset. US 2005/0060142 A1 relates in a more general manner to the use of two spaced-apart microphones operated with a BSS algorithm for voice separation from background noise in audio applications. EP 1 509 065 A1 relates to a binaural hearing aid system wherein the audio signals captured by the microphone of the right ear hearing aid and the microphone of the left ear hearing aid undergo a BSS algorithm, followed by additional signal processing, in order to increase the intelligibility of speech in background noise by the user of the hearing aid system.

**[0007]** It is an object of the invention to provide for a system and a method for separation of a person's voice from ambient sound wherein good intelligibility of speech is achieved while nevertheless discomfort to the person is to be avoided as far as possible.

**[0008]** According to the invention this object is achieved by a system as defined in claims 1 and 11, and by corresponding methods as defined in claims 14 and 15, respectively.

**[0009]** The invention is beneficial in that, by using a first microphone and a second microphone, wherein according to the solution of claims 1 and 14 the first microphone is oriented acoustically outwardly towards the environment and the second microphone oriented acoustically inwardly towards the user's ear canal and according to the solution of claims 11 and 15 the first microphone is located at the right ear and the second microphone is located at the left ear, and by processing the audio signals from the first and second microphone by a blind source separation algorithm, good separation of the user's voice from ambient sound with resulting high intelligibility of the user's speech is achieved without the need for additional restrictions regarding the location of the microphones, so that in particular the need for a boom microphone or a bone-conduction microphone can be avoided. In particular, by orienting the first microphone towards the environment and orienting the second microphone towards the user's ear canal or by locating the first microphone at the right ear and the second microphone at the left ear these two microphones pick up sufficiently differently mixed signals of the ambient sound and the user's voice so that a BSS algorithm will work efficiently.

**[0010]** Generally, blind source separation (also referred to as "independent component analysis" (ICA)) is a technique for separating mixed source signals (components) which are presumably statistically independent from each other. In its simplified form, blind source separation applies an "un-mixing" matrix of weights to the mixed signals, for example, multiplying the matrix with the mixed signals, to produce separated signals. The weights are assigned initial values, and then adjusted to

maximize joint entropy of the signals in order to minimize information redundancy. This weight-adjusting and entropy-increasing process is repeated until the information redundancy of the signals is reduced to a minimum. Because this technique does not require information on the source of each signal, it is referred to as "blind source separation". An introduction to blind source separation is found, for example, in US 2005/0060142 A1.

**[0011]** In the most simple case, BSS is applied to two different mixtures of two (acoustic) sources, wherein the two different mixtures are obtained by using two spaced apart microphones. Mixing of the two sources can be represented by a matrix A, with the BSS algorithm corresponding mathematically to finding the inverse matrix of A without knowing anything about the matrix nor about the sources, except that they are statistically independent. In the case of a person's voice mixed with background noise the latter assumption usually is valid. The mixtures of the two sources could be different with respect to amplitude and/or phase of the two sources. In other words, by picking up sound signals with two differently oriented microphones the signal of each of these microphones will correspond to a mixture which is different with regard to the difference in amplitude and/or phase of the two acoustic sources (i.e. user's voice on the one hand and ambient noise on the other hand). By orienting one of the microphones outwardly towards the environment and the other microphone inwardly to the ear canal, a particularly large difference between the two mixtures can be obtained in a simple and particularly comfortable manner, i.e. no boom microphones or bone-conduction microphones which would cause discomfort to the user need to be used.

**[0012]** According to one embodiment, the two microphones are part of a hearing protection device. With such a configuration, the microphones can be arranged such that the ambient sound reaching the inwardly oriented microphone is attenuated by the hearing protection device relative to ambient sound reaching the outwardly oriented microphone. Although such hearing protection device could be an earmuff, according to a preferred embodiment the hearing protection device is an earplug comprising a shell which is to be inserted at least partially into the user's ear canal. According to one embodiment, the shell is a customized hard shell having an elasticity from shore D85 to D65 and having an outer shape according to the measured inner shape of the user's outer ear and ear canal. According to an alternative embodiment, the shell is a generic soft shell capable of adapting to the shape of the user's outer ear and ear canal.

**[0013]** Preferably, the inwardly oriented microphone is located at or is open to the inner part of the shell which is to be inserted into the ear canal, with the inwardly oriented microphone preferably being located at the inner end of the shell or within a channel of the shell open to the inner end of the shell.

**[0014]** Preferably, the outwardly oriented microphone is located at or is open to the outer part of the shell which

is not to be inserted into the ear canal, with the outwardly oriented microphone preferably being located at the outer end of the shell or within a channel of the shell open to the outer end of the shell.

5 **[0015]** If the hearing protection device is an earmuff, the first microphone is located at or is open to the outer side of the earmuff and the second microphone is located at or is open to the inner side of the earmuff.

10 **[0016]** In all embodiments, the device preferably comprises a speaker adapted to provide an external audio signal to the user's ear. Thereby bidirectional communication with the user is achieved. Preferably the speaker is located at or is open to a portion of the device which is to be worn within the user's ear canal, whereby the speaker is brought acoustically close to the user's ear drum so that good intelligibility of the sound provided by the speaker is achieved even in noisy environments.

15 **[0017]** Usually the device will be binaural, i.e. it will comprise one unit for the right ear and another unit for the left ear. The speaker and the microphones may be integrated in the same unit, i.e. in at least one of the units, or the speaker may be part of the unit for one ear and the microphones may be part of the unit for the other ear.

20 **[0018]** According to one embodiment, the device may be adapted to be worn completely within the user's ear canal, whereby the device can be more or less completely hidden from the views of other persons. According to other embodiments, the device may be any other kind of a wired or wireless headset.

25 **[0019]** Preferably the audio signal processing unit is integrated within the device. In an alternative embodiment, the audio signal processing unit may be adapted to be worn behind the user's ear or somewhere at the user's body. In this case, although the device becomes more handy, more space, and hence also more power, is available for the audio signal processing unit, which may reduce the costs and/or may improve the performance of the blind source separation. In such case, the audio signal processing unit may be connected to the microphone either by wires, which is the most simple solution, or via a wireless link, for example, a radio frequency link such as Bluetooth link, an inductive link or an infrared link, which solution would result in enhanced wearing comfort for the user.

30 **[0020]** As a further alternative, the audio signal processing unit could be designed to be located remote from the user and is connected to the microphones via a radio frequency link such as Bluetooth link. In this case, there would be even less restrictions regarding the size and power consumption of the audio signal processing unit, which might result in reduced costs and/or increased performance of the blind source separation.

35 **[0021]** In all embodiments, the system preferably comprises a radio frequency transmitter for transmitting the processed audio signal output of the audio signal processing unit to a remote radio frequency receiver in order to provide the user's voice to another person. According to one embodiment, the radio frequency trans-

mitter is integrated within the audio signal processing unit, i.e. the radio frequency transmitter may be either integrated within the device or it may be adapted to be worn behind the user's ear or at the user's body or it could be even located remote from the user. However, in an alternative embodiment, the radio frequency transmitter could be remote from the audio signal processing unit, in which case the processed audio signal output of the audio signal processing unit would be provided to a radio frequency transmitter by wires or via a radio frequency link, an inductive link or an infrared link. In this case the location of the audio signal processing unit and the radio frequency transmitter can be optimized independently from each other.

**[0022]** In all embodiments, the blind source separation algorithm preferably works in the frequency domain, i.e. the algorithm is simultaneously carried out in different frequency bands/bins and the outcomes of these bands/bins are combined in an appropriate way.

**[0023]** In all embodiments, the blind source separation algorithm preferably works with the assumption that the sources are statistically independent, i.e. that the user's voice is independent of the ambient sound.

**[0024]** In the following, examples of the invention will be explained in detail by reference to the attached drawings.

Fig. 1 shows a schematic view of a first embodiment of a hearing protection earplug system according to the invention inserted into a person's ear canal with a block diagram of the most relevant electronic components;

Fig. 2 shows a schematic view of a modified embodiment of a hearing protection earplug according to the invention;

Figs. 3 and 4 show further modified embodiments of a system according to the invention;

Fig. 5 shows a modification of the embodiment of Fig. 1;

Fig. 6 shows a modification of the embodiment of Fig. 5;

Fig. 7 shows a schematic view of an embodiment of a BTE hearing instrument according to the invention with a block diagram of the most relevant electronic components;

Fig. 8 shows a modified embodiment of a BTE hearing instrument according to the invention;

Fig. 9 shows a schematic view of an embodi-

ment of a headset according to the invention with a block diagram of the most relevant electronic components; and

5 Fig. 10 shows a modified embodiment of a headset according to the invention.

**[0025]** The system of Fig. 1 comprises a device 10 designed as a hearing protection earplug which may have a hard shell with an elasticity from shore D85 to shore D65, which is customized, i.e. it has an outer shape according to the individual measured inner shape of the user's outer ear and ear canal. The hard shell may be manufactured by layer-by-layer laser sintering of a powder material, for example, polyamide powder, or by laser stereo-lithography or photopolymerization. An overview regarding such additive layer-by-layer build-up processes for manufacturing customized shells of hearing devices can be found, for example, in US 2003/0133583 A1 or US 6,533,062 B1. The inner shape of the person's ear canal and outer ear can be measured, for example, by taking an impression which then undergoes laser scanning or by direct laser scanning of the ear.

**[0026]** Preferably the hard shell is designed such that it provides for an acoustic attenuation, averaged over the audible frequency range, of at least 10 dB when inserted into the user's ear canal.

**[0027]** Rather than having a customized hard shell, earplug 10 may have a generic soft shell which adapts to the shape of the user's outer ear and ear canal due to its elasticity.

**[0028]** In Fig. 1 the earplug 10 is shown to be inserted with its inner end portion into a user's ear canal 12. The earplug 10 comprises an outer microphone M1, which is located at the outer part of the earplug 10 and which is open to the outer end 14 of the earplug 10 via a sound channel 16, and an inner microphone M2, which is located at the inner part of the earplug 10 and which is open to the inner end 18 of the earplug 10 via a sound channel 20. The earplug 10 further comprises a speaker S which is likewise located at the inner part of the earplug 10 and is open to the inner end 18 via a sound channel 22. The earplug 10 also includes a digital audio signal processing unit 24 comprising a digital signal processor as well as a radio frequency transmitter unit T1 and a radio frequency receiver unit R1. The audio signal processing unit 24 functionally includes a unit 26 for applying a blind source separation algorithm to the audio signals provided by the microphones M1 and M2. It is evident to the skilled person that the earplug 10 includes additional electrical components, such as amplifiers and analogue-to-digital converters for the audio signals provided by the microphones M1 and M2, a digital-to-analogue converter and an amplifier for the audio signal to be transformed into sound by the speaker S, program and data memory components for the audio signal processing unit 24, a battery for power supply, a demodulator, a modulator, an antenna, etc., which are not shown in Fig. 1 for the sake of

simplicity.

**[0029]** The transmitter T1 of the earplug 10 is adapted to transmit audio signals from the earplug 10 to a remote receiver R2 via a radio link, while the receiver R1 of the earplug 10 is adapted to receive audio signals from a remote transmitter T2. The audio signals received by the receiver R1 are demodulated and then undergo signal processing in the audio signal processing unit 24 as input to the speaker S in order to provide remote audio signals to the user. Such remote audio signals could be the speech of another person picked up by a microphone whose output is sent to the remote transmitter T2 by wires or via, for example, a mobile telephone or mobile radio device.

**[0030]** The audio signals provided by the microphones M1 and M2 are passed as input to the blind source separation unit 26, in which a processed audio signal output for the transmitter T1 is produced, with the processed audio signal output consisting completely or at least essentially of the user's voice which has been separated from the ambient sound by action of the blind source separation algorithm carried out in the BSS unit 26. Such BSS signal processing utilizes the fact that the sound mixtures picked up by the microphone M1 which is oriented towards the environment and M2 which is oriented towards the ear canal 12, respectively, consist - due to the different orientation of the microphones M1 and M2 - of essentially different mixtures of the ambient sound and the user's voice, which are different regarding amplitude ratio of these two signal contributions or sources (i.e. ambient sound on the one hand and user's voice on the other hand) and regarding phase difference of these two signal contributions of the mixture.

**[0031]** The output signal of the BSS unit 26 is transmitted via the transmitter T1 to the remote receiver R2 which usually will be connected to a remote speaker for presenting the user's voice to another person. The remote speaker and the remote microphone connected to the remote transmitter T2 could be part of an earpiece or an earplug worn by another person, which may be similar or identical to the earplug 10. Thereby in-the-ear hearing protection devices with integrated communication function can be achieved. Such a system could be used by any persons who need to communicate in a noisy environment, such as workers, soldiers, firemen, etc. However, the remote receiver R2 also might serve for communication via a mobile telephone or a mobile radio device.

**[0032]** In general, the remote receiver R2 / transmitter T2 could be a part of an interface of a standard wireless communication device, such as a mobile telephone device or a mobile radio device. Preferably, the wireless link between the transmitter T1 / receiver R1 and the remote receiver R2 / remote transmitter T2 is a Bluetooth link. The remote receiver R2 / transmitter T2 then could be a part of the Bluetooth interface of a standard wireless communication device, such as a mobile telephone device or a mobile radio device.

**[0033]** According to Fig. 1, the audio signal produced by the microphones M1 and M2, which is used as input to the BSS unit 26, in addition could undergo other audio signal processing within the audio signal processing unit 24, for example, in order to provide the ambient sound picked up by the microphone M1 to the speaker S for enabling perception of desired ambient sounds during times when the noise level is low so that the hearing protection function provided by the earplug 10 is not needed, or to provide for an in-situ measurement of the actual acoustic attenuation provided by the earplug 10 when inserted into the user's ear canal 12 by comparing the sound levels measured by the microphones M1 and M2.

**[0034]** In Fig. 2 a modified embodiment is shown, wherein the transmitter T1 and the receiver R1 have been removed from the earplug 10 and now are located in an external unit 28 which is connected by wires 30 to the earplug 10 and which is to be worn at an appropriate location at the user's body, for example behind the user's ear or somewhere within or below the user's clothing, for example, within a helmet. The external unit 28 may include further electrical components removed from the earplug 10, for example, the power supply battery.

**[0035]** In Fig. 3 a further modified embodiment is shown, wherein not only the transmitter T1 and the receiver R1 (and the power supply battery) but in addition also the audio signal processing unit 24 including the BSS unit 26 has been removed from the earplug 10 and is connected via corresponding wires to the microphones M1 and M2 and the speaker S, respectively.

**[0036]** In Fig. 4 a still further modified embodiment is shown, wherein the wire connection 30 between the earplug 10 and the external unit 28 has been replaced by a bidirectional wireless link 32, which is established by a transmitter T3 and a receiver R3 located in the earplug 10 and a corresponding receiver R4 and transmitter T4 located in the external unit 28. The wireless link 32 could be a radio frequency link, an inductive link or an infrared link. If it is an inductive link, the external unit 28 would have to be located relatively close to the earplug 10, for example at a distance of not more than 20 cm. With an RF (radio frequency) link, the distance could be larger; in this case it would be even be possible to locate the external unit 28 at a position remote from the user's body, for example, within a distance of a few meters. Preferably the wireless link 32 of the embodiment of Fig. 4 is a Bluetooth link.

**[0037]** Although in the embodiments shown in Figs. 1 to 4 the speaker S is shown as being integrated in the same earplug 10 as the microphones M1 and M2, in other embodiments the speaker S may be provided at an earplug other than the earplug at which the microphones M1 and M2 are provided.

**[0038]** Fig. 5 shows a modified version of the embodiment of Fig. 1, wherein the inwardly oriented second microphone M2 is not part of the earplug 10 - as shown in Fig. 1 - but rather is provided at the earplug 11 for the

other ear. The second microphone M2 is located at the inner part of the earplug 11 and is open to the inner end 18 of the earplug 11 via a sound channel 20. In addition, the earplug 11 further comprises a speaker S which is likewise located at the inner part of the earplug 11 and is open to the inner end 18 via a sound channel 22. The microphone M2 and the speaker S of the earplug 11 are connected to the audio signal processing unit 24 located in the earplug 10 via a wire connection 40 which be integrated in a mechanical connection (not shown) between the earplugs 10 and 11 which may be provided for preventing loss of the earplugs 10, 11.

**[0039]** According to a modification of the embodiment of Fig. 5, the outwardly oriented first microphone M1 may be provided at the earplug 11, while the inwardly oriented second microphone M2 may be provided at the earplug 10 as in Fig. 1.

**[0040]** An alternative modification of the embodiment of Fig. 5 is shown in Fig. 6, wherein both the first microphone M1 of the earplug 10 and the second microphone M2 of the earplug 11 are outwardly oriented. In this case the differences in the sound mixtures picked up by the microphone M1 of the earplug 10 and the microphone M2 of the earplug 11 are due to the different location of the microphone M1 at one ear and the microphone M2 at the other ear (for example, a disturbing noise source usually will be located closer to one of the two ears and hence will contribute more strongly and with different phase to the signal picked up by the microphone located at that ear than to that located at the other ear).

**[0041]** According to a modification of the embodiment of Fig. 6 both microphones M1 and M2 could be inwardly oriented rather than outwardly oriented.

**[0042]** While Figs. 5 and 6 and the above-discussed variants thereof are modifications of the embodiment of Fig. 1, according to which both the audio signal processing unit 24 and the transmitter T1 / receiver R1 are part of the earplug 10, it is to be understood that the embodiments of Figs. 2 to 4 may be analogously modified, i.e. by providing the second microphone M2 at the earplug 11 rather than at the earplug 10.

**[0043]** While the examples discussed so far relate to an application of the communication system to hearing protection earplugs, the invention also may be applied to earmuffs serving as a hearing protection device or generally to any kind of headset, i.e. also to hearing devices which do not provide for a hearing protection function. For example, the headset may consist of a device with a customized or a generic shell which is designed such that it can be worn completely in the ear canal 12 (i.e. as a "CIC device") and which serves exclusively communication purposes, for example, for security persons, policemen, firemen, etc., i.e. for persons who are exposed to a noisy environment, with the noise level, however, being below a threshold value which would require the use of hearing protection devices. Such CIC device generally could have the construction of the earplug of Fig. 1, however, without considerable acoustic attenuation

provided due to the material and the design of the shell, and would be reduced in size so that it can be worn completely within the ear canal 12.

**[0044]** In general, the device need not be designed as an earplug but it may rather be any kind of headset.

**[0045]** By "oriented acoustically outwardly towards the environment" it is meant that the respective microphone is acoustically open to the environment, whereas by "oriented acoustically outwardly towards the user's ear canal" it is meant that the respective microphone is acoustically open to the user's ear canal. This does not necessarily imply that there is line-of-sight connection to the environment or the ear canal, respectively; rather, it is sufficient that there is an acoustic connection to the environment or the ear canal, respectively, for example by a sound channel or a sound tube.

**[0046]** By "earplug" any device is meant which is to be worn in the ear canal or in the concha, so that also earmolds, i.e. devices to be worn in the concha rather than in the ear canal, are included.

**[0047]** In Fig. 7 an embodiment is shown, wherein the device 10, in contrast to the embodiments shown in Figs. 1 to 6, is not designed as a hearing protection earplug but rather as a hearing instrument to be worn behind the user's ear, with the design corresponding to that of a BTE hearing instrument. The device 10 comprises a housing 50 to be worn behind the user's ear, with a sound tube 52 extending from the housing 50 to an earplug 54 to be worn in the user's ear canal or concha, respectively. The earplug 54 is provided at the free end of the sound tube 52, while at the other end the speaker S and the microphone M2 are provided in order to acoustically connect the speaker S and the microphone M2 to the user's ear canal. The earplug 54 usually will not act as a hearing protection device.

**[0048]** The housing 50, in addition to the speaker S and the microphone M2, also includes an outwardly oriented microphone M1, an audio signal processing unit 24 with a BSS unit 26, a RF transmitter unit T1, a RF receiver unit R1 and a power supply 56.

**[0049]** The functionality of the electronic components may correspond, for example, to that of the embodiment of Fig. 1, i.e. the audio signals captured by the outwardly oriented microphone M1 and the inwardly oriented microphone M2 are supplied to the BSS unit 26 in order to extract the user's voice from ambient sound, and the output signal of the BSS unit 26 is transmitted via the transmitter unit T1 to an external receiver unit (not shown) for supplying the user's voice to, for example, another person. External audio signals may be received by the receiver unit R1 and may be supplied via the audio signal processing unit 24 and the speaker S to the user. In addition, the audio signals captured by the outwardly oriented microphone M1 may be processed in the audio signal processing unit 24 and then may be supplied to the user's ear via the speaker S, whereby the device 10 may function as a hearing aid.

**[0050]** In Fig. 8 a modified version of embodiment of

Fig. 7 is shown, wherein both the speaker S and the microphone M2 are provided directly in the earplug 54 rather than being acoustically connected to the earplug 54 via a sound tube 52 as in Fig. 7. The speaker S and the microphone M2 are connected to the housing 50 and to the audio signal processing unit 24 via a cable connection 58.

**[0051]** According to the embodiment shown in Fig. 9 the device 10 is designed as a headset comprising a housing 50 which is to be worn below the user's ear and is fixed to the user's pinna by means of a loop 60 which may be made of wire and which is adjustable to the individual size of the user's pinna. To this end, the housing 50 is provided with an adjustment element which is fixed to one end of the loop and through which the other end 64 of the loop is guided in such a manner that it can be fixed in various positions. The size of the loop 60 can be adjusted by the user by pulling at the free end 64 of the loop 60. Such a loop is described, for example, in the German Patent Application 10 2006 016 052.5 or in DE 10 2005 002 482 B3.

**[0052]** According to Fig. 9, the audio signal processing unit 24, the receiver unit R1, the transmitter unit T1 and the power supply may be integrated in a separate housing 50A, which is electrically and mechanically connected via a connector 66 to the housing 50 which includes the microphones M1 and M2 and the speaker S. The transmission unit T1 and the receiver unit R1 serve to establish a bi-directional wireless link to communication devices, such as a mobile phone or a walkie-talkie.

**[0053]** In Figs. 7 through 9, element 56 is a power supply, such as a primary or rechargeable battery.

**[0054]** The speaker S and the microphone M2 are located at one end of a sound tube 52 which extends with its free end 68 into the user's ear canal. As in the embodiment of Fig. 7, the free end 68 may be provided with an earplug.

**[0055]** The housing 50A with the electronic components 24, T1, R1, and power supply 56 included therein forms a communication unit which, on the one hand, receives external audio signals from a communication device, which are reproduced via the speaker S to the user's ear. On the other hand, the communication device extracts the user's voice by blind source separation of audio signals from the microphones M1 and M2 in the BSS unit 26, with the separated audio signals corresponding to the user's voice and being transmitted to the communication device.

**[0056]** As an alternative to the embodiment shown in Fig. 9 the housing 50 in addition to the inwardly oriented microphone M2, the speaker S, and the outwardly oriented microphone M1 may also include the audio signal processing unit 24 with the BSS unit 26, the RF transmitter unit T1, the RF receiver unit R1 and the power supply 56. In this case the additional housing 50A would be obsolete.

**[0057]** A modification of the embodiment of Fig. 9 is shown in Fig. 10, wherein a cable connector 70, rather

than the communication unit 50A of Fig. 9, is received in the connector 66. The cable connector 70 serves to connect the microphones M1 and M2 and the speaker S to an external audio signal processing unit (not shown) which includes a BSS unit in order to apply BSS to the signals of the microphones M1 and M2 in order to separate the user's voice. This external audio signal processing unit also is connected to a communication device in order to supply the user's voice to such communication device and to receive external audio signals which are to be reproduced by the speaker S.

## Claims

1. A system for separation of a user's voice from ambient sound, comprising a device (10) to be worn at the user's ear or at least partly in the user's ear canal (12) comprising a first microphone (M1) oriented acoustically outwardly towards the environment and a second microphone (M2) oriented acoustically inwardly towards the user's ear canal, an audio signal processing unit (24, 26) for processing audio signals from the first and second microphone by a blind source separation algorithm adapted to separate the user's voice from ambient sound, and a radio frequency transmitter (T1) for transmitting the processed audio signal output of the audio signal processing unit (24, 26) to a remote radio frequency receiver (R2) in order to provide the user's voice to another person..
2. The system of claim 1, wherein the device (10) is designed as a hearing protection device to provide for an acoustic attenuation, averaged over the audible frequency range, of at least 10 dB.
3. The system of claim 2, wherein the microphones (M1, M2) are arranged such that ambient sound reaching the second microphone (M2) is attenuated by the hearing protection device (10) relative to ambient sound reaching the first microphone (M1).
4. The system of one of claims 2 or 3, wherein the hearing protection device is an earplug (10) comprising a shell which is to be inserted at least partially into the user's ear canal (12).
5. The system of one of claims 1 to 3, wherein the hearing protection device is an earmuff and wherein the first microphone is located at or is open to the outer side of the earmuff and the second microphone is located at or is open to the inner side of the earmuff.
6. The system of one of the preceding claims, wherein the device comprises a speaker (S) adapted to provide an external audio signal to the user's ear.

7. The system of claim 1, wherein the housing (50, 50A) of the device (10) is to be worn behind or below the user's ear and wherein a sound tube (52) is provided to extend from the second microphone (M2) into the user's ear canal. 5
8. The system of claim 7, wherein the free end (68) of the sound tube (52) is provided with an earplug (54).
9. The system of claim 1, wherein the housing (50) of the device is to be worn behind or below the user's ear, wherein the second microphone (M2) is included in an earplug (54) to be inserted into the user's ear canal and/or the user's concha and wherein the second microphone (M2) is connected to the housing (50) of the device (10) via a cable (58). 10 15
10. The system of claim 6, wherein the system comprises a radio frequency receiver (R1) for receiving the external audio signal from a remote, radio frequency transmitter (T2). 20
11. A system for separation of a user's voice from ambient sound, comprising: a first device (10) to be worn at the user's right ear or at least partly in the user's right ear canal (12), a second device (11) to be worn at the user's left ear or at least partly in the user's left ear canal (12), the first device comprising a first microphone (M1) and the second device comprising a second microphone (M2), an audio signal processing unit (24, 26) for processing audio signals from the first and second microphone by a blind source separation algorithm adapted to separate the user's voice from ambient sound, and a radio frequency transmitter (T1) for transmitting the processed audio signal output of the audio signal processing unit (24, 26) to a remote radio frequency receiver (R2) in order to provide the user's voice to another person. 25 30 35
12. The system of claim 11, wherein one of the first microphone (M1) and second microphone (M2) is oriented outwardly towards the environment and the other one of the first microphone and second microphone is oriented inwardly towards the user's ear canal (12). 40
13. The system of one of claims 11 and 12, wherein the audio signal processing unit (24, 26) is located in one of the first device (10) and the second device (11) or is adapted to be worn behind the user's ear or at the user's body or is designed to be located remote from the user and is connected to the microphones via a radio frequency link (32) such as a Bluetooth link. 50
14. A method for separation of a user's voice from ambient sound, comprising: 55

providing the user with a device (10) to be worn at a user's ear or at least partly in the user's ear canal (12) and comprising a first microphone (M1) oriented acoustically towards the environment and a second microphone (M2) oriented acoustically towards the user's ear canal (12), picking up sound by the first microphone to create a first audio signal and by the second microphone to create a second audio signal, and processing the first and second audio signals by a blind source separation algorithm in order to produce a processed audio signal wherein the user's voice is separated from ambient sound, wherein the processed audio signal is provided to another person via a wireless link.

15. A method for separation of a user's voice from ambient sound, comprising:

providing the user with a first device (10) to be worn at the user's right ear or at least partly in the user's right ear canal (12) and a second device (11) to be worn at the user's left ear or at least partly in the user's left ear canal (12), the first device comprising a first microphone (M1) and the second device comprising a second microphone (M2), picking up sound by the first microphone to create a first audio signal and by the second microphone to create a second audio signal, and processing the first and second audio signals by a blind source separation algorithm in order to produce a processed audio signal wherein the user's voice is separated from ambient sound, wherein the processed audio signal is provided to another person via a wireless link.

#### Patentansprüche

1. System zum Trennen der Stimme eines Nutzers von Umgebungsschall, mit einem am Ohr des Nutzers oder mindestens teilweise im Gehörgang (12) des Nutzers zu tragenden Gerät (10), welches ein erstes, akustisch nach außen zur Umgebung hin orientiertes Mikrofon (M1) und ein zweites, akustisch nach innen zum Gehörgang des Nutzers hin orientiertes Mikrofon (M2) aufweist, einer Audiosignalverarbeitungseinheit (24, 26) zum Verarbeiten von Audiosignalen von dem ersten und dem zweiten Mikrofon mittels eines Blind-Quellen-Trennungs-Algorithmus, welcher geeignet ist, um die Stimme des Nutzers von Umgebungsschall zu trennen, und einem Radiofrequenzsender (T1) zum Senden der verarbeiteten Audiosignalausgabe der Audiosignalverarbeitungseinheit (24, 26) an einem entfernt angeordneten Radiofrequenzempfänger (R2), um einer anderen Person die Stimme des Nutzers zuzuführen.

2. System gemäß Anspruch 1, wobei das Gerät (10) als Hörschutzgerät ausgelegt ist, um für eine akustische Dämpfung, gemittelt über den Hörbandfrequenzbereich, von mindestens 10 dB zu sorgen.
3. System gemäß Anspruch 2, wobei die Mikrofone (M1, M2) so angeordnet sind, dass das zweite Mikrofon (M2) erreichender Umgebungsschall durch das Hörschutzgerät (10) relativ zu das erste Mikrofon (M1) erreichendem Umgebungsschall gedämpft wird.
4. System gemäß einem der Ansprüche 2 oder 3, wobei die Hörschutzvorrichtung als Ohrstopfen (10) ausgebildet ist, der eine Schale aufweist, welche mindestens teilweise in den Gehörgang (12) des Nutzers einzusetzen ist.
5. System gemäß einem der Ansprüche 1 bis 3, wobei das Gehörschutzgerät als Ohrschützer ausgebildet ist und wobei das erste Mikrofon an der Außenseite des Ohrschützers angeordnet oder zu dieser hin offen ist und das zweite Mikrofon an der Innenseite des Ohrschützers angeordnet oder zu dieser hin offen ist.
6. System gemäß einem der vorhergehenden Ansprüche, wobei das Gerät einen Lautsprecher (S) aufweist, der ausgebildet ist, um dem Ohr des Nutzers ein externes Audiosignal darzubieten.
7. System gemäß Anspruch 1, wobei das Gehäuse (50, 50A) des Geräts (10) hinter oder unter dem Ohr des Nutzers zu tragen ist, und wobei eine Schallröhre (52) vorgesehen ist, die sich von dem zweiten Mikrofon (M2) in den Gehörgang des Nutzers erstreckt.
8. System gemäß Anspruch 7, wobei das freie Ende (68) der Schallröhre (52) mit einem Ohrstopfen (54) versehen ist.
9. System gemäß Anspruch 1, wobei das Gehäuse (50) des Geräts hinter oder unterhalb dem Ohr des Nutzers zu tragen ist, wobei das zweite Mikrofon (M2) in einem Ohrstopfen (54) vorgesehen ist, der in den Gehörgang des Nutzers und/oder die Concha des Nutzers einzusetzen ist, und wobei das zweite Mikrofon (M2) mit dem Gehäuse (50) des Geräts (10) über ein Kabel (58) verbunden ist.
10. System gemäß Anspruch 6, wobei das System einen Radiofrequenzempfänger (R1) zum Empfangen des externen Audiosignals von einem entfernten Radiofrequenzsender (T2) aufweist.
11. System zum Trennen der Stimme eines Nutzers von Umgebungsschall, mit: einem ersten, an dem rechten Ohr des Nutzers oder mindestens teilweise in dem rechten Gehörgang (12) des Nutzers zu tragenden Gerät (10), einem zweiten, an dem linken Ohr des Nutzers oder mindestens teilweise in dem linken Gehörgang (11) des Nutzers zu tragenden Gerät (11), wobei das erste Gerät ein erstes Mikrofon (M1) und das zweite Gerät ein zweites Mikrofon (M2) aufweist, einer Audiosignalverarbeitungseinheit (24, 26) zum Verarbeiten von Audiosignalen von dem ersten und zweiten Mikrofon mittels eines Blind-Quellen-Trennungs-Algorithmus, der geeignet ist, um die Stimme des Nutzers von Umgebungsschall zu trennen, und einem Radiofrequenzsender (T1) zum Senden der verarbeiteten Radiosignalausgabe der Audiosignalverarbeitungseinheit (24, 26) zu einem entfernt angeordneten Radiofrequenzempfänger (R2), um einer anderen Person die Stimme des Nutzers zuzuführen.
12. System gemäß Anspruch 11, wobei das erste Mikrofon (M1) oder das zweite Mikrofon (M2) nach außen zur Umgebung hin orientiert ist und das andere der beiden Mikrofone in den zum Gehörgang (12) des Nutzers hin orientiert ist.
13. System gemäß einem der Ansprüche 11 und 12, wobei die Audiosignalverarbeitungseinheit (24, 26) in dem ersten Gerät (10) oder dem zweiten Gerät (11) angeordnet ist oder ausgebildet ist, um hinter dem Ohr des Nutzers oder am Körper des Nutzers getragen zu werden, oder ausgebildet ist, um entfernt von dem Nutzer angeordnet zu sein und mit den Mikrofonen über eine Radiofrequenzstrecke (32), beispielsweise Bluetooth-Strecke, verbunden zu sein.
14. Verfahren zum Trennen der Stimme eines Nutzers von Umgebungsschall, wobei:
- der Nutzer mit einem an einem Ohr des Nutzers oder mindestens teilweise im Gehörgang (12) des Nutzers zu tragenden Gerät (10) versehen wird, welches ein erstes, akustisch zur Umgebung hin orientiertes erstes Mikrofon (M1) und ein zweites, akustisch zum Gehörgang (12) des Nutzers hin orientiertes Mikrofon (M2) aufweist, Schall mittels des ersten Mikrofons zwecks Erzeugung eines ersten Audiosignals und mittels des zweiten Mikrofons zwecks Erzeugung eines zweiten Audiosignals aufgenommen wird, und
- das erste und zweite Audiosignal mittels eines Blind-Quellen-Trennungs-Algorithmus verarbeitet wird, um ein verarbeitetes Audiosignal zu erzeugen, in welchem die Stimme des Nutzers vom Umgebungsschall getrennt ist, wobei eine andere Person über eine drahtlose Strecke mit dem verarbeiteten Audiosignal versorgt wird.

15. Verfahren zum Trennen der Stimme eines Nutzers von Umgebungsschall, wobei:

der Nutzer mit einem ersten, an dem rechten Ohr des Nutzers oder mindestens zum Teil im rechten Gehörgang (12) des Nutzers zu tragenden ersten Gerät (10) und einem zweiten, an dem linken Ohr des Nutzers oder mindestens zum Teil im linken Gehörgang (12) des Nutzers zu tragenden zweiten Gerät (11) versehen wird, wobei das erste Gerät ein erstes Mikrofon (M1) und das zweite Gerät ein zweites Mikrofon (M2) aufweist, Schall mittels des ersten Mikrofons zwecks Erzeugung eines ersten Audiosignals und mittels des zweiten Mikrofons zwecks Erzeugung eines zweiten Audiosignals aufgenommen wird, und das erste und zweite Audiosignal mittels eines Blind-Quellen-Trennungs-Algorithmus verarbeitet wird, um ein verarbeitetes Audiosignal zu erzeugen, in welchem die Stimme des Nutzers von Umgebungsschall getrennt ist, wobei eine andere Person über eine drahtlose Strecke mit dem verarbeiteten Audiosignal versorgt wird.

#### Revendications

1. Système pour séparer la voix d'un utilisateur d'un son ambiant, comprenant un dispositif (10) devant être porté à l'oreille de l'utilisateur ou au moins partiellement dans le canal auditif (12) de l'utilisateur, comprenant un premier microphone (M1) orienté acoustiquement vers l'extérieur et vers l'environnement et un second microphone (M2) orienté acoustiquement vers l'intérieur et vers le canal auditif de l'utilisateur, une unité de traitement de signal audio (24, 26) destinée à traiter des signaux audio provenant des premier et second microphones au moyen d'un algorithme de séparation de source aveugle apte à séparer la voix de l'utilisateur du son ambiant, et un émetteur radiofréquence (T1) destiné à émettre le signal audio traité fourni en sortie de l'unité de traitement de signal audio (24, 26) vers un récepteur radiofréquence distant (R2) afin de fournir la voix de l'utilisateur à une autre personne.
2. Système selon la revendication 1, dans lequel le dispositif (10) est conçu sous la forme d'un dispositif de protection de l'audition destiné à fournir une atténuation acoustique, moyennée sur la gamme de fréquences audibles, d'au moins 10 dB.
3. Système selon la revendication 2, dans lequel les microphones (M1, M2) sont agencés de façon que le son ambiant atteignant le second microphone (M2) soit atténué par le dispositif de protection de l'audition (10) par rapport au son ambiant atteignant le premier microphone (M1).
4. Système selon l'une des revendications 2 ou 3, dans lequel le dispositif de protection de l'audition est un bouchon d'oreille (10) comprenant une coquille devant être insérée au moins partiellement dans le canal auditif (12) de l'utilisateur.
5. Système selon l'une des revendications 1 à 3, dans lequel le dispositif de protection de l'audition est une coquille antibruit et dans lequel le premier microphone est situé ou s'ouvre sur la face extérieure de la coquille antibruit et le second microphone est situé ou s'ouvre sur la face intérieure de la coquille antibruit.
6. Système selon l'une des revendications précédentes, dans lequel le dispositif comprend un haut-parleur (S) apte à fournir un signal audio externe à l'oreille de l'utilisateur.
7. Système selon la revendication 1, dans lequel le boîtier (50, 50A) du dispositif (10) doit être porté à l'arrière ou en dessous de l'oreille de l'utilisateur et dans lequel un tube sonore (52) est prévu de manière à s'étendre du second microphone (M2) à l'intérieur du canal auditif de l'utilisateur.
8. Système selon la revendication 7, dans lequel l'extrémité libre (68) du tube sonore (52) est munie d'un bouchon d'oreille (54).
9. Système selon la revendication 1, dans lequel le boîtier (50) du dispositif doit être porté à l'arrière ou en dessous de l'oreille de l'utilisateur, dans lequel le second microphone (M2) est contenu dans un bouchon d'oreille (54) devant être inséré dans le canal auditif de l'utilisateur et/ou la conque de l'utilisateur et dans lequel le second microphone (M2) est connecté au boîtier (50) du dispositif (10) par l'intermédiaire d'un câble (58).
10. Système selon la revendication 6, dans lequel le système comprend un récepteur radiofréquence (R1) destiné à recevoir le signal audio externe d'un émetteur radiofréquence distant (T2).
11. Système pour la séparation de la voix d'un utilisateur d'un son ambiant, comprenant : un premier dispositif (10) devant être porté à l'oreille droite de l'utilisateur ou au moins partiellement dans le canal auditif droit (12) de l'utilisateur, un second dispositif (11) devant être porté à l'oreille gauche de l'utilisateur ou au moins partiellement dans le canal auditif gauche (12) de l'utilisateur, le premier dispositif comprenant un premier microphone (M1) et le second dispositif

- comprenant un second microphone (M2), une unité de traitement de signal audio (24, 26) destinée à traiter des signaux audio provenant des premier et second microphones au moyen d'un algorithme de séparation de source aveugle apte à séparer la voix de l'utilisateur du son ambiant, et un émetteur radiofréquence (T1) destiné à émettre le signal audio traité fourni en sortie de l'unité de traitement de signal audio (24, 26) vers un récepteur radiofréquence distant (R2) afin de fournir la voix de l'utilisateur à une autre personne.
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12. Système selon la revendication 11, dans lequel l'un du premier microphone (M1) et du second microphone (M2) est orienté vers l'extérieur et vers l'environnement et l'autre du premier microphone et du second microphone est orienté vers l'intérieur et vers le canal auditif (12) de l'utilisateur.
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13. Système selon l'une des revendications 11 et 12, dans lequel l'unité de traitement de signal audio (24, 26) est située dans l'un du premier dispositif (10) et du second dispositif (11) ou est apte à être portée à l'arrière de l'oreille de l'utilisateur ou sur le corps de l'utilisateur ou est conçue pour être placée à distance de l'utilisateur et est connectée aux microphones par l'intermédiaire d'une liaison radiofréquence (32) telle qu'une liaison Bluetooth.
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14. Procédé pour la séparation de la voix d'un utilisateur d'un son ambiant, consistant à :
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- fournir à l'utilisateur un dispositif (10) devant être porté à l'oreille d'un utilisateur ou au moins partiellement dans le canal auditif (12) de l'utilisateur et comprenant un premier microphone (M1) orienté acoustiquement vers l'environnement et un second microphone (M2) orienté acoustiquement vers le canal auditif (12) de l'utilisateur, capter un son au moyen du premier microphone afin de créer un premier signal audio et au moyen du second microphone afin de créer un second signal audio, et
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- 40
- traiter les premier et second signaux audio au moyen d'un algorithme de séparation de source aveugle afin de produire un signal audio traité dans lequel la voix de l'utilisateur est séparée du son ambiant,
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- dans lequel le signal audio traité est fourni à une autre personne par l'intermédiaire d'une liaison sans fil.
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15. Procédé pour la séparation de la voix d'un utilisateur d'un son ambiant, consistant à :
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- fournir à l'utilisateur un premier dispositif (10) devant être porté à l'oreille droite d'un utilisateur ou au moins partiellement dans le canal auditif
- droit (12) de l'utilisateur et un second dispositif (11) devant être porté à l'oreille gauche de l'utilisateur ou au moins partiellement dans le canal auditif gauche (12) de l'utilisateur, le premier dispositif comprenant un premier microphone (M1) et le second dispositif comprenant un second microphone (M2), acquérir un son au moyen du premier microphone afin de créer un premier signal audio et au moyen du second microphone afin de créer un second signal audio, et traiter les premier et second signaux audio au moyen d'un algorithme de séparation de source aveugle afin de produire un signal audio traité dans lequel la voix de l'utilisateur est séparée du son ambiant, dans lequel le signal audio traité est fourni à une autre personne par l'intermédiaire d'une liaison sans fil.

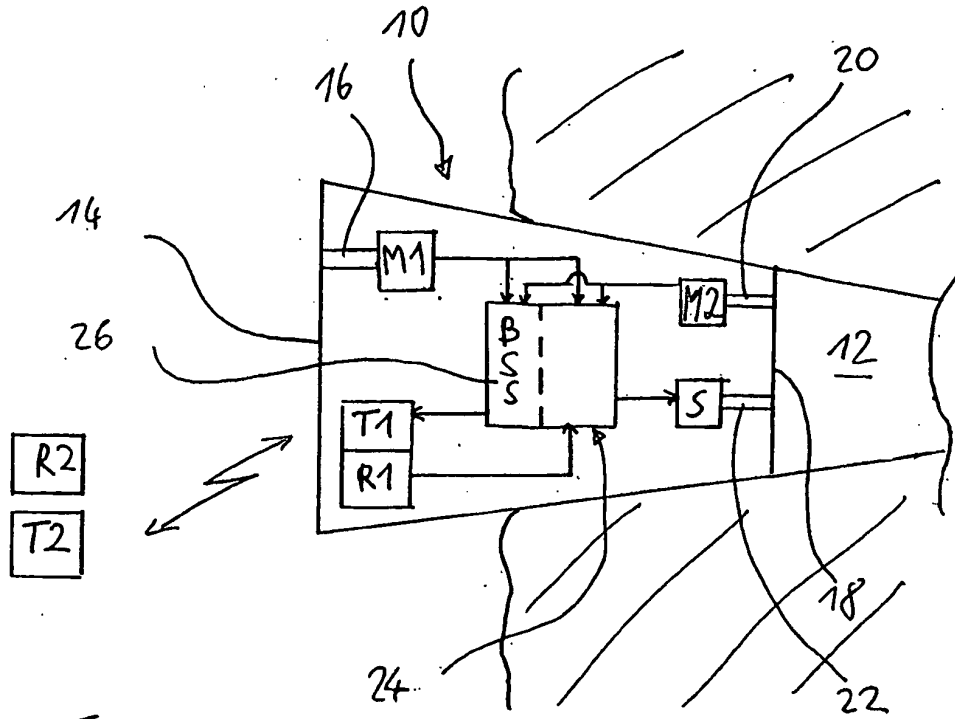


Fig. 1

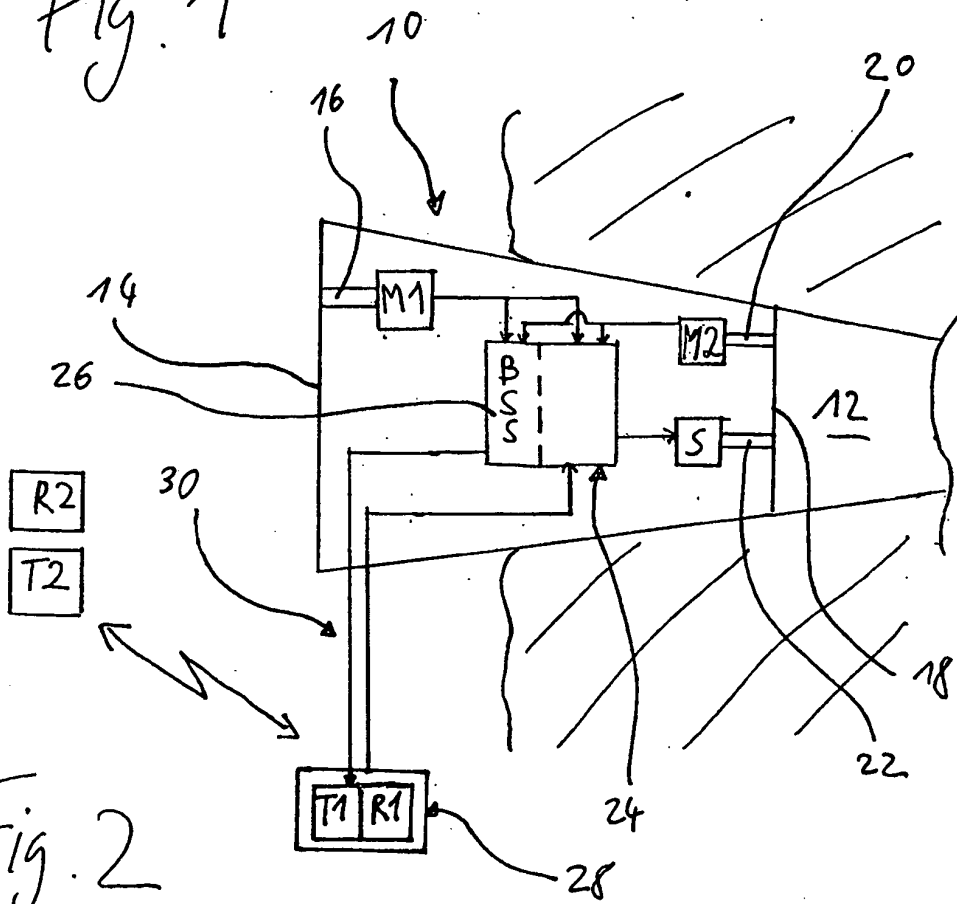


Fig. 2



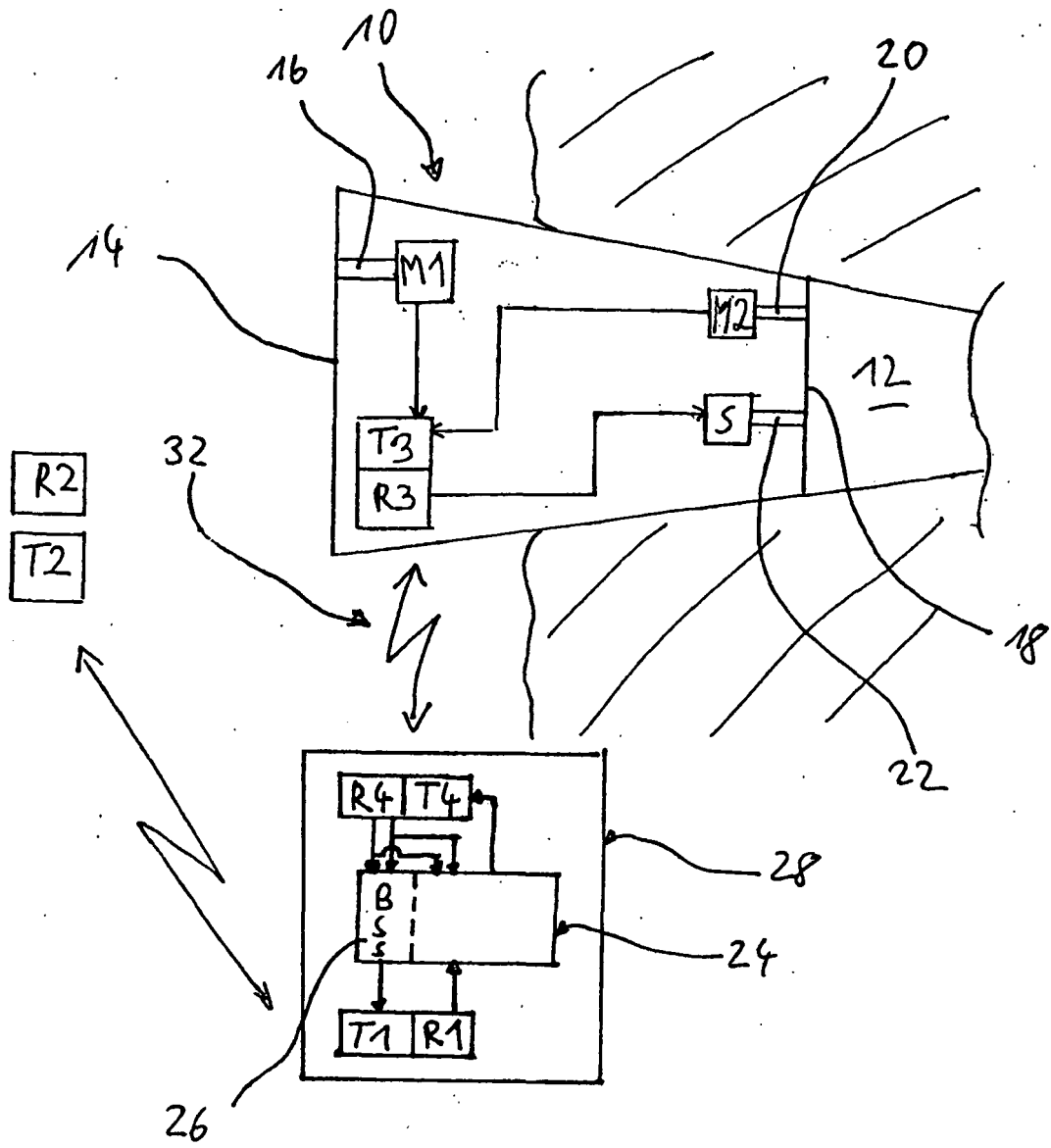


Fig. 4

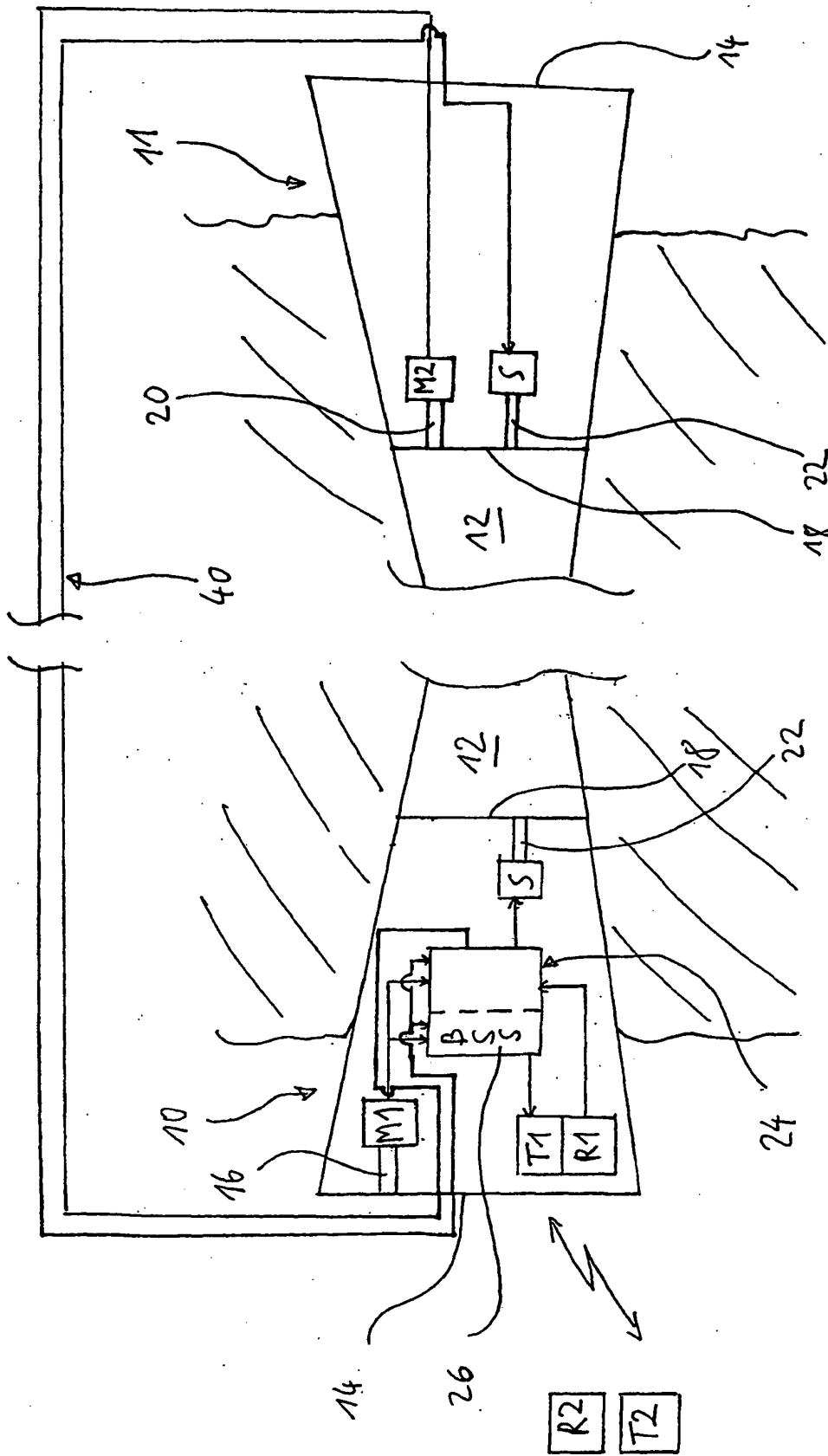


Fig. 5

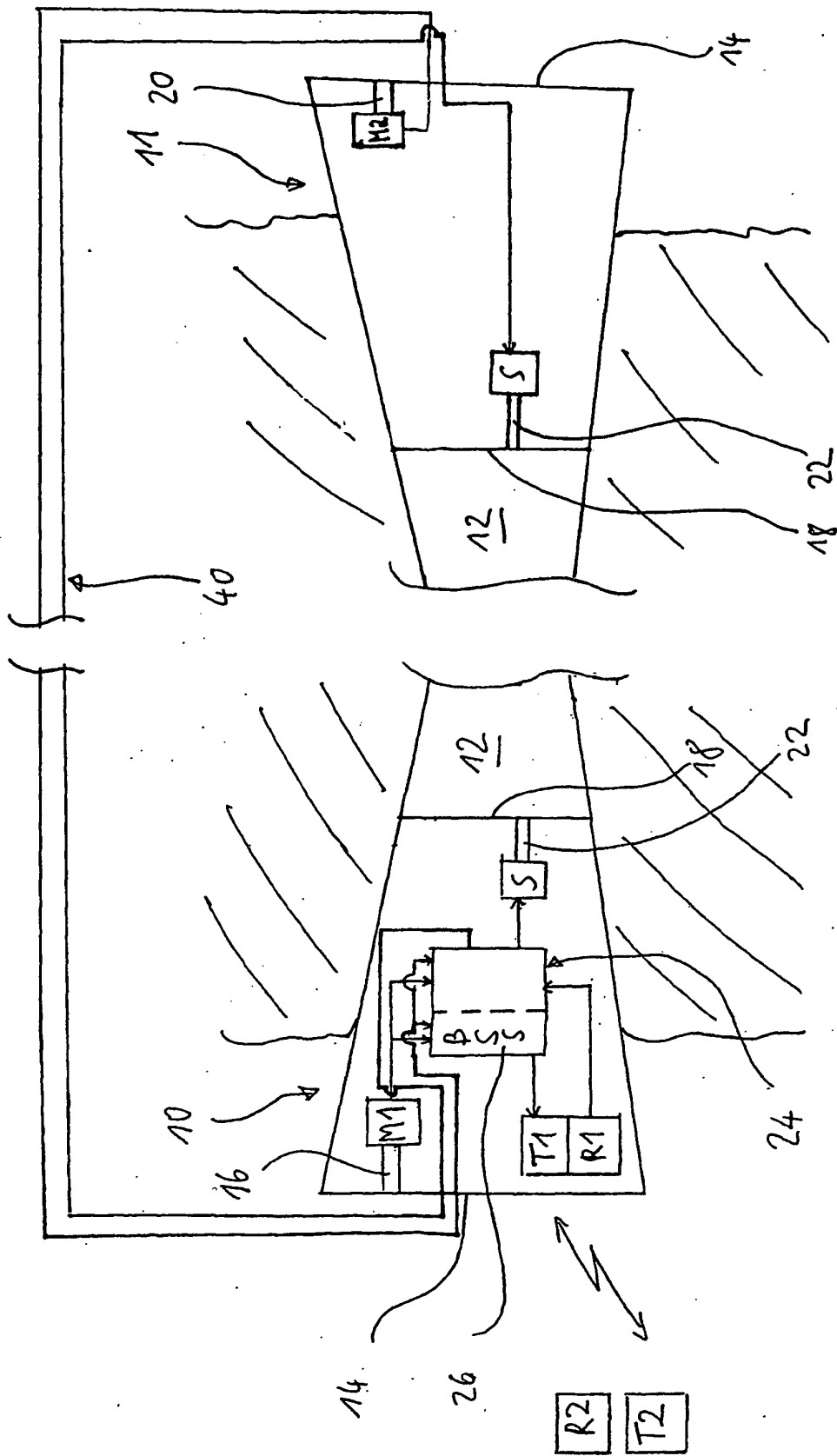


Fig. 6

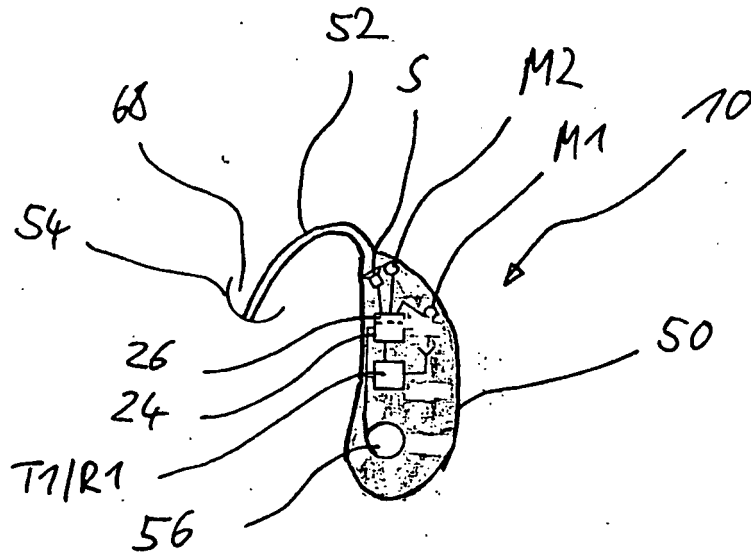


Fig. 7

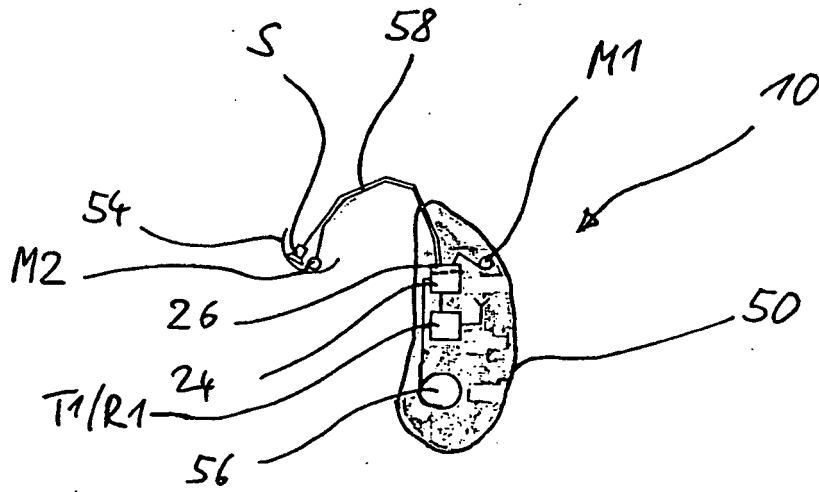
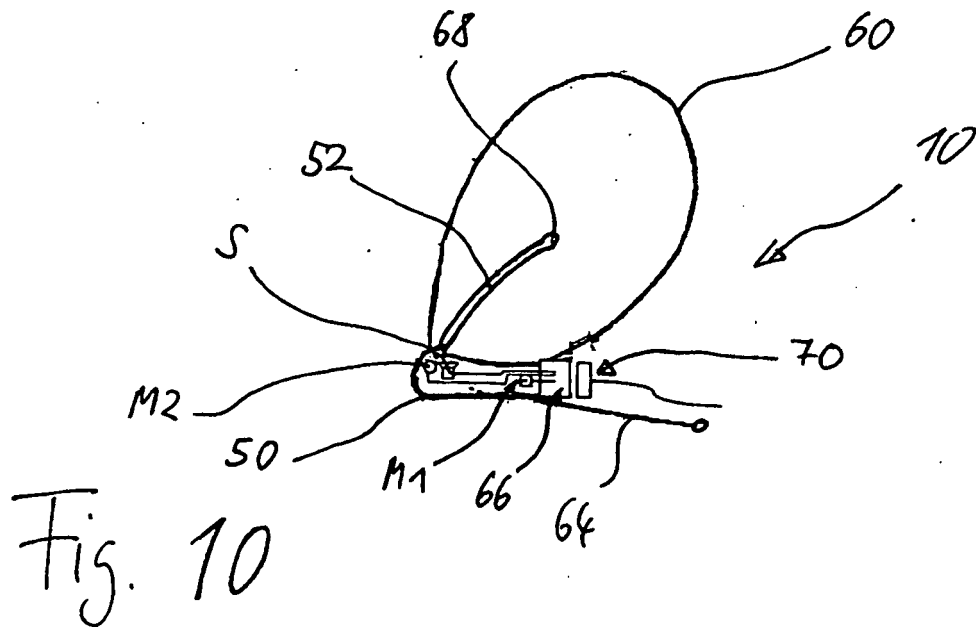
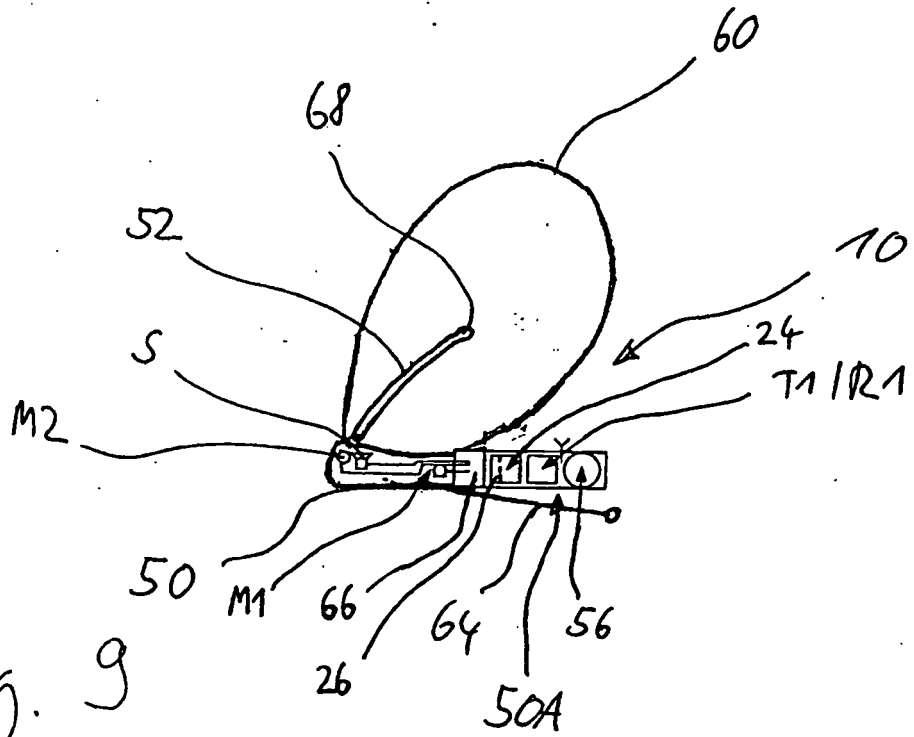


Fig. 8



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- US 6661901 B1 [0005]
- US 20030055535 A1 [0006]
- US 20050060142 A1 [0006] [0010]
- EP 1509065 A1 [0006]
- US 20030133583 A1 [0025]
- US 6533062 B1 [0025]
- DE 102006016052 [0051]
- DE 102005002482 B3 [0051]