

METHOD AND APPARATUS FOR STIMULATING A HAIR CELL USING AN ACOUSTIC SIGNAL

BACKGROUND OF THE INVENTION

[0001] Example embodiment of the present invention relates to a method and an apparatus for stimulating a hair cell using an acoustic signal. More particularly, the present invention relates to a method and an apparatus for diagnosing accurately hearing ability of a user and improving the hearing ability through the diagnosed result.

[0002] Every organ for delivering sound to a brain is referred to as a hearing organ.

[0003] The hearing organ is divided into an outer ear, a middle ear and an inner ear. Sound inputted from an outside through the outer ear is vibrated by a tympanic membrane, and then the vibrated sound is delivered to a cochlea of the inner ear via the middle ear.

[0004] Auditory hair cells are disposed on a basement membrane of the cochlea. Here, the number of the hair cells disposed on the basement membrane equals to approximately 12,000.

[0005] The basement membrane has length of approximately 2.5 to 3cm. The hair cell located on an initial part of the basement membrane senses sound having high frequency, and the hair cell located on an end of the basement membrane senses sound having low frequency. This is referred to as frequency specificity of the hair cell. Generally, resolution of the frequency specificity corresponding to ideal stimulation intensity equals to approximately 0.2mm (0.5 semitone) on the basement membrane.

[0006] In recently, since use of a portable acoustic device has been increased and

people are exposed to various noises, many people have neural hearing loss disease.

[0007] The neural hearing loss is a hearing ability degeneration phenomenon caused by damage of the hair cell, and is generated by aging, noise exposure, adverse drug reaction, and genetic cause, etc.

[0008] The neural hearing loss is divided into mild hearing loss, moderate hearing loss, severe hearing loss and profound hearing loss. Generally, it is difficult to have a normal talk in the moderate hearing loss, the severe hearing loss and the profound hearing loss.

[0009] Now, it is estimated that about ten percent of total world population has the mild hearing loss in which people feel degeneration of his hearing ability. In addition, it is estimated that approximately 260,000,000 people or more have the moderate hearing loss, the severe hearing loss or the profound hearing loss in only developing countries.

[0010] However, a method of curing the hearing loss disease is not existed, but only a hearing aid is provided as a hearing aid device related to the hearing loss.

[0011] The hearing aid amplifies outside sound so that the sound is highly heard, and thus the hearing aid may not prevent degeneration of the hearing ability. Specially, a problem exists in that the hearing ability of a user using the hearing aid is more degenerated due to the amplified sound.

[0012] Accordingly, a method of curing radically the hearing loss disease without using the hearing aid has been required.

[0013] On the other hand, a pure hearing test method as a method of diagnosing the hearing loss is widely used as international standard hearing ability test method, wherein the pure hearing test method uses the frequency specificity of the hair cell.

[0014] The common pure hearing test method divides uniformly the basement

membrane into six parts through one octave interval resolution, and observes the frequency specificity of the hair cells located on each of the six parts through six frequency (for example 250, 500, 1000, 2000, 4000 and 8000Hz) signals.

[0015] In case that normal frequency specificity is observed because the hair cell is not damaged, reaction corresponding to the frequency specificity of the hair cell may be induced in response to stimulation intensity having small sound pressure.

[0016] For example, in case that the frequency specificity of the hair cell corresponding to 1000Hz is normal, electrical reaction about pure stimulation may be induced in the hair cell, wherein the pure stimulation is provided under the condition of 1000Hz and -1.4dBSPL (sound pressure level).

[0017] In conventional technique, to diagnose hearing ability, a skilled examiner provides audio signals corresponding to the parts divided with one octave resolution to an examined person using a complex examining device. In this case, the examined person hears the audio signals corresponding to each of the parts, and then pushes a response button in accordance with the hearing result. Hence, it is difficult to diagnose accurately the hearing ability because the resolution is low. Additionally, it is inconvenient to diagnose the hearing ability.

SUMMARY OF THE INVENTION

[0018] Accordingly, the present invention is provided to substantially obviate one or more problems due to limitations and disadvantages of the related art.

[0019] It is a feature of the present invention to provide a method and an apparatus for stimulating a hair cell using an acoustic signal so as to improve hearing loss disease.

[0020] It is another feature of the present invention to provide a method and an

apparatus for stimulating a hair cell using an acoustic signal for diagnosing more accurately hearing ability of a user.

It is still another feature of the present invention to provide a method and an apparatus for stimulating a hair cell using an acoustic signal for diagnosing accurately hearing ability of a user at a remote place and providing a service for improving hearing loss disease.

A recording media readable by a digital processor and having a program of commands executed by the digital processor for the purpose of stimulating hair cell using acoustic stimulation, the recording media performing: (a) discriminating a frequency band corresponding to damaged hair cell region in accordance with preset algorithm; (b) determining the frequency band corresponding to the damaged hair cell region as a target frequency band; and (c) outputting an acoustic signal having given intensity to the target frequency band so as to stimulate the damaged hair cell region.

A recording media readable by a digital processor and having a program of commands executed by the digital processor for the purpose of stimulating hair cell using acoustic stimulation, the recording media performing: outputting cochlear interface including hair cell region images divided with $1/k$ octave resolution, wherein the k is positive integer of above 2; outputting an acoustic signal of a frequency band corresponding to at least one region selected from the above hair cell region images; and detecting damaged hair cell region on the basis of the user's response on the outputted acoustic signal.

[0021] A method of providing a hair cell stimulating service in a server connected electrically to a client through a network according to one example embodiment of the present invention includes (a) transmitting application for diagnosis of hearing ability to the client, wherein the application outputs cochlear interface having hair cell region

images divided with $1/k$ octave resolution; (b) receiving response information of a user in accordance with an audio signal of a frequency band corresponding to at least one of the hair cell region images; (c) determining a frequency band corresponding to damaged hair cell region as a target frequency band using the response information; and (d) transmitting an acoustic signal of the target frequency band having given intensity to the client.

[0022] An apparatus of stimulating a hair cell using acoustic stimulation according to one example embodiment of the present invention includes a hearing ability diagnosing section configured to measure hearing ability threshold about a hair cell region by using response information of a user in accordance with specific audio signal; a stimulation part detecting section configured to determine a frequency band corresponding to damaged hair cell region as a target frequency band using the measured hearing ability threshold; and a stimulation curing section configured to output an acoustic signal having preset intensity to the determined target frequency band.

[0023] As described above, in a method and an apparatus of stimulating a hair cell of the present invention, a user may diagnose easily and accurately hearing ability through cochlear interface.

[0024] In a method and an apparatus of stimulating a hair cell of the present invention, a user may verify visually acoustic signal stimulation and improving rate of hearing ability.

[0025] A method and an apparatus of stimulating a hair cell of the present invention may improve fundamentally hearing ability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Example embodiments of the present invention will become more apparent by describing in detail example embodiments of the present invention with reference to the accompanying drawings, in which:

[0027] FIG. 1 is a block diagram illustrating an apparatus for stimulating a hair cell according to one example embodiment of the present invention;

[0028] FIG. 2 is a block diagram illustrating an apparatus for stimulating a hair cell according to one example embodiment of the present invention;

[0029] FIG. 3 is a view illustrating cochlear interface according to one example embodiment of the present invention;

[0030] FIG. 4 is a flow chart illustrating a process of diagnosing the hearing ability according to one example embodiment of the present invention;

[0031] FIG. 5 is a flow chart illustrating a process of stimulating the hair cell according to one example embodiment of the present invention;

[0032] FIG. 6 is a view illustrating a hearing ability improving service system according to one example embodiment of the present invention;

[0033] FIG. 7 is a view illustrating a graph indicating pure hearing examination result of one examined person;

[0034] FIG. 8 is a view illustrating the target frequency band determined for the examined person in FIG. 7;

[0035] FIG. 9 is a view illustrating schedule for acoustic signal stimulation;

[0036] FIG. 10 is a view illustrating a table in which hearing ability result measured before providing acoustic signal stimulation to a right ear is compared with that measured after the acoustic signal stimulation is provided to the right ear for ten days;

[0037] FIG. 11 is a view illustrating a table in which hearing ability result measured after acoustic signal stimulation is provided to the right ear for ten days is compared with that measured after the acoustic signal stimulation is provided to the right ear for fifteen days;

[0038] FIG. 12 is a view illustrating a graph showing hearing ability threshold of the right ear before and after the acoustic signal stimulation is provided;

[0039] FIG. 13 is a view illustrating schedule for verifying whether or not improving of the hearing ability is continuously maintained after the acoustic signal stimulation about the right ear is stopped;

[0040] FIG. 14 is a view illustrating a table showing measurement result of the hearing ability about the right ear after the acoustic signal stimulation is stopped; and

[0041] FIG. 15 is a view illustrating a graph corresponding to the table in FIG. 14.

DESCRIPTION OF SPECIFIC EMBODIMENTS

[0042] Example embodiments of the present invention are disclosed herein. However, specific structural and functional details disclosed herein are merely representative for purposes of describing example embodiments of the present invention, however, example embodiments of the present invention may be embodied in many alternate forms and should not be construed as limited to example embodiments of the present invention set forth herein.

[0043] Accordingly, while the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the invention to the particular forms disclosed, but on the

contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention. Like numbers refer to like elements throughout the description of the figures.

[0044] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the present invention. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0045] It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (i.e., "between" versus "directly between", "adjacent" versus "directly adjacent", etc.).

[0046] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "includes" and/or "including", when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0047] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0048] FIG. 1 is a block diagram illustrating an apparatus for stimulating a hair cell according to one example embodiment of the present invention.

[0049] In FIG. 1, the apparatus for stimulating the hair cell of the present embodiment includes a hearing ability diagnosing section 100, a stimulation part detecting section 102 and a stimulation curing section 104.

[0050] The hearing ability diagnosing section 100 provides an audio signal corresponding to specific frequency band to a user, and measures hearing ability of the user about the frequency band through response of the user in accordance with the provided audio signal. Here, the hearing ability may be measured through a pure tone audiometry PTA, an otoacoustic emission OAE and an evoked response audiometry ERA, etc.

[0051] In one example embodiment of the present invention, the hearing ability diagnosing section 100 provides the audio signal of the frequency band divided with resolution smaller than one octave resolution in a related art to the user, and detects location of a damaged hair cell and a damaged rate of the hair cell in accordance with the provided audio signal.

[0052] Preferably, the hearing ability diagnosing section 100 provides the audio signal of the frequency band having $1/k$ (is positive integer of above 2) octave resolution,

more preferably $1/3$ to $1/24$ octave resolution to the user as an examined person, and diagnoses hearing ability of the user in accordance with the provided audio signal. Here, in one example embodiment of the present invention, the audio signal provided to the user corresponds to a medium frequency in a range of 250Hz to 12000Hz, i.e. a medium frequency. In case of dividing the medium frequency range with maximum $1/24$ octave resolution, whole hair cell region of the user may be divided into 134 frequency bands (frequency band regions).

[0053] In case of examining the hearing ability, the audio signal of specific frequency band selected from 134 frequency bands is provided to the user, and the user inputs response information in response to the provided audio signal of which volume is adjusted.

[0054] The response information in accordance with the volume adjustment is stored as hearing ability threshold corresponding to the audio signal of the selected frequency band. Here, the hearing ability threshold means a hearing ability threshold of the hair cell region having frequency specificity about the selected frequency band.

[0055] The simulation part detecting section 102 detects a simulation part using the hearing ability threshold about the audio signal of each of the frequency bands. Here, the detection of the simulation part indicates detection of the hair cell region to which acoustic signal stimulation is to be provided. Particularly, the detection of the simulation part determines the frequency band corresponding to a damaged hair cell region.

[0056] The simulation curing section 104 outputs the acoustic signal having preset intensity to the frequency band of the damaged hair cell region in accordance with the detection of the stimulation part detecting section 102. Here, the acoustic signal may be provided with intensity (decibel) higher by predetermined level than the hearing

ability threshold of pre-stored corresponding frequency band.

[0057] In one example embodiment of the present invention, the acoustic signal corresponds to at least one of amplitude modulated tone, frequency modulated tone, pulse tone and amplitude modulated narrowband noise, or combination of the tones and the noise.

[0058] Furthermore, in case that a plurality of hair cell regions are damaged, the acoustic signal may be provided to the damaged hair cell regions in an order of damage rate, be provided randomly to the damaged hair cell regions, or be provided simultaneously to the damaged hair cell regions.

[0059] In case that the acoustic signal is provided to the damaged hair cell regions of the user with various intensities, kinds or orders, the hearing ability of the user may be improved.

[0060] Hereinafter, the apparatus of stimulating the hair cell of the present embodiment will be described in detail with reference to accompanying drawing FIG. 2.

[0061] FIG. 2 is a block diagram illustrating a hair cell stimulating apparatus according to one example embodiment of the present invention.

[0062] In FIG. 2, the hearing ability diagnosing section 100 of the present embodiment includes an UI outputting section 200 and a response information storing section 202.

[0063] In one example embodiment of the present invention, the UI outputting section 200 displays cochlear interface shown in FIG. 3 on a displaying section 232 so that the examined person not a skilled expert can diagnose his hearing ability by himself.

[0064] As shown in FIG. 3, the cochlear interface of the present embodiment has an image 300 corresponding to the hair cell regions divided with high resolution. Here, since whole frequency range for diagnosing the hearing ability corresponds to the medium frequency, i.e. 250Hz to 12000Hz, the cochlear interface may have 134 hair cell

region images 300 in case of dividing the medium frequency range with 1/24 octave resolution.

[0065] In case that the user selects one of the hair cell region images 300 in order to measure the hearing ability, an audio signal of a frequency band matched with the selected hair cell region image is outputted. Here, the frequency band matched with the hair cell region image means a frequency band having frequency specificity corresponding to the hair cell region related to the image. In addition, the hair cell region image 300 may be selected by using a key button, a mouse or a touch screen method, etc.

[0066] In case that the audio signal is outputted, the user may adjust intensity of the audio signal through volume control 302, and inputs response information about an intensity point at which the audio signal is not heard.

[0067] The response information storing section 202 receives the response information corresponding to each of the audio signals from a user inputting section 220, and stores the received response information. Here, the user inputting section 220 may be a keypad, a mouse or a touch screen. In one example embodiment of the present invention, the response information may be stored as the hearing ability threshold of the frequency band related to corresponding audio signal as mentioned above.

[0068] The hearing ability about the hair cell regions may be measured through the above method.

[0069] In FIG. 2, the stimulation part detecting section 102 includes a hearing ability threshold comparing section 204 and a target frequency band determining section 206.

[0070] The hearing ability threshold comparing section 204 compares the hearing ability threshold of the user stored in the response information storing section 202 with a reference hearing ability threshold.

[0071] The hearing ability threshold comparing section 204 discriminates whether or not the hearing ability threshold of the measured frequency band is higher than the reference hearing ability threshold.

[0072] The target frequency band determining section 206 determines a frequency band which should be cured in accordance with the comparing result as a target frequency band. Here, the determination of the target frequency band indicates detection of damaged hair cell region, and the target frequency band may be determined in a unit of $1/k$ octave resolution like in the hearing ability diagnosing section 100. However, the determination of the target frequency band is not limited as the above method. For example, a frequency band range corresponding to damaged hair cell regions having high hearing ability threshold and located continuously may be determined as the target frequency band.

[0073] Information concerning the determined one target frequency band or more and order information in accordance with damage rate are stored in the memory 208 with matched with user identification information.

[0074] The stimulation curing section 104 of the present embodiment includes an acoustic signal intensity determining section 210, an acoustic signal kind determining section 212, a stimulation order determining section 214, an acoustic signal outputting section 216 and a timing section 218, and provides the acoustic signal to the user using the information stored in the memory 208.

[0075] The acoustic signal intensity determining section 210 determines intensity of the acoustic signal to be provided to the user.

[0076] It is desirable that the acoustic signal intensity determining section 210 determines intensity higher by 3 decibel to 20 decibel than the hearing ability threshold of each of the target frequency bands as the intensity of the acoustic signal.

[0077] In case that the target frequency band is determined as the frequency band range corresponding to the hair cell regions located continuously, the acoustic signal intensity determining section 210 may determine intensity higher by 3 decibel to 20 decibel than average value of the hearing ability thresholds of the hair cell regions as the intensity of the acoustic signal.

[0078] Preferably, the intensity of the acoustic signal may be determined in a range of 3 decibel to 10 decibel.

[0079] The acoustic signal kind determining section 212 determines kind of the acoustic signal to be provided to the user considering selection of the user, hearing loss rate of the user to which curing is required or the target frequency band.

[0080] In one example embodiment of the present invention, source tone of the acoustic signal may have amplitude modulated tone, frequency modulated tone, continuous tone, pulse tone and amplitude modulated narrowband noise, etc. Here, the acoustic signal kind determining section 212 determines at least one of the tones, the continuous tone and the noise or combination of the tones, the continuous tone and the noise as the acoustic signal to be provided to the user.

[0081] The stimulation order determining section 214 determines output order of the acoustic signal about the target frequency bands considering selection of the user, hearing loss rate of the user to which curing is required or adjacent rate of the target frequency band.

[0082] Preferably, the stimulation order determining section 214 may determine the output order so that the acoustic signal is outputted in sequence from the frequency band corresponding to most damaged hair cell region. However, the above output order is not limited as the order mentioned above. For example, the acoustic signal may be randomly outputted, or be simultaneously outputted to the target frequency

bands.

[0083] The acoustic signal outputting section 216 outputs the acoustic signal having the determined intensity, kind and order. Here, in case that the target frequency bands are existed and the acoustic signals of the target frequency bands are individually outputted, output time of each of the acoustic signals may be set. The timing section 218 detects whether or not the output time of each of the acoustic signals is finished, and controls the acoustic signal outputting section 216 in accordance with the detection result so that the acoustic signal outputting section 216 outputs an acoustic signal of next target frequency band or finishes output of the acoustic signal.

[0084] In one example embodiment of the present invention, the UI outputting section 200 displays information on the cochlear interface when the acoustic signal for curing the hearing ability of the user is outputted, wherein the user senses visually fact as to whether or not the acoustic signal is outputted, intensity and kind, etc through the information.

[0085] For example, the UI outputting section 200 may change color or size of the hair cell region image 300 corresponding to the frequency band (target frequency band) of the acoustic signal outputted now in accordance with control of a controller 230.

[0086] In case that the acoustic signal is the amplitude modulated tone, the UI outputting section 200 may change color or size of corresponding hair cell region image 300 with synchronizing with amplitude change of the amplitude modulated tone.

[0087] In case that the acoustic signal is the frequency modulated tone, the UI outputting section 200 may change color or size of the hair cell region image 300 corresponding to a frequency changed by synchronized with frequency change of the frequency modulated tone.

[0088] In case that the acoustic signal is the continuous tone or the pulse tone, the UI

outputting section 200 may sense that the acoustic signal provided now to the user is the continuous tone or the pulse tone through change of color or size of corresponding hair cell region image 300.

[0089] In one example embodiment of the present invention, the user may verify intuitively through the cochlear interface whether or not the hearing ability of each of the hair cell regions is improved.

[0090] The UI outputting section 200 shows the cochlear interface so that the hair cell region image 300 of the target frequency band determined in accordance with diagnosis of the hearing ability is separated from other hair cell region image. Additionally, the UI outputting section 200 may show the image 300 of the damaged hair cell region with color or size varied in accordance with damage rate.

[0091] The UI outputting section 200 changes color or size of corresponding hair cell region image 300 in accordance with improvement rate of each of the hair cell regions after the above stimulation through the acoustic signal (hereinafter, referred to as “acoustic signal stimulation”) so that the user verifies improvement rate of the hearing ability.

[0092] The improvement rate of the hearing ability may be discriminated by measuring again hearing ability threshold about the target frequency band.

[0093] Hereinafter, a method of diagnosing the hearing ability and a method of improving the hearing ability of the present invention will be described in detail with reference to accompanying drawings FIG. 4 and FIG. 5.

[0094] FIG. 4 is a flow chart illustrating a process of diagnosing the hearing ability according to one example embodiment of the present invention. Here, the displaying section 232 of the apparatus for stimulating the hair cell is embodied with a touch screen.

[0095] Referring to FIG. 4, the apparatus for stimulating the hair cell displays the cochlear interface shown in FIG. 3 on the touch screen 232 in case that the user requests diagnosis of his hearing ability in step S400. Here, the cochlear interface has a plurality of hair cell region images in which frequency bands generated by dividing medium frequency with maximum $1/24$ octave resolution are visually sensed.

[0096] In step S402, it is discriminated whether or not the user selects the hair cell region image 300 displayed on the cochlear interface.

[0097] In step S404, in case that the user selects the hair cell region image 300, an audio signal of the frequency band corresponding to the hair cell region related to the selected image 300 is outputted.

[0098] In step S406, the apparatus for stimulating the hair cell discriminates whether or not response information of the user in accordance with the audio signal is received.

[0099] The user may adjust volume in accordance with result as to whether or not the user hears the audio signal, and input the response information about an intensity point at which the audio signal is not heard.

[0100] In step S408, the response information is stored as the hearing ability threshold of the frequency band corresponding to each of the audio signals.

[0101] In step S410, the apparatus for stimulating the hair cell compares the hearing ability threshold of the user with the reference hearing ability threshold after input of the response information is finished.

[0102] In step S412, the target frequency band is determined through the comparing result, wherein the acoustic signal stimulation is required for the target frequency band.

[0103] In step S414, information concerning the target frequency band is stored in the memory 208. Here, the information concerning the target frequency band may have user identification information, hearing ability threshold information of a frequency

band about which the hearing ability is diagnosed, target frequency band information, order information in accordance with damage rate, etc.

[00104] In case that the audio signals corresponds dividedly to the frequency bands having 1/24 octave resolution, the target frequency band may be determined in each of the frequency bands. However, the determination of the target frequency band is not limited as the above method. That is, specific frequency band range in which average of hearing ability thresholds of the frequency bands is higher than a reference value may be determined as the target frequency band. For example, in case of measuring the hearing ability using each of the audio signals corresponding to the frequency bands of 5920Hz to 6093Hz (first interval), 6093Hz to 6272Hz (second interval) or 6272Hz to 6456Hz (third interval) generated by dividing the medium frequency with 1/24 octave resolution, the target frequency band may be determined in a unit of intervals or in new interval having the above three intervals, i.e. 5920Hz to 6456Hz.

[00105] FIG. 5 is a flow chart illustrating a process of stimulating the hair cell according to one example embodiment of the present invention.

[00106] The apparatus for stimulating the hair cell determines intensity, kind and order, etc of the target frequency band after the target frequency band is determined as mentioned above, and outputs the acoustic signal for improving the hearing ability of the user in accordance with the determination result.

[00107] Referring to FIG. 5, the apparatus for stimulating the hair cell reads information concerning the target frequency band from the memory 208 and then determines intensity of the acoustic signal of the target frequency band in step S502 in case that the user requests providing of the acoustic signal in step S500.

[00108] In steps S504 and S506, kind and output order of the acoustic signal are determined.

[00109] As described above, the output order of the acoustic signal may be determined in accordance with damage rate, or be determined so that the acoustic signal is randomly or simultaneously outputted.

[00110] In step S508, the acoustic signal is outputted in accordance with the determined intensity, kind and order.

[00111] In step S510, in case that the acoustic signal is outputted in accordance with damage rate or is randomly outputted, the apparatus for stimulating the hair cell discriminates whether or not output time of the acoustic signal is finished.

[00112] In step S512, in case that the output time is finished, an acoustic signal of next target frequency band is outputted.

[00113] On the other hand, in case that the acoustic signal is outputted, the apparatus for stimulating the hair cell synchronizes the cochlear interface with output, amplitude change, frequency change or pulse period of the acoustic signal, and changes color or size of the hair cell region image 300 of the cochlear interface in accordance with the synchronization.

[00114] The method of stimulating the hair cell of the present embodiment is provided through a computer or a portable terminal established by the user or in a hospital, etc. In addition, the method may be provided through a network at a remote place.

[00115] FIG. 6 is a view illustrating a hearing ability improving service system according to one example embodiment of the present invention.

[00116] In FIG. 6, the hearing ability improving service system of the present embodiment includes a hearing ability improving server 600 connected electrically to at least one user client 602 through a network. Here, the network includes a wire network having an Internet and a private line and a wireless network having a wireless Internet, a mobile communication network and a satellite network.

[00117] The hearing ability improving server 600 provides an application for outputting the cochlear interface shown in FIG. 3 to the user client 602 in accordance with request of the user. Here, the hearing ability improving server 600 may provide the application through various methods such as a download method or a method of inserting the application into a webpage, etc.

[00118] In case that the user selects a certain hair cell region image 300 through the cochlear interface, the application outputs an audio signal of a frequency band corresponding to the hair cell region selected by the user.

[00119] Subsequently, in case that the user inputs the response information about an intensity point at which the audio signal is not heard in accordance with volume control of the audio signal, the user client 602 transmits the response information to the hearing ability improving server 600.

[00120] The hearing ability improving server 600 has the stimulation part detecting section as shown in FIG. 1 and FIG. 2, and determines the target frequency band for which curing is required using the transmitted response information of the user.

[00121] Additionally, the hearing ability improving server 600 stores information concerning the target frequency band, determines intensity, kind, order, etc of the target frequency band in accordance with request of the user, and provides the acoustic signal of the target frequency band to the user client 602 through the network in accordance with the determined result.

[00122] The user client 602 may be embodied with a terminal which operates the application and has a speaker, and include a desktop, a laptop, a mobile communication terminal, etc.

[00123] The user client 602 stimulates the hair cell of the user by outputting the acoustic signal provided from the hearing ability improving server 600.

[00124] Hearing ability improving rate by the apparatus for stimulating the hair cell of the present embodiment may be verified through an experiment.

[00125] FIG. 7 is a view illustrating a graph indicating pure hearing examination result of one examined person. Particularly, FIG. 7 shows result generated by examining hearing ability in the range of 2000Hz to 8000Hz with 1/24 octave resolution using the hearing ability diagnosing section.

[00126] As shown in FIG. 7, right ear of the examined person has flat type hearing loss in a frequency band of 3000Hz to 7000Hz.

[00127] FIG. 8 is a view illustrating the target frequency band determined for the examined person in FIG. 7. Particularly, a frequency band range of 5920Hz to 6840Hz having hearing ability threshold of approximately 50dBHL is determined as the target frequency band for the examined person having the result in FIG. 7.

[00128] The acoustic signal such as frequency modulated tone or amplitude modulated narrowband tone related to the target frequency band determined in FIG. 8 is provided to the right ear for thirty minutes in the morning and evening over fifteen days. Here, the acoustic signal has intensity of 5 dBSL (sensational level) to 10 dBSL.

[00129] FIG. 9 is a view illustrating schedule for acoustic signal stimulation. Particularly, hearing ability is measured before the acoustic signal stimulation is provided (first case), after providing the acoustic signal stimulation for five days (second case), and after providing the acoustic signal stimulation for fifteen days (third case), and then hearing ability thresholds corresponding to the measurement are compared.

[00130] In each of cases, the hearing ability is measured ten times with 1/24 octave resolution and then average of the measured values is used as the hearing ability so as to prevent experimental error.

[00131] FIG. 10 is a view illustrating a table in which hearing ability result measured before the acoustic signal stimulation is provided to a right ear is compared with that measured after the acoustic signal stimulation is provided to the right ear for ten days. FIG. 11 is a view illustrating a table in which the hearing ability result measured after acoustic signal stimulation is provided to the right ear for ten days is compared with that measured after the acoustic signal stimulation is provided to the right ear for fifteen days.

[00132] Referring to FIG. 10 and FIG. 11, the hearing ability threshold of the target frequency band becomes small after the acoustic signal stimulation is provided, i.e. the hearing ability is improved.

[00133] FIG. 12 is a view illustrating a graph showing the hearing ability threshold of the right ear before and after the acoustic signal stimulation is provided.

[00134] In FIG. 12, hearing ability threshold (right ear) of a frequency band of 5920Hz to 6840Hz before the acoustic signal stimulation is provided equals to 45.4 dBHL. However, the hearing ability threshold of the frequency band after the acoustic signal stimulation is provided for ten days equals to 38.2 dBHL, i.e. the hearing ability threshold is lowered. In addition, the hearing ability threshold after the acoustic signal stimulation is provided for fifteen days equals to 34.2 dBHL, i.e. the hearing ability threshold is more lowered.

[00135] This may be mentioned as meaningful result.

[00136] FIG. 13 is a view illustrating schedule for verifying whether or not improving of the hearing ability is continuously maintained after the acoustic signal stimulation about the right ear is stopped.

[00137] The hearing ability is measured from five days to eighteen days after the acoustic signal stimulation is stopped.

[00138] FIG. 14 is a view illustrating a table showing measurement result of the hearing ability about the right ear after the acoustic signal stimulation is stopped. FIG. 15 is a view illustrating a graph corresponding to the table in FIG. 14.

[00139] Referring to FIG. 14 and FIG. 15, improving effect of the hearing ability is maintained after the acoustic signal stimulation is stopped. Additionally, it is verified that the hearing ability is improved by approximately 7.9 dB after lapse of eighteen days from stop of the acoustic signal stimulation.

[00140] Any reference in this specification to “one embodiment,” “an embodiment,” “example embodiment,” etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to affect such feature, structure, or characteristic in connection with other ones of the embodiments.

[00141] Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

WHAT IS CLAIMED IS:

1. A recording media readable by a digital processor and having a program of commands executed by the digital processor for the purpose of stimulating hair cell using acoustic stimulation, the recording media performing:

(a) discriminating a frequency band corresponding to damaged hair cell region in accordance with preset algorithm;

(b) determining the frequency band corresponding to the damaged hair cell region as a target frequency band; and

(c) outputting an acoustic stimulation signal having given intensity to the target frequency band so as to stimulate the damaged hair cell region,

wherein the acoustic stimulation signal corresponds to at least one of amplitude modulated tone, frequency modulated tone, pulse tone, continuous tone, and amplitude modulated narrowband noise, or combination of the tones and the noise,

wherein in the step (c), the acoustic stimulation signal is outputted with intensity higher approximately by 3dB to 20dB than hearing threshold of the damaged hair cell region.

2. The recording media of claim 1, wherein in case that several hair cell regions are damaged, the step (b) determines a frequency band range corresponding to hair cell regions located continuously among the damaged hair cell regions as the target frequency band.

3. The recording media of claim 1, wherein in case that several target frequency bands are determined, the step (c) outputs the corresponding acoustic stimulation signals in order of damage severity, or outputs randomly the acoustic stimulation signals.

4. The recording media of claim 1, wherein in case that several target frequency bands are determined, the step (c) outputs simultaneously the acoustic stimulation signals corresponding to the target frequency bands.

5. The recording media of claim 1, wherein the step (a) includes:
outputting cochlear interface comprising hair cell region images divided with $1/k$ octave resolution, wherein the k is positive integer of above 2; and
in case that a user selects at least one of the hair cell region images, outputting an acoustic signal with a frequency band corresponding to the selected hair cell region image and determining hearing threshold using the user's response information on the outputted acoustic signal.

6. The recording media of claim 5, wherein the k is a positive integer among 3 to 24.

7. The recording media of claim 5, wherein the step (b) determines a frequency band of a hair cell region of which hearing threshold is higher than a preset reference value as the target frequency band,

and wherein the method further performing:

(d) outputting the hair cell region image corresponding to the determined target frequency band, wherein the outputted hair cell region image is visualized.

8. The recording media of claim 5, further performing:

outputting the hair cell region image corresponding to the frequency band of a amplitude modulated tone in case that the type of the acoustic stimulation signal is the amplitude modulated tone, wherein amplitude variation of the amplitude modulated tone is visualized on the hair cell region image.

9. The recording media of claim 5, further performing:

outputting the hair cell region image corresponding to the frequency band of a frequency modulated tone in case that the type of the acoustic stimulation signal is the frequency modulated tone, wherein frequency variation of the frequency modulated tone is visualized on the hair cell region image.

10. The recording media of claim 9, wherein the frequency modulated tone has a resolution less than $1/3$ octave.

11. The recording media of claim 5, further performing:

outputting the hair cell region image corresponding to the frequency band of the acoustic stimulation signal in case that the type of the acoustic stimulation signal is the continuous tone or the pulse tone, wherein it is sensed through the hair cell region image that the acoustic stimulation signal corresponds to at least one of the continuous tone and the pulse tone.

12. The recording media of claim 5, wherein the hair cell region image is outputted with different color or size depending on the extent of hearing ability improvement.

13. A method for providing a hair cell stimulation service in a server connected electrically to a client through a network, the method comprising:

(a) transmitting application for hearing diagnosis to the client, wherein the application outputs cochlear interface including hair cell region images divided with $1/k$ octave resolution;

(b) receiving response information of a user in accordance with an acoustic signal of a frequency band corresponding to at least one region selected from the above hair cell region images;

(c) determining a frequency band corresponding to damaged hair cell region as a

target frequency band on the basis of the response information; and

(d) transmitting an acoustic stimulation signal of the target frequency band with given intensity to the client,

wherein the acoustic stimulation signal corresponds to at least one of amplitude modulated tone, frequency modulated tone, pulse tone, continuous tone, and amplitude modulated narrowband noise, or combination of the tones and the noise,

wherein the transmitted acoustic stimulation signal has intensity higher approximately by 3dB to 20dB than hearing threshold of the damaged hair cell region.

14. An apparatus for hair cell stimulation by acoustic signals comprising:

a hearing diagnosis section configured to measure hearing threshold of a hair cell region on the basis of a user's response information on a specific acoustic signal;

a stimulation region detecting section configured to determine a frequency band corresponding to damaged hair cell region as a target frequency band using the measured hearing threshold; and

a stimulation treatment section configured to output an acoustic stimulation signal with preset intensity to the determined target frequency band,

wherein the acoustic stimulation signal of the target frequency band is determined as at least one among amplitude modulated tone, frequency modulated tone, pulse tone, continuous tone and amplitude modulated narrow noise, or combination of the tones and the noise,

and wherein the intensity of the acoustic stimulation signal is higher by

approximately 3dB to 20dB than hearing threshold of the damaged hair cell region.

15. The apparatus of claim 14, wherein the hearing diagnosis section includes:
an interface output section configured to output cochlear interface comprising hair cell region images divided with $1/k$ octave resolution, wherein the k is positive integer of above 2; and

a response information storage section configured to store the user's response information on the acoustic signal as the hearing threshold.

16. The apparatus of claim 15, wherein the stimulation treatment section determines a frequency band of a hair cell region in which hearing threshold of the corresponding frequency band selected from the hair cell region images is higher than a preset reference value as the target frequency band.

17. The apparatus of claim 14, wherein the stimulation treatment section determines at least one among intensity, type and order of the acoustic stimulation signal of the target frequency band.