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(54) **Bte hearing aid having a balanced antenna**

BTE-Hörgerät mit ausgeglichener Antenne

Prothèse auditive BTE possédant une antenne équilibrée

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Description

[0001] The present disclosure relates to a hearing aid having an antenna, such as a balanced antenna, the antenna being configured for providing the hearing aid with wireless data communication features.

Hearing aids are very small and delicate devices and comprise many electronic and metallic components contained in a housing small enough to fit in the ear canal of a human or behind the outer ear. The many electronic and metallic components in combination with the small size of the hearing aid housing impose high design constraints on radio frequency antennas to be used in hearing aids with wireless communication capabilities.

Conventionally, antennas in hearing aids have been used for receiving radio broadcasts or commands from a remote control. Typically, such antennas are designed to fit in the hearing aid housing without special concern with relation to the obtained directivity of the resulting radiation pattern. For example, behind-the-ear hearing aid housings typically accommodate antennas positioned with their longitudinal direction in parallel to the longitudinal direction of the banana shaped behind-the-ear hearing aid housing. In-the-ear hearing aids have typically been provided with patch antennas positioned on the face plate of the hearing aids as for example disclosed in WO 2005/081583; or wire antennas protruding outside the hearing aid housing in a direction perpendicular to the face plate as for example disclosed in US 2010/20994.

[0002] US 2010/0158293, discloses a hearing aid with a radio circuit and an antenna. The antenna is a loop antenna, such as a single or multi loop antenna and the radio circuit is at least substantially within the aperture of the loop antenna, see paragraphs [0029] and [0030].

[0003] It is an object of the present invention to provide an improved wireless communication.

In one aspect of the present invention, the above-mentioned and other objects are obtained by provision of a hearing aid according to the subject-matter of claim 1.

[0004] In one or more embodiments, the current induced in the first segment may be symmetric with respect to a plane substantially partitioning the first segment in the middle of the segment.

The first segment, may be provided in a position substantially orthogonal to a side of the head, when the hearing aid is worn by a user in its intended operational position. In one or more embodiments, the first segment may extend in a direction having at least a vector component being orthogonal to the side of the head, for example the vector component being orthogonal to the side of the head may be at least the same length as a vector component extending parallel to the side of the head.

The first segment may short circuit the part of the antenna proximate the first side of the hearing aid and the part of the antenna proximate the second side of the hearing aid to provide a current bridge between the first side of the hearing aid and the second side of the hearing aid.

Hereby, an electromagnetic field emitted by the antenna may propagate along the surface of the head of the user with its electrical field substantially orthogonal to the surface of the head of the user when the hearing aid is worn in its operational position by a user.

[0005] Preferably, the electromagnetic field emitted by the antenna propagates primarily along the surface of the head or body of the user.

[0006] Upon excitation, a substantial part of the electromagnetic field, such as 60%, such as 80%, emitted by the antenna may propagate along the surface of the head of the user with its electrical field substantially orthogonal to the surface of the head of the user. When the electromagnetic field is diffracted around the head of a user, losses due to the interaction with the surface of the head are minimized. Hereby, a significantly improved reception of the electro-magnetic radiation by either a second hearing aid in a binaural hearing aid system, typically located at the other ear of a user, or by a hearing aid accessory, such as a remote control, a telephone, a television set, a spouse microphone, a hearing aid fitting system, an intermediary component, such as a Bluetooth bridging device, etc., is obtained.

[0007] In that the electromagnetic field is diffracted around the head, or the body, of a user with minimum interaction with the surface of the head, or the surface of the body, the strength of the electromagnetic field around the head, or the body, of the user is significantly improved. Thus, the interaction with other antennas and/or transceivers, as provided in either a second hearing aid of a binaural hearing aid system located at the other ear of a user, or as provided in accessories as mentioned above, which typically are located in front of a user, or other wearable computing devices, is enhanced. It is a further advantage of providing an electromagnetic field around the head of a user that an omni-directional connectivity to external devices, such as accessories, is provided.

[0008] Due to the current component normal to the side of the head or normal to any other body part, the surface wave of the electromagnetic field may be more efficiently excited. Hereby, for example an ear-to-ear path gain may be improved, such as by 10 -15 dB, such as by 10-20 dB.

[0009] The antenna may emit a substantially TM polarized electromagnetic field for diffraction around the head of a user, i.e. TM polarised with respect to the surface of the head of a user.

[0010] It is an advantage that, during operation, the first segment of the antenna contributes to an electromagnetic field that travels around the head of the user thereby providing a wireless data communication that is robust and has low loss.

[0011] In that the antenna does not, or substantially does not, emit an electromagnetic field in the direction of the first segment, such as in a direction along the first segment, the antenna does not, or substantially does not, emit an electromagnetic field in the direction of the ear to ear axis of the user when the hearing aid is positioned

in its operational position at the ear of the user; rather, the antenna emits an electromagnetic field that propagates in a direction parallel to the surface of the head of the user when the hearing aid is positioned in its operational position during use, whereby the electric field of the emitted electromagnetic field has a direction that is orthogonal to, or substantially orthogonal to, the surface of the head at least along the side of the head, or the part of the body, at which the antenna is positioned during operation. In this way, propagation loss in the tissue of the head is reduced as compared to propagation loss of an electromagnetic field with an electric field component that is parallel to the surface of the head. Diffraction around the head makes the electromagnetic field emitted by the antenna propagate from one ear and around the head to the opposite ear.

[0012] The hearing aid typically further comprises a microphone for reception of sound and conversion of the received sound into a corresponding first audio signal, a signal processor for processing the first audio signal into a second audio signal compensating a hearing loss of a user of the hearing aid, and a receiver that is connected to an output of the signal processor for converting the second audio signal into an output sound signal.

[0013] The first segment may preferably be structured so that upon excitation of the antenna, the current flows in at least the first segment in a direction substantially orthogonal to a surface of the head of a user when the hearing aid is worn in its operational position by the user. Thus, the first segment may extend in a direction substantially parallel with an ear to ear axis of the user, and thus, substantially orthogonal to a surface of the head, when the hearing aid is worn in its operational position by a user.

[0014] In one or more embodiments, a part of the antenna extending proximate the first side of the hearing aid is substantially identical to a part of the antenna extending proximate the second side of the hearing aid. Thus, the physical shape of the part of the antenna extending proximate the first side of the hearing aid may be substantially identical to the physical shape of the part of the antenna extending proximate the second side of the hearing aid. Additionally, or alternatively, the part of the antenna extending proximate the first side of the hearing aid and the part of the antenna extending proximate the second side of the hearing aid may have substantially the same free-space antenna radiation pattern.

[0015] The feed system may comprise a first feed point for exciting at least the antenna proximate the first side of the hearing aid and a second feed point for exciting at least the antenna proximate the second side of the hearing aid. The first feed point and the second feed point may be initially balanced, that is out of phase.

[0016] The part of the antenna extending proximate the first side of the hearing aid and/or the part of the antenna extending proximate the second side of the hearing aid may be actively fed. Thus, the part of the antenna extending proximate the first side of the hearing

aid may have a first feed point and the part of the antenna extending proximate the second side of the hearing aid may have a second feed point. In one or more embodiments, the part of the antenna extending proximate the first side of the hearing aid and the part of the antenna extending proximate the second side of the hearing aid may be fed from the transceiver in the hearing aid.

[0017] The feed system may furthermore comprise one or more transmission lines for connecting the part of the antenna extending proximate the first side of the hearing aid and the part of the antenna extending proximate the second side of the hearing aid to the source, such as to the transceiver. The first feed point may reflect the connection between a first transmission line and the part of the antenna extending proximate the first side of the hearing aid, and the second feed point may reflect the connection between another transmission line and the part of the antenna extending proximate the second side of the hearing aid.

[0018] The antenna may be a balanced antenna, and in one or more embodiments, the current from the transceiver to a feed point for the part of the antenna extending proximate the first side of the hearing aid and the current to the feed point for the part of the antenna extending proximate the second side of the hearing aid may thus have substantially the same magnitude but run in opposite directions, thereby establishing a balanced feed line and a balanced antenna. It is envisaged that the current magnitudes may not be exactly the same, so that some radiation, though principally unwanted, from the feed line may occur.

[0019] It is an advantage of using a balanced antenna that no ground plane is needed for the antenna. As the size of the hearing aids is constantly reduced, also the size of printed circuit boards within the hearing aids are reduced. This has been found to pose a challenge as conventional hearing aid antennas typically use the printed circuit board as ground plane, and thereby, by reducing the size of the printed circuit boards, also the ground plane for the hearing aid antennas is reduced. Thereby, the efficiency of conventional hearing aid antennas needing a good RF ground will be reduced, thus it is a significant advantage of the present antenna that no ground plane is needed for the antenna.

[0020] The antenna may form a mirrored inverted F-antenna wherein the part of the antenna extending proximate the first side of the hearing aid, and substantially half of the first segment is mirrored to the part of the antenna extending proximate the second side of the hearing aid and substantially the other half of the first segment. The width of the antenna may determine the bandwidth for the antenna, thus by increasing the width of the inverted F-antenna, the bandwidth may also be increased.

[0021] The part of the antenna extending proximate the first and/or second side of the hearing aid may be monopole antenna structure(s), such as any antenna structure having a free end, such as a linear monopole

antenna structure, etc. The length of the part of the antenna extending proximate the first and/or second side of the hearing aid as measured from the short circuit to the free end may be substantially $\lambda/4$, or any odd multiple thereof, where λ is the center wavelength for the antenna.

[0022] In one or more embodiments, the part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may be an antenna structure having a circumference of substantially $\lambda/2$ or any multiple thereof. Thus, the antenna structure may be a circular antenna structure, an annular or ringshaped antenna structure, or the antenna structure may be any closed antenna structure having a circumference of substantially $\lambda/2$. The closed structure may be a solid structure, a strip like structure having an opening in the center, etc. and/or the closed structure may have any shape and be configured so that the current sees a length of $\lambda/2$.

[0023] In one or more embodiments, the part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may extend in a plane being substantially parallel to a side of the head when the hearing aid is worn in its operational position by a user. The part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may be planar antennas extending only in the plane being substantially parallel to a side of the head, or the first resonant structure and/or the second resonant structure may primarily extend in the plane being substantially parallel to a side of the head, so that the resonant structures may exhibit e.g. minor, as compared to the overall extent of the resonant structure, folds in a direction not parallel to the side of the head.

[0024] The area of the part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may be maximized relative to the size of the hearing aid to for example increase the bandwidth of the antenna. The part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may be a solid structure extending over the entire side of the hearing aid, or at least extending over a large part of the side of the hearing aid, furthermore, the circumference of the part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may be maximized allowing for an opening in the structure to accommodate e.g. a hearing aid battery, electronic components, or the like.

[0025] The part of the antenna extending proximate the first and/or extending proximate a second side of the hearing aid may form part of a hearing aid housing encompassing at least a part of the hearing aid.

[0026] In one or more embodiments of the present invention, the hearing aid may have a partition plane, such as a plane of intersection, extending between the first side and the second side of the hearing aid. At least a part of the antenna may intersect the partition plane so

that there is a first distance from the first feed point to the partition plane and a second distance from the second feed point to the partition plane. The first distance and the second distance may be substantially the same so that the first and second feed points are provided substantially symmetrically with respect to the partition plane. A relative difference between the first distance and the second distance may be less than or equal a first threshold, such as less than 25%, such as less than 10%, such as about 0.

[0027] The partition plane may be any plane partitioning the hearing aid, such as a plane parallel to the first and/or second side of the hearing aid, such as a plane parallel to the side of a head when the hearing aid is worn in its operational position on the head of a user. The partition plane may form a symmetry plane for the antenna, so that for example the first resonant structure is symmetric with the second resonant structure with respect to the partition plane.

[0028] The first distance and the second distance may be measured along a shortest path between the first feed point and the partition plane, and the second feed point and the partition plane, such that the distance is the shortest physical distance. Alternatively, the first distance and the second distance may be the distance as measured along a current path between the first or second feed point and the partition plane.

[0029] The part of the antenna extending proximate the first side of the hearing aid and/or the part of the antenna extending proximate the second side of the hearing aid may form a first resonant structure and a second resonant structure, respectively.

[0030] The current flowing in a resonant antenna structure forms standing waves along the length of the antenna; and for proper operation, the resonant antenna structure is operated at, or approximately at, a resonance frequency at which the length of the linear antenna equals a quarter wavelength of the emitted electromagnetic field, or any odd multiple, thereof.

[0031] The first and second resonant structures may be resonant around a center frequency, i.e. around the resonance frequency for the antenna, and typically, the resonant antenna structure may be resonant within a given bandwidth around the center frequency.

[0032] The first resonant structure and/or the second resonant structure may be actively fed resonant structures. In the present context, the term actively fed resonant structure encompasses that the resonant structure is electrically connected to a source, such as a radio, such as a transceiver, a receiver, a transmitter, etc. Thus, the first and second resonant structures may be driven structures, such as driven resonant structure, such as a driven resonant antenna structure. Thus, the actively fed resonant structure is opposed to the passive antenna structure which is not electrically connected to the surroundings. The first resonant structure and the second resonant structure may in some embodiments be fed symmetrically.

[0033] In one or more embodiments, the first feed point and the second feed point, respectively, are configured with respect to the short circuit so as to obtain a desired antenna impedance. Typically, a distance between the first feed point and the short circuit along the first resonant structure may be configured to achieve the desired impedance, and likewise, a distance between the second feed point and the short circuit along the second resonant structure may be configured to achieve the desired impedance.

[0034] It is envisaged that the overall physical length of the antenna may be decreased by interconnecting the antenna with an electronic component, a so-called antenna shortening component, having an impedance that modifies the standing wave pattern of the antenna thereby changing its effective length. The required physical length of the antenna may for example be shortened by connecting the antenna in series with an inductor or in shunt with a capacitor.

[0035] The antenna may be configured for operation in the ISM frequency band. Preferably, the antenna is configured for operation at a frequency of at least 1 GHz, such as at a frequency between 1.5 GHz and 3 GHz such as at a frequency of 2.4 GHz.

[0036] In a further aspect of the present invention, an antenna system configured to be worn on a body of a user is provided, the antenna system comprises a transceiver for wireless data communication interconnected with an antenna for emission and reception of an electromagnetic field. The antenna may extend on a first side of the hearing aid and a second side of the hearing aid. A first segment of the antenna may extend from proximate the first side of the hearing aid to proximate the second side of the hearing aid and a feed system may be provided for exciting the antenna to thereby induce a current in at least the first segment. The feed system may be configured such that the current induced in the first segment has a first local maxima proximate the first side of the hearing aid and a second local maxima proximate the second side of the hearing aid. Thus, the current induced on the antenna may reach its maximum on the first segment of the antenna that extends from proximate the first side of the hearing aid to proximate the second side of the hearing aid.

[0037] The current induced in the first segment may have a first local maximum proximate the first side of the hearing aid and a second local maximum proximate the second side of the hearing aid, depending on the excitation of the antenna. Thus, the current induced on the antenna may reach its maximum on the first segment of the antenna that extends from proximate the first side of the hearing aid to proximate the second side of the hearing aid.

[0038] The current induced in the first segment may have a first local maximum proximate the first side of the hearing aid and a second local maximum proximate the second side of the hearing aid, depending on the excitation of the antenna.

[0039] The antenna system may be provided in for example a wearable computing device, the wearable computing device having a first side configured to be proximate a users body and a second side configured to be proximate the surroundings when the wearable computing device is worn in the operational position by a user.

[0040] Hereby, an electromagnetic field emitted by the antenna propagates along the surface of the body of the user with its electrical field substantially orthogonal to the surface of the body of the user.

[0041] It is an advantage of providing such an antenna system that interconnection between for example a Body Area Network, BAN, or a wireless body area network, WBAN, such as a wearable wireless body area network, and a body external transceiver may be obtained. The body external transceiver may be a processing unit and may be configured to be connected to an operator, an alarm service, a health care provider, a doctors network, etc., either via the internet or any other intra- or interconnection between a number of computers or processing units, either continuously or upon request from either a user, an operator, a provider, or a system generated trigger.

[0042] Preferably, the electromagnetic field emitted by the antenna propagates primarily along the surface of the head or body of the user.

[0043] In the above the invention has been described primarily with reference to a hearing aid, such as a behind the ear hearing aid or such as a binaural hearing aid. It is however envisaged that the disclosed features and embodiments may be used in combination with any aspect of the invention.

[0044] The above and other features and advantages of the present invention will become more apparent to those of ordinary skill in the art by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

The current flowing in a resonant antenna structure forms standing waves along the length of the antenna; and for proper operation, the resonant antenna structure is operated at, or approximately at, a resonance frequency at which the length of the linear antenna equals a quarter wavelength of the emitted electromagnetic field, or any odd multiple, thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045]

Fig. 1 is a phantom head model of a user together with an ordinary rectangular three dimensional coordinate system with an x, y and z axis for defining the geometrical anatomy of the head of the user,

Fig. 2 shows a block-diagram of a typical hearing aid,

Fig. 3 shows a behind the ear hearing aid having an antenna according to one embodiment of the present

invention,

Fig. 4 shows a behind the ear hearing aid having an antenna according to another embodiment of the present invention,

Fig. 5 shows a behind the ear hearing aid having an antenna according to a further embodiment of the present invention,

Fig. 6 shows a behind the ear hearing aid having an antenna according to a still further embodiment of the present invention,

Fig. 7 shows a behind the ear hearing aid having an antenna according to a another embodiment of the present invention,

Figs. 8a-8e show schematically the feed and the short circuit for different embodiments,

Figs. 9a-b show schematically the length of the current path on an antenna,

Figs. 10a-d show schematically the current distribution along an antenna,

Figs. 11a-d show schematically a partition plane for different antenna structures,

DETAILED DESCRIPTION OF THE DRAWINGS

[0046] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments 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.

[0047] The radiation pattern of an antenna is typically illustrated by polar plots of radiated power in horizontal and vertical planes in the far field of the antenna. The plotted variable may be the field strength, the power per unit solid angle, or directive gain. The peak radiation occurs in the direction of maximum gain.

[0048] Fig. 1 is a phantom head model of a user seen from the front together with the ordinary rectangular three dimensional coordinate system.

[0049] When designing antennas for wireless communication proximate the human body, the human head can be approximated by a rounded enclosure with sensory organs, such as the nose, ears, mouth and eyes attached thereto. Such a rounded enclosure 3 is illustrated in Fig. 1. In Fig. 1, the phantom head model is shown from the front together with an ordinary rectangular three dimensional coordinate system with an x, y and z axis for de-

fining orientations with relation to the head and for defining the geometrical anatomy of the head of the user;

[0050] Every point of the surface of the head has a normal and tangential vector. The normal vector is orthogonal to the surface of the head while the tangential vector is parallel to the surface of the head. An element extending along the surface of the head is said to be parallel to the surface of the head, likewise a plane extending along the surface of the head is said to be parallel to the surface of the head, while an object or a plane extending from a point on the surface of the head and radially outward from the head into the surrounding space is said to be orthogonal to the head.

[0051] As an example, the point with reference numeral 2 in Fig. 1 furthest to the left on the surface of the head in Fig. 1 has tangential vectors parallel to the yz-plane of the coordinate system, and a normal vector parallel to the x-axis. Thus, the y-axis and z-axis are parallel to the surface of the head at the point 2 and the x-axis is orthogonal to the surface of the head at the point 2.

[0052] The user modeled with the phantom head of Fig. 1 is standing erect on the ground (not shown in the figure), and the ground plane is parallel to xy-plane. The torso axis from top to toe of the user is thus parallel to the z-axis, whereas the nose of the user is pointing out of the paper along the y-axis.

[0053] The axis going through the right ear canal and the left ear canal is parallel to the x-axis in the figure. This ear to ear axis (ear axis) is thus orthogonal to the surface of the head at the points where it leaves the surface of the head. The ear to ear axis as well as the surface of the head will in the following be used as reference when describing specific configurations of the elements of the present invention.

[0054] Since the auricle of the ear is primarily located in the plane parallel to the surface of the head on most test persons, it is often described that the ear to ear axis also functions as the normal to the ear. Even though there will be variations from person to person as to how the plane of the auricle is oriented.

[0055] The in the ear canal type of hearing aid will have an elongated housing shaped to fit in the ear canal. The longitudinal axis of this type of hearing aid is then parallel to the ear axis, whereas the face plate of the in the ear type of hearing aid will typically be in a plane orthogonal to the ear axis. The behind the ear type of hearing aid will typically also have an elongated housing most often shaped as a banana to rest on top of the auricle of the ear. The housing of this type of hearing aid will thus have a longitudinal axis parallel to the surface of the head of the user.

[0056] A block-diagram of a typical (prior-art) hearing instrument is shown in Fig. 2. The hearing aid 20 comprises a microphone 21 for receiving incoming sound and converting it into an audio signal, i.e. a first audio signal. The first audio signal is provided to a signal processor 22 for processing the first audio signal into a second audio signal compensating a hearing loss of a user of the hear-

ing aid. A receiver 23 is connected to an output of the signal processor 22 for converting the second audio signal into an output sound signal, e.g. a signal modified to compensate for a users hearing impairment, and provides the output sound to a speaker 24. Thus, the hearing instrument signal processor 22 may comprise elements such as amplifiers, compressors and noise reduction systems etc. The hearing instrument or hearing aid may further have a feedback loop 25 for optimizing the output signal. The hearing aid may furthermore have a transceiver 26 for wireless data communication interconnected with an antenna 27 for emission and reception of an electromagnetic field. The transceiver 26 may connect to the hearing instrument processor 22 and an antenna, for communicating with external devices, or with another hearing aid, located at another ear, in a binaural hearing aid system.

However, also other embodiments of the antenna and the antenna configurations may be contemplated.

[0057] The specific wavelength, and thus the frequency of the emitted electromagnetic field, is of importance when considering communication involving an obstacle. In the present invention the obstacle is a head with a hearing aid comprising an antenna located closed to the surface of the head. If the wavelength is too long such as a frequency of 1 GHz and down to lower frequencies greater parts of the head will be located in the near field region. This results in a different diffraction making it more difficult for the electromagnetic field to travel around the head. If on the other hand the wavelength is too short, the head will appear as being too large an obstacle which also makes it difficult for electromagnetic waves to travel around the head. An optimum between long and short wavelengths is therefore preferred. In general the ear to ear communication is to be done in the band for industry, science and medical with a desired frequency centred around 2.4 GHz.

[0058] It is envisaged that even though only a behind-the-ear hearing aid have been shown in the figures, the described antenna structure may be equally applied in all other types of hearing aids, including in-the-ear hearing aids, as long as the conducting segment, or first segment, is configured to guide the current in a direction parallel to an ear-to-ear axis of a user, when the user is wearing the hearing aid in the operational position and furthermore, equally applied to other body wearable devices, as long as the first segment is configured to guide the current in a direction orthogonal to a surface of the body, when the user is wearing the hearing aid in the operational position.

[0059] In general, various sections of the antenna can be formed with many different geometries, they can be wires or patches, bend or straight, long or short as long as they obey the above relative configuration with respect to each other such that at least one conducting segment will carry a current being primarily parallel to the ear axis (orthogonal to the surface of the head 1 of the user at a point 2 in proximity to the ear) such that the field will be

radiated in the desired direction and with the desired polarization such that no attenuation is experienced by the surface wave travelling around the head.

[0060] The specific wavelength, and thus the frequency of the emitted electromagnetic field, is of importance when considering communication involving an obstacle. In the present invention the obstacle is a head with a hearing aid comprising an antenna located closed to the surface of the head. If the wavelength is too long such as a frequency of 1 GHz and down to lower frequencies greater parts of the head will be located in the near field region. This results in a different diffraction making it more difficult for the electromagnetic field to travel around the head. If on the opposite side the wavelength is too short the head will appear as being too large an obstacle which also makes it difficult for electromagnetic waves to travel around the head. An optimum between long and short wavelengths is therefore preferred. In general the ear to ear communication is to be done in the band for industry, science and medical with a desired frequency centred around 2.4 GHz.

[0061] In Fig. 3, a hearing aid 30 is shown schematically, the hearing aid 30 is a hearing aid of the type to be worn behind the ear, typically referred to as a behind the ear hearing aid, or a BTE hearing aid. The hearing aid 30 comprises a battery 31, a signal processor 32, a sound tube 33 connecting to the inner ear, a radio or transceiver 34, transmission lines 35, 36 for feeding the antenna 37. The hearing aid has a first side 38 and a second side 39. In one or more embodiments, the antenna proximate the first side of the hearing aid, i.e. a first part, 40 extends along or proximate the first side 38 of the hearing aid, and the antenna proximate the second side of the hearing aid, i.e. a second part, 41 extend along or proximate a second side 39 of the hearing aid 30. The first part of the antenna 40 may in one or more embodiments be a first resonant structure provided proximate the first side 38 of the hearing aid, and the second part of the antenna 41 may in one or more embodiments a second resonant structure provided proximate a second side 39 of the hearing aid. A first segment 42 short circuits the first part 40 and the second part 41 to provide a current bridge between the first side of the hearing aid and the second side of the hearing aid. The first part 40 is fed via transmission line 35 to feed point 43 and is thus an actively fed part 40. The second part 41 is fed via transmission line 36 to feed point 44 and thus forms a second actively fed part 41. The feed system for the antenna may thus comprise the first and second transmission lines 35, 36 and first and second feed points 43, 44 for feeding antenna 37.

[0062] In Fig. 4, a hearing aid 30 is shown schematically, wherein the width 45 of the first part 40 of the antenna 37 and the second part 41 of the antenna 37 is increased to increase the bandwidth of the antenna 37.

[0063] In Fig. 5, a hearing aid 30 is shown schematically, wherein the antenna 37 is folded around the hearing aid 30, and thus the antenna extends along the first side

38 and the second side 39.

[0064] Fig. 6 shows a further embodiment of the invention, wherein the hearing aid 30 has an antenna 37 having a first part 61 and a second part 62. The first part 61 and/or second part 62 are closed antennas having a width 63 allowing for an opening 64 to be formed within the antenna 37. The opening may allow for configuring the antenna so as not to extend over battery 31 and other larger electrical components. The first part 61 and/or the second part 62 may have any width and/or any shape configured according to hearing aid restrictions and/or antenna optimization. For the first part 61 and/or the second part 62 to be resonant structures, the circumference of the first and/or second parts 61, 62 is approximate $\lambda/2$, where λ is the resonance wavelength for the antenna 37. The first segment 65 short circuits the first part 61 and the second part 62 thereby creating a current bridge along the first segment 65. It is seen that the current bridge forms an elongated structure, and is positioned so that the elongated structure has a direction substantially orthogonal to the surface of the head, that is substantially parallel to an ear-to-ear axis of a user when the hearing aid is positioned in its operational position behind the ear of a user.

[0065] Fig. 7 shows a further shape of the antenna 37, wherein the first part 40 and the second part 41 has a meander form of the antenna.

[0066] It is envisaged that even though the first segment in Figs. 3-7 is shown as being orthogonal to the surface of the head, also other configurations may be applied, so that the first segments form a non-perpendicular angle with the surface of the head, such as an angle of between 90° and 45° , such as between 90° and 80° . Hereby, the current will show at least a current component in the direction being orthogonal to the surface of the head. Furthermore, even though the first part 40, 61 and the second part 41, 62 are shown to be identical in Figs. 3-7, it is envisaged that the shapes of the first part 40, 61 and the second parts 41, 62 may differ.

[0067] In Figs. 8a-e, schematic antennas 80 are shown, illustrating the feed points 83, 84 and the length of the first and second parts 40, 41, 61, 62 and the distances δ between the feed points 83, 84 and the short circuit.

[0068] In Fig. 8a, an antenna 80 is shown. The antenna has a first part 85 and a second part 86 and a transceiver 82 located between the first side and the second side. First transmission line 87 feeds the first part 85 in a feed point 83 and second transmission line 88 feeds the second part 86 in a feed point 84. The first segment 89 extends from the first part 85 to the second part 86 and short circuits the first and second parts 85, 86. In that the antenna is balanced, the current in the short circuit will be maximized. The distance δ along the first part 85 between the first feed point 83 and the short circuit 89 is tailored to the desired impedance for the antenna, and the length l of the first part 85 is measured from the short circuit 89 to the free end of the antenna 90 and is $\lambda/4$

in order for the first part to form a resonant antenna structure. Likewise the distance δ along the second part 86 between the second feed point 84 and the short circuit 89 is tailored to the desired impedance for the antenna, and the length l of the second part 86 is measured from the short circuit 89 to the free end of the antenna 91 and is $\lambda/4$ in order for the second part to form a first resonant structure. The first resonant structure 85 is actively fed in the feed point 83 and second resonant structure 86 is actively fed in the feed point 84.

[0069] Fig. 8b shows another embodiment, in which the first and second parts 85, 86 extends a length of $\lambda/4$ on both sides of the short circuit.

[0070] Fig. 8c shows a further embodiment, in which the antenna 80 extends around the sides of the hearing aid. The length of the sides is larger than $\lambda/4$.

[0071] Fig. 8d shows a further embodiment in which the short circuit 89 is provided on another side of the transceiver 82. Thus, the length of the first part 85 is measured from the short circuit 89 to the free end 90, and is $\lambda/4$ to form a first resonant structure. Likewise, the length of the second part 86 is measured from the short circuit 89 to the free end 90, and is $\lambda/4$ to form a second resonant structure. The antenna 80 may extend beyond the feed points 83, 84, however, the length of this extension is typically minimized.

[0072] Fig. 8e shows an embodiment having a closed antenna structure 80 having a first part 95 and a second part 96. The length of the first and second closed part is $\lambda/2$ to obtain a resonant structure. The widths of the first part 95 and the second part 96 may be tailored according to a desired antenna impedance.

[0073] Figs. 9a-b show how the length of the antenna may be measured along the current path in the first and second parts. In Fig. 9a, the first part is a wide antenna structure, and the length along a top part is $\lambda/8$ and the length along a side part is $\lambda/8$, thus having a total length along the current path of $\lambda/4$.

[0074] Fig. 9b shows an example of thinner first and second parts, wherein the length of the first part along the current path is $\lambda/4$.

[0075] Figs. 10a-d shows the current along an antenna 40, 80. The current is seen to be zero at the free ends 90 of the antenna. It is furthermore seen that the maximum current is found along the first segment or the conducting segment 42, 89. As seen in Fig. 10a, showing a wide BTE hearing aid, that is a relatively long current bridge or first segment, the current exhibits two local maxima at each side of the short circuit with a slight decrease towards the middle. If the BTE hearing aid is a narrow hearing aid, the current may as shown in Fig. 10c, be substantially constantly high across the short circuit or the first segment. Thus, as is seen from Figs. 10b and 10d, the current is maximized in a direction being substantially orthogonal to the side of the head.

The first segment, or the conducting segment may have a length being between at least one sixteenth wavelength and a full wavelength of the electromagnetic

field.

Figs. 11a-d show different embodiments of a partition plane 110 partitioning the antenna 80. The antenna 80 is seen to intersect the partition plane 110 at an intersection 111, thus, the antenna may intersect at least at a point 111, or along an axis of the antenna extending through the plane 110. The distances d_1 , d_2 from the feed points 83, 84, to the intersection 111, respectively may be measured along the current path as shown in Figs. 11a and 11c, or the distances d_1 and d_2 may be measured along the shortest distance from the feed points 83, 84, to the intersection 111.

The partition plane 110 may be a symmetry plane 110 for the antenna so that the first part 85 of the antenna is symmetric with the second part 86 of the antenna with respect to the symmetry plane 110. The partition plane 110 may extend exactly mid through the hearing aid, or the partition plane may extend anywhere between a first side of the hearing aid and a second side of the hearing aid. In one or more embodiments, the partition plane extends through the receiver.

Claims

1. A behind the ear hearing aid (30) comprising
 - a microphone for reception of sound and conversion of the received sound into a corresponding first audio signal,
 - a signal processor (32) for processing the first audio signal into a second audio signal compensating a hearing loss of a user of the hearing aid,
 - a receiver that is connected to an output of the signal processor for converting the second audio signal into an output sound signal,
 - a transceiver (34) for wireless data communication interconnected with an antenna (37) for emission and reception of an electromagnetic field, the antenna extending on a first side (38) of the hearing aid and a second side (39) of the hearing aid,
 - a first segment of the antenna (42) extending from the first side of the hearing aid to the second side of the hearing aid,
 - a feed system (35, 36, 43, 44) for exciting the antenna to thereby induce a current in at least the first segment, **characterized in that** the feed system is configured such that the current induced in the first segment has a first local maxima at the first side of the hearing aid and a second local maxima at the second side of the hearing aid.
2. A hearing aid according to claim 1, wherein the antenna is a balanced antenna.
3. A hearing aid according to any of the previous claims, wherein a part of the antenna extending along the first side of the hearing aid is substantially identical

to a part of the antenna extending along the second side of the hearing aid.

4. A hearing aid according to any of the previous claims, wherein the feed system comprises a first feed point for exciting at least the antenna extending along the first side of the hearing aid and a second feed point for exciting at least the antenna extending along the second side of the hearing aid.
5. A hearing aid according to any of the previous claims, wherein the first segment has a direction substantially orthogonal to the surface of the head of a user when the hearing aid is worn in its operational position by a user.
6. A hearing aid according to any of the previous claims, wherein the first segment short circuits the part of the antenna extending along the first side of the hearing aid and the part of the antenna extending along the second side of the hearing aid to provide a current bridge between the first side of the hearing aid and the second side of the hearing aid.
7. A hearing aid according to any of the previous claims, wherein the part of the antenna extending along the first side of the hearing aid and/or the part of the antenna extending along the second side of the hearing aid has the shape of a monopole antenna structure.
8. A hearing aid according to any of claims 6-7, wherein a length of the part of the antenna extending along the first side of the hearing aid and/or a length of the part of the antenna extending along the second side of the hearing aid as measured from the short circuit to a free end is substantially $\lambda/4$.
9. A hearing aid according to any of claims 1-6, wherein the part of the antenna extending along the first side of the hearing aid and/or the part of the antenna extending along the second side of the hearing aid has a circumference of $\lambda/2$.
10. A hearing aid according to any of claims 1-6, wherein the antenna is a strip shaped closed antenna structure, such as an annulus shaped antenna structure, having a circumference of $\lambda/2$.
11. A hearing aid according to any of the previous claims, wherein the part of the antenna extending along the first side of the hearing aid is a first resonant structure and/or wherein the part of the antenna extending along the second side of the hearing aid is a second resonant structure.
12. A hearing aid according to any of claims 4-11, wherein the hearing aid has a plane of partition extending

between the first side of the hearing aid and the second side of the hearing aid, and wherein at least a part of the antenna intersects the partition plane, and wherein a relative difference between a distance from the first feed point to the intersection and a distance from the second feed point to the intersection is less than or equal a first threshold.

13. A hearing aid according to claim 12, wherein the partition plane is a symmetry plane for the first and second antenna structures.
14. A hearing aid according to any of claims 11-13, wherein the threshold is less than 25 %, such as 0.
15. A hearing aid according to any of claims 4-14, wherein a distance between the first feed point and the short circuit, and a distance between the second feed point and the short circuit, respectively, are tailored according to a desired antenna impedance.

Patentansprüche

1. Hinter-dem-Ohr-Hörgerät (30), umfassend

- ein Mikrofon zum Empfang eines Schalls und Umwandlung des empfangenen Schalls in ein entsprechendes erstes Audiosignal,
- einen Signalprozessor (32) zur Verarbeitung des ersten Audiosignals in ein zweites Audiosignal, das einen Hörverlust eines Benutzers des Hörgeräts kompensiert,

einen Empfänger, der mit einem Ausgang des Signalprozessors verbunden ist, um das zweite Audiosignal in ein Ausgangsschallsignal umzuwandeln, einen Sender/Empfänger (34) zur drahtlosen Datenkommunikation, verkoppelt mit einer Antenne (37) zum Aussenden und Empfang eines elektromagnetischen Feldes, wobei sich die Antenne auf einer ersten Seite (38) des Hörgeräts und einer zweiten Seite (39) des Hörgeräts erstreckt, ein erstes Segment der sich von der ersten Seite des Hörgeräts zur zweiten Seite des Hörgeräts erstreckenden Antenne (42), ein Speisesystem (35, 36, 43, 44) zum Erregen der Antenne, um dadurch in dem zumindest ersten Segment einen Strom zu induzieren, **dadurch gekennzeichnet, dass** das Speisesystem so ausgelegt ist, dass der im ersten Segment induzierte Strom an der ersten Seite des Hörgeräts ein erstes lokales Maximum und an der zweiten Seite des Hörgeräts ein zweites lokales Maximum aufweist.

2. Hörgerät nach Anspruch 1, wobei die Antenne eine ausgeglichene Antenne ist.

3. Hörgerät nach einem der vorgehenden Ansprüche, wobei ein Teil der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne einem Teil der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne im Wesentlichen identisch ist.

4. Hörgerät nach einem der vorgehenden Ansprüche, wobei das Speisesystem einen ersten Speisepunkt zum Erregen wenigstens der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne und einen zweiten Speisepunkt zum Erregen wenigstens der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne umfasst.

5. Hörgerät nach einem der vorgehenden Ansprüche, wobei das erste Segment eine zur Oberfläche des Kopfes eines Benutzers im Wesentlichen orthogonale Richtung aufweist, wenn das Hörgerät in seiner Betriebsstellung von einem Benutzer getragen wird.

6. Hörgerät nach einem der vorgehenden Ansprüche, wobei das erste Segment den Teil der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne und den Teil der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne kurzschließt, um eine Strombrücke zwischen der ersten Seite des Hörgeräts und der zweiten Seite des Hörgeräts bereitzustellen.

7. Hörgerät nach einem der vorgehenden Ansprüche, wobei der Teil der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne und/oder der Teil der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne die Form einer Monopolantennenstruktur aufweist.

8. Hörgerät nach einem der Ansprüche 6 bis 7, wobei eine Länge des Teils der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne und/oder eine Länge des Teils der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne, wie gemessen von dem Kurzschluss zu einem freien Ende, im Wesentlichen $\lambda/4$ ist.

9. Hörgerät nach einem der Ansprüche 1 bis 6, wobei der Teil der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne und/oder der Teil der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne einen Umfang von $\lambda/2$ aufweist.

10. Hörgerät nach einem der Ansprüche 1 bis 6, wobei die Antenne eine streifenförmige geschlossene Antennenstruktur, wie etwa eine ringförmige Antennenstruktur, ist, die einen Umfang von $\lambda/2$ aufweist.

11. Hörgerät nach einem der vorgehenden Ansprüche,

wobei der Teil der sich entlang der ersten Seite des Hörgeräts erstreckenden Antenne eine erste Resonanzstruktur ist, und/oder wobei der Teil der sich entlang der zweiten Seite des Hörgeräts erstreckenden Antenne eine zweite Resonanzstruktur ist.

12. Hörgerät nach einem der Ansprüche 4 bis 11, wobei das Hörgerät eine sich zwischen der ersten Seite des Hörgeräts und der zweiten Seite des Hörgeräts erstreckende Trennebene aufweist, und wobei zumindest ein Teil der Antenne die Trennebene schneidet, und wobei ein relativer Unterschied zwischen einem Abstand vom ersten Speisepunkt zur Schnittstelle und einem Abstand vom zweiten Speisepunkt zur Schnittstelle weniger als oder gleich einem ersten Schwellenwert ist.
13. Hörgerät nach Anspruch 12, wobei die Trennebene eine Symmetrieebene für die erste und zweite Antennenstruktur ist.
14. Hörgerät nach einem der Ansprüche 11 bis 13, wobei der Schwellenwert weniger als 25 %, wie etwa 0, beträgt.
15. Hörgerät nach einem der Ansprüche 4 bis 14, wobei ein Abstand zwischen dem ersten Speisepunkt bzw. dem Kurzschluss und ein Abstand zwischen dem zweiten Speisepunkt bzw. dem Kurzschluss auf eine gewünschte Antennenimpedanz zugeschnitten sind.

Revendications

1. Prothèse auditive en arrière de l'oreille (30), comprenant
un microphone pour la réception du son et la conversion du son reçu en un premier signal audio correspondant,
un processeur de signal (32) pour traiter le premier signal audio en un deuxième signal audio en compensation d'une perte auditive d'un utilisateur de la prothèse auditive,
un récepteur qui est relié à une sortie du processeur de signal pour convertir le deuxième signal audio en un signal sonore de sortie,
un émetteur-récepteur (34) pour une communication de données sans fil inter-connectée avec une antenne (37) pour émettre et recevoir un champ électromagnétique, l'antenne s'étendant sur un premier côté (38) de la prothèse auditive et un deuxième côté (39) de la prothèse auditive,
un premier segment de l'antenne (42) s'étendant depuis le premier côté de la prothèse auditive jusqu'au deuxième côté de la prothèse auditive,
un système d'alimentation (35, 36, 43, 44) pour exciter l'antenne de manière à induire un courant dans

au moins le premier segment,

caractérisée en ce que le système d'alimentation est configuré si bien que le courant induit dans le premier segment présente un premier maximum local au premier côté de la prothèse auditive et un deuxième maximum local au deuxième côté de la prothèse auditive.

2. Prothèse auditive selon la revendication 1, dans laquelle l'antenne est une antenne équilibrée.
3. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle une partie de l'antenne s'étendant le long du premier côté de la prothèse auditive est essentiellement identique à une partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive.
4. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle le système d'alimentation comprend un premier point d'alimentation pour exciter au moins l'antenne s'étendant le long du premier côté de la prothèse auditive et un deuxième point d'alimentation pour exciter au moins l'antenne s'étendant le long du deuxième côté de la prothèse auditive.
5. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle le premier segment présente une direction essentiellement orthogonale à la surface de la tête d'un utilisateur lorsque la prothèse auditive est portée dans sa position opérationnelle par un utilisateur.
6. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle le premier segment court-circuite la partie de l'antenne s'étendant le long du premier côté de la prothèse auditive et la partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive pour fournir un pont de courant entre le premier côté de la prothèse auditive et le deuxième côté de la prothèse auditive.
7. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle la partie de l'antenne s'étendant le long du premier côté de la prothèse auditive et / ou la partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive présente la forme d'une structure monopôle d'antenne.
8. Prothèse auditive selon l'une quelconque des revendications 6 à 7, dans laquelle une longueur de la partie de l'antenne s'étendant le long du premier côté de la prothèse auditive et / ou une longueur de la partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive telle que mesurée à partir du court-circuit jusqu'à une extrémité libre est es-

sentiellement $\lambda/4$.

9. Prothèse auditive selon l'une quelconque des revendications 1 à 6, dans laquelle la partie de l'antenne s'étendant le long du premier côté de la prothèse auditive et / ou la partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive présente une circonférence de $\lambda/2$. 5

10. Prothèse auditive selon l'une quelconque des revendications 1 à 6, dans laquelle l'antenne est une structure d'antenne fermée en forme de bande, telle qu'une structure d'antenne en forme d'annulaire, ayant une circonférence de $\lambda/2$. 10
15

11. Prothèse auditive selon l'une quelconque des revendications précédentes, dans laquelle la partie de l'antenne s'étendant le long du premier côté de la prothèse auditive est une première structure résonnante, et / ou la partie de l'antenne s'étendant le long du deuxième côté de la prothèse auditive est une deuxième structure résonnante. 20

12. Prothèse auditive selon l'une quelconque des revendications 4 à 11, dans laquelle la prothèse auditive comporte un plan de séparation s'étendant entre le premier côté de la prothèse auditive et le deuxième côté de la prothèse auditive, et dans laquelle au moins une partie de l'antenne coupe le plan de partition, et dans laquelle une différence relative entre une distance allant du premier point d'alimentation à l'intersection et une distance allant du deuxième point d'alimentation à l'intersection est inférieure ou égale à un premier seuil. 25
30
35

13. Prothèse auditive selon la revendication 12, dans laquelle le plan de partition est un plan de symétrie pour les première et deuxième structures d'antenne.

14. Prothèse auditive selon l'une quelconque des revendications 11 à 13, dans laquelle le seuil est inférieur à 25 %, tel que 0. 40

15. Prothèse auditive selon l'une quelconque des revendications 4 à 14, dans laquelle respectivement une distance entre le premier point d'alimentation et le court-circuit, et une distance entre le deuxième point d'alimentation et le court-circuit sont adaptées en fonction d'une impédance d'antenne souhaitée. 45
50
55

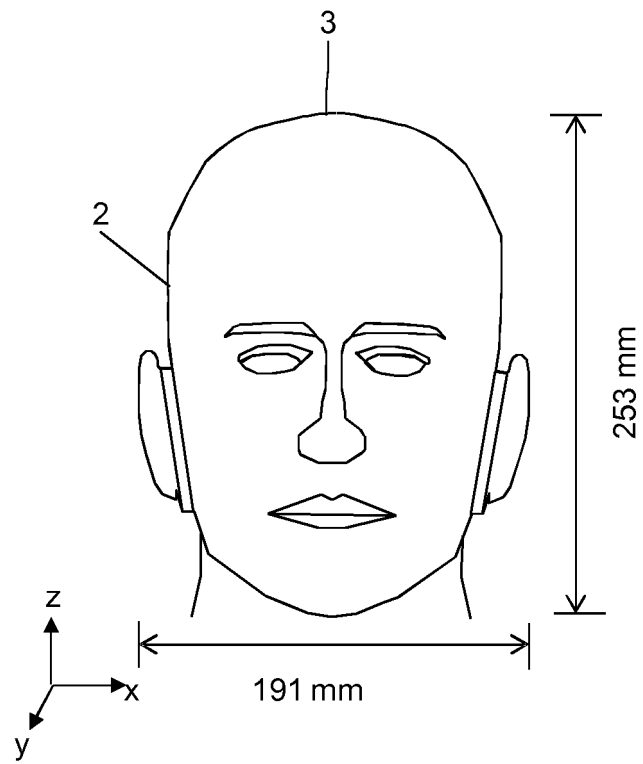


Fig. 1

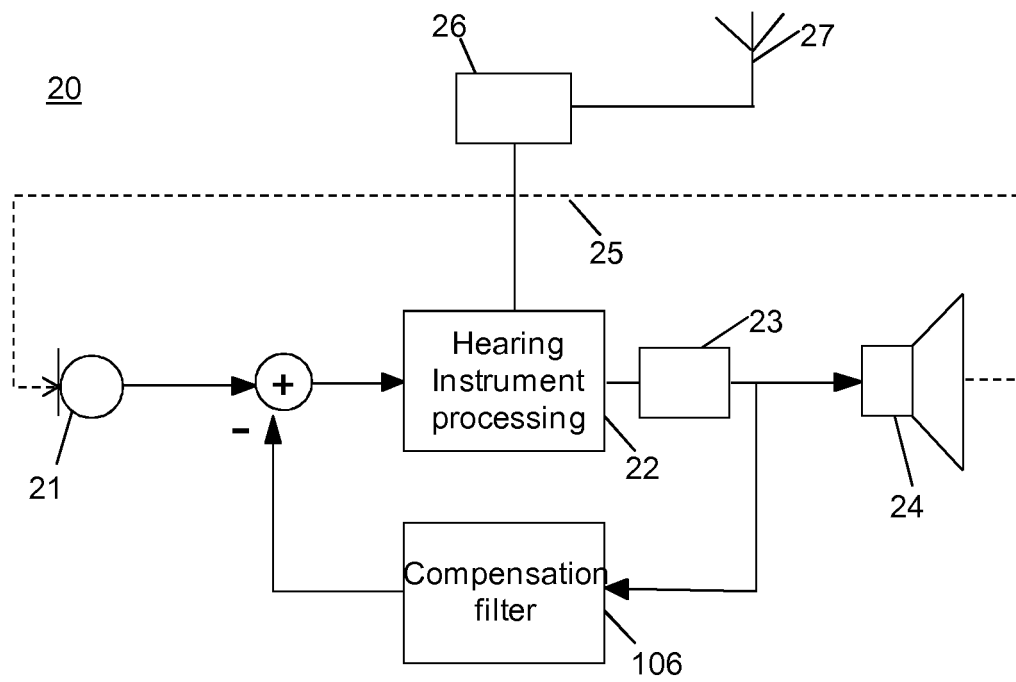


Fig. 2

30

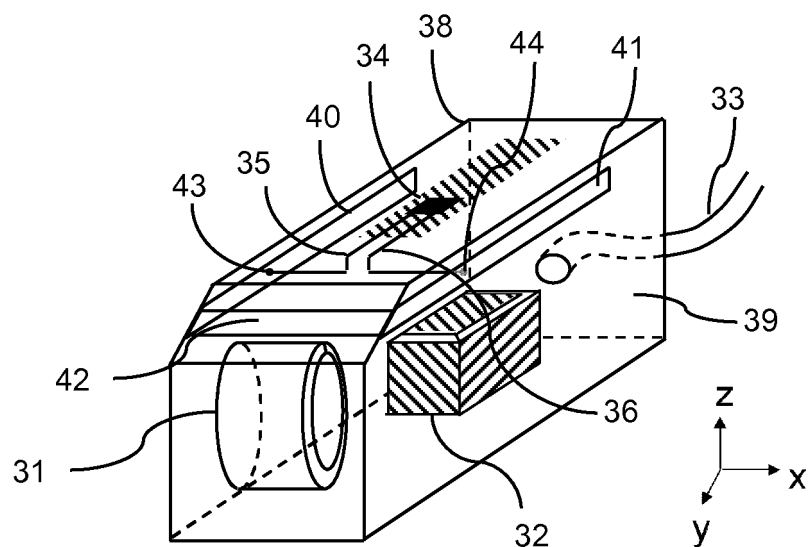


Fig. 3

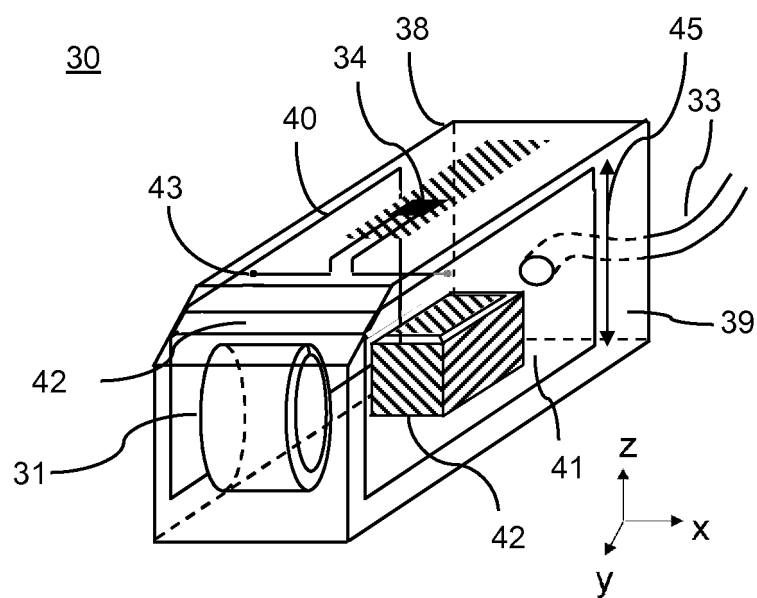


Fig. 4

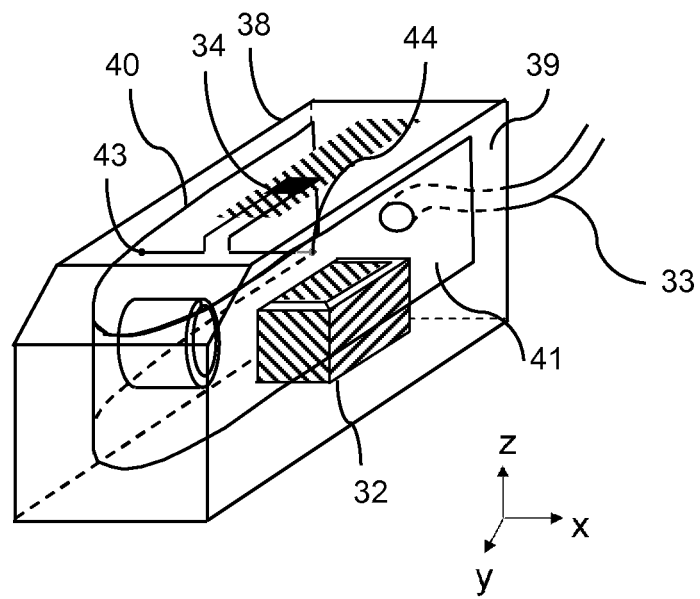


Fig. 5

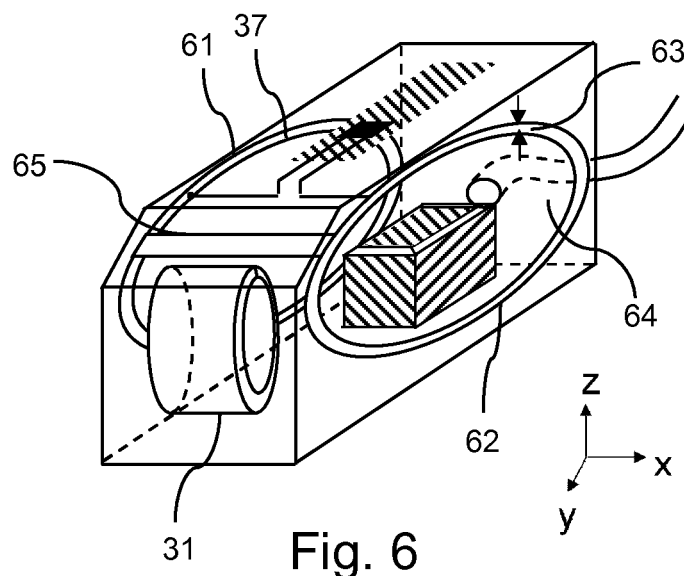


Fig. 6

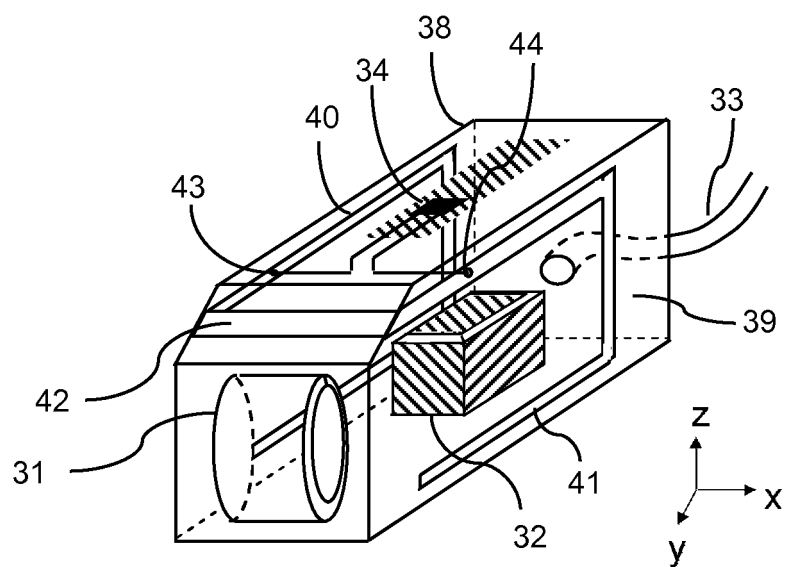


Fig. 7

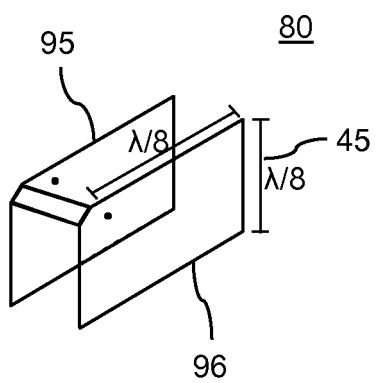


Fig. 9a

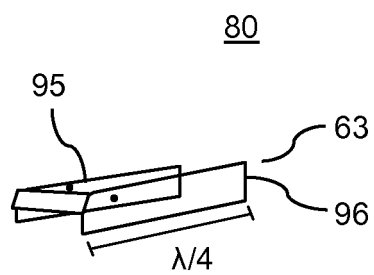
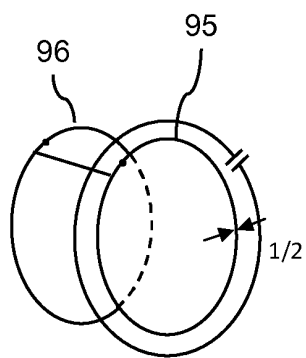
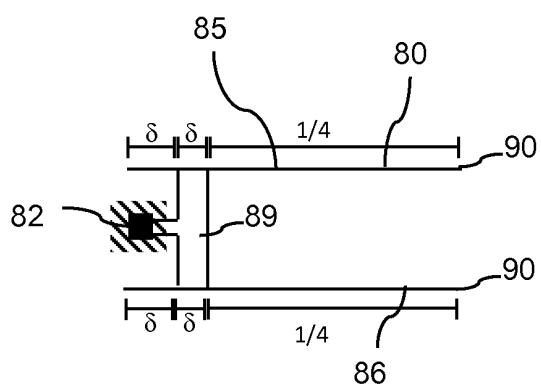
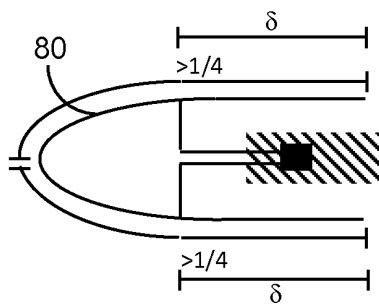
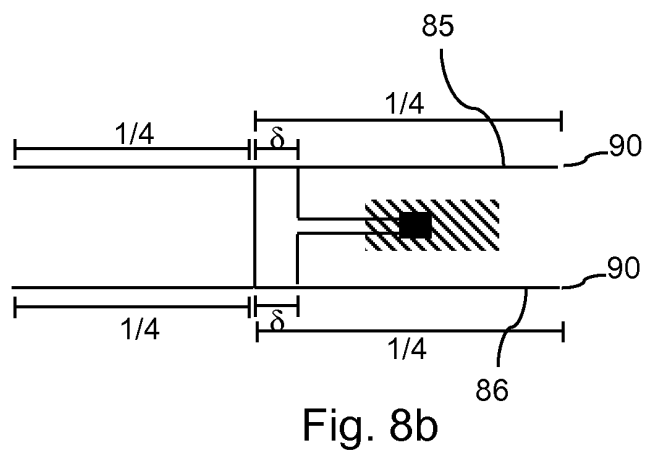
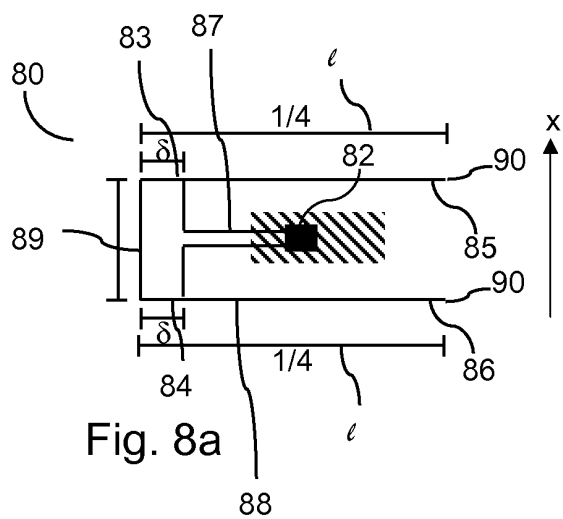


Fig. 9b



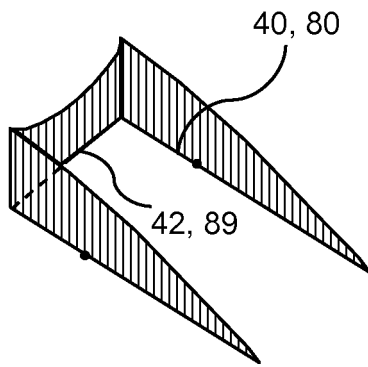


Fig. 10a

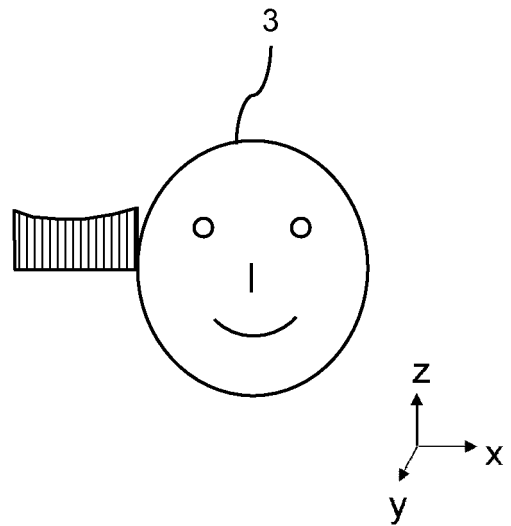


Fig. 10b

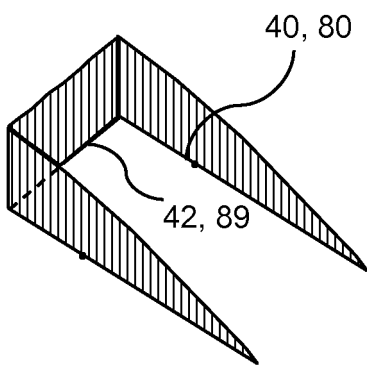


Fig. 10c

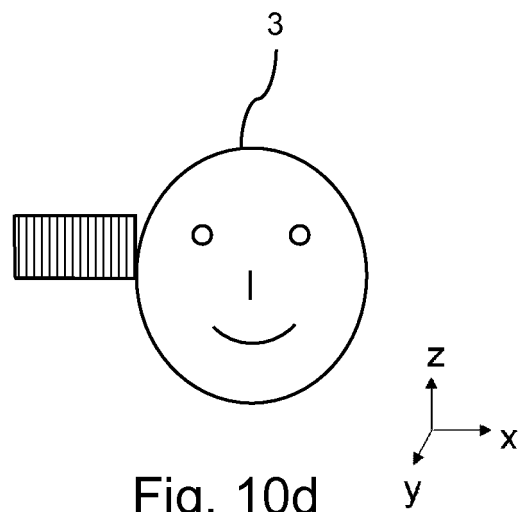


Fig. 10d

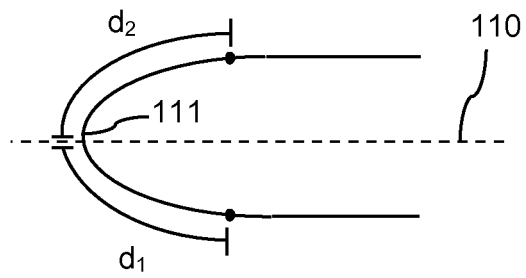


Fig. 11a

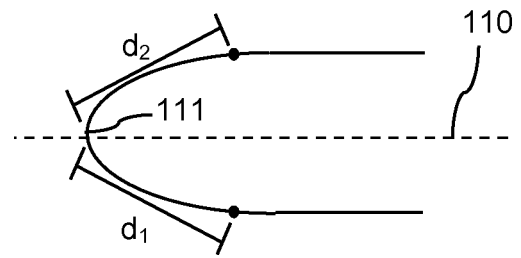


Fig. 11b

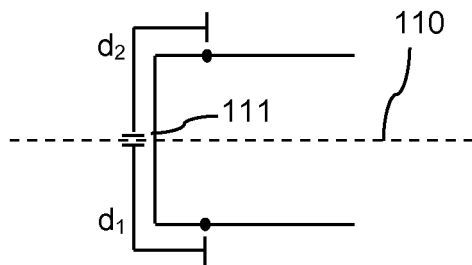


Fig. 11c

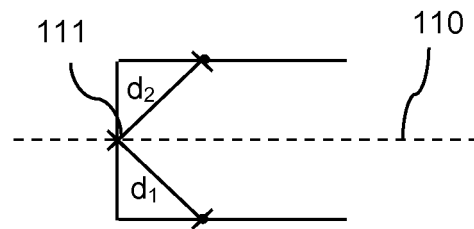


Fig. 11d

REFERENCES CITED IN THE DESCRIPTION

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