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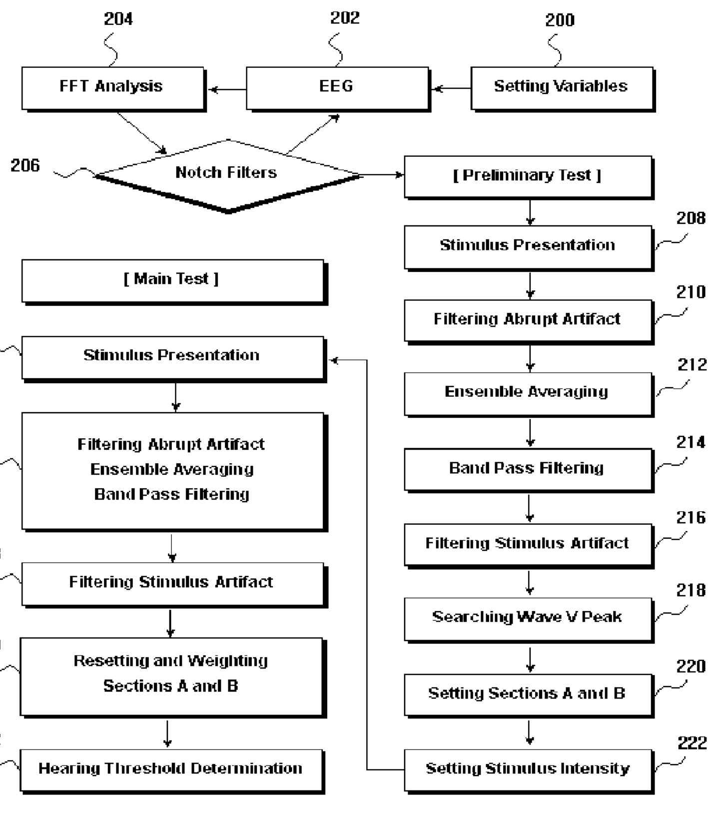
(54) Title: THE METHOD AND DEVICE FOR OBJECTIVE AUTOMATED AUDIOMETRY



(57) Abstract: The present invention relates to a m ethod for autom ation of objective hearing test based on the assessm ent of auditory evoked potential (AEP), for shortening of testing tim e, and for the m inim ization of inaccuracy and errors which m ay be resulted from the autom ation and tim e shortening. The m ethod includes the steps for: as a prelim inary test, presenting standard test stim ulus to a subject; searching the wave V peak and SN1 0 peak; and as a m ain test, presenting test stim ulus of each frequency, searching the m inim al intensity and determ ining objective hearing threshold of each frequency.

WO 2008/035850 A1

Description

THE METHOD AND DEVICE FOR OBJECTIVE AUTOMATED AUDIOMETRY

Technical Field

[1] The present invention relates to a method and device for automation of objective hearing test based on assessment of auditory evoked potential (AEP), for shortening testing time, and for minimization of inaccuracy and errors of hearing test that may be resulted from the automation and time shortening.

[2]

Background Art

[3] The auditory brainstem response (ABR) audiometry is the most widely used method for objective hearing test.

[4] For ABR audiometry, an electrode is placed on a subject's head and test stimulus is repetitively presented at least more than 1,500 times. After averaging the data, patient's audibility is determined by presence or absence of Wave V.

[5]

[6] Although a click is commonly used for ABR audiometry, this stimulus is inappropriate for estimate of hearing thresholds on specific frequencies, such as 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz, and 8000Hz. For this reason, tone-pip (or tone-burst) stimulus which has very short duration and can be presented as individual frequency, is used for estimate of the frequency-specific threshold. In this case, the term "tone-pip (or tone-burst) ABR audiometry" is currently used.

[7]

Disclosure of Invention

[8] In the conventional tone-pip ABR audiometry, as each frequency-specific threshold should be estimated separately, it takes about 1.5~2 hours to test hearing thresholds. In addition, because user's determination of a subject's hearing threshold depends on visual discrimination of wave V peak in which amplitude decrease more and more when stimulus intensity gets closer to hearing threshold, it is difficult to avoid intervention of user's subjective judgment.

[9]

[10] It is the most serious problem of the conventional ton-pip ABR audiometry that very long time is required for the hearing test. It takes long time to set manually the test stimulus presented separately according to frequency and intensity. In addition, each test stimulus should be presented more than 1,500 times to obtain a significant signal-to-noise ratio. Most of all, because the more stimulus intensity gets closer to hearing

threshold, the more amplitude of wave V decreases, it takes long time for a user to determine the presence or absence of wave V peak.

[11]

[12] In order to solve above-mentioned problems of the conventional method, the present invention provides a method for automation of tone-pip (or tone-burst) ABR audiometry, which can exclude both manual operation and user's subjective judgment. Another object of the present invention is to provide a method for determining objective hearing threshold by computing the gap between wave V and SN10. Still another object of the present invention is to provide a method for obtaining excellent signal-to-noise ratio even after minimizing the number of averaging. Finally, the present invention provides a device for performing all above-mentioned objects.

[13]

[14] In order to achieve above-mentioned objects, there is provided a method and device for objective automated hearing test comprising the steps of: (a) setting test condition which is arbitrarily done by a user before starting test; (b) converting subject's spontaneous EEG which is influxed from an electrode placed on a subject's head before starting test, into a real-time graphic image; (c) quantitative visualization of FFT analysis data on periodic artifacts among subject's spontaneous EEG; (d) filtering distinctive periodic artifacts based on the FFT analysis data which is arbitrarily done by a user; (e) as a preliminary test, presenting standard test stimulus (e.g. 2KHz, 90dBHL) to a subject according to the test condition with random time interval which is set in step (a), tracing the wave V peak, and setting time sections which are both A and B sections containing wave V peak and SN10 peak respectively; (f) setting initial intensity of the test stimulus which is the minimal intensity where the potential difference between A and B section does not exceed the critical value fixed in advance in step (a); and (g) as a main test, presenting test stimulus of each frequency, searching the minimal intensity where the potential difference between A and B section does not exceed the critical value fixed in advance in step (a), and determining objective hearing threshold of each frequency.

[15]

[16] The step (a) is for setting test condition. This step comprises the steps of: choosing the number of testing frequency; setting filtering frequency of notch filter to eliminate electrical background noise influxed from electrical source; setting frequencies of high-pass band filter and low-pass band filter to eliminate low-frequency artifact from brain and high-frequency electrical harmonics, respectively; setting the number of averaging; setting time range to randomize the time intervals between sequentially presented stimuli; setting both time range and critical intensity value of potential change, which is needed to classify an abrupt potential change during the test as an

artifact and to exclude the epoch with the abrupt potential change from averaging process; setting a critical value which means a significant potential difference between section A containing positive peak of wave V and section B containing negative peak of SN10; and setting specifications for both coordinates and graphic images which are visualized in a user interface.

[17]

[18] The step (b) is the same as the conventional method for converting subject's spontaneous EEG, which is influxed from electrodes placed on a subject's head before starting test, into a real-time graphic image.

[19]

[20] The step (c) is a quantitative visualization of FFT analysis data on periodic artifacts among subject's spontaneous EEG. In this step, a large number of notch filters are needed to completely eliminate minute artifacts influxed from electrical harmonics, because the minute artifacts cannot be completely eliminated by a small number of notch filters, which are generally used for elimination of electrical harmonics. For accurate filtering of minute artifacts influxed from electrical harmonics, real-time frequency spectrum analysis for influxed potential is required, and it is desirable to use FFT analysis.

[21]

[22] The step (d) is an arbitrary filtering by a user of distinctive periodic artifacts, which is based on the FFT analysis data of step (c). In this step, it is desirable to prudently use notch filters by considering the frequency and intensity of electrical harmonics, and the same frequency as that of the corresponding harmonics artifact is applied as the frequency of a notch filter.

[23]

[24] The step (e) is a preliminary test. In this step, after searching the wave V peak, the A and B section, which comprises wave V peak and SN10 peak, respectively, is determined. In detail, the step (e) comprises the steps of: presenting standard test stimulus (e.g. 2KHz, 90dBHL, standard stimulus can be arbitrarily set by a user) to a subject according to the test condition with random time interval which is set in step (a); real-time counting and notifying the number of epochs included (accepted) for averaging and the number of epochs excluded (rejected) from averaging process according to the criteria of the epoch with the abrupt potential change fixed in step (a); averaging the accepted epochs where there seems to be no abrupt potential change; band-pass filtering of averaged data by applying the frequencies determined in step (a) to eliminate low-frequency artifact from brain and high-frequency electrical harmonics; notch filtering of stimulus artifact generated in concert with the presented stimulus, by applying the same frequency as that of the test stimulus; real-time imaging

of the averaged EEG data on coordinates, according to the number of averaging and coordinates standard fixed in step (a); and after searching the positive peak of evoked wave V, setting time sections which are both A and B sections containing wave V positive peak and SN10 negative peak, respectively. An example of conditional sentences used to set the A and B section is as follows; "if the generation time of wave V peak, which is between 6 ms and 9 ms of averaged EEG section, is set to X, A section is (X - 0.5) ms ~ (X + 0.5) ms and B section is (X + 1.5) ms ~ (X + 3.5) ms."

[25]

[26] The step (f) is setting initial intensity of the test stimulus for main test. By gradually decreasing stimulus intensity (e.g. 90, 85, 80, 75 dBHL or dBnHL) in the preliminary test, minimal intensity, at which the potential difference between A and B section does not exceed the critical value fixed in advance in step (a), is found out and set to Y. The initial stimulus intensity of a main test is set to Y + Z dB. (Z could be 5, 10, 15, 30, etc.)

[27]

[28] Finally, the step (g) is a main test. After presenting test stimulus of each frequency to a subject and searching the minimal intensity of each frequency where the potential difference between A and B section does not exceed the critical value fixed in advance in step (a), the objective hearing threshold of each stimulus frequency is determined. Detail methods and processes applied to step (g) are the same as that of step (e).

[29]

Brief Description of the Drawings

[30] FIG. 1 is a configuration chart of a device for performing objective automated hearing test according to a preferred embodiment of the present invention.

[31]

[32] FIG. 2 is a flow chart illustrating whole process of objective automated hearing test according to a preferred embodiment of the present invention.

[33]

Mode for the Invention

[34] Hereinafter, the preferred embodiment of the present invention will be described with reference to the accompanying drawings.

[35]

[36] The present invention provides with a method and a device for automated tone-pip (or tone-burst) ABR test without both manual operation and user's subjective judgment, for determination of objective hearing thresholds based on the gap between wave V and SN10, and for acquisition of excellent signal-to-noise ratio by only minimal number of averaging.

[37]

[38] The device for performing objective automated hearing test is firstly described and embodiments for performing automated tone-pip ABR test without both manual operation and user's subjective judgment, determination of objective hearing thresholds based on the gap between wave V and SN10, and obtaining excellent signal-to-noise ratio by only minimal number of averaging are described in this specification.

[39]

[40] FIG. 1 is a configuration chart of a device for performing objective automated hearing test according to a preferred embodiment of the present invention.

[41]

[42] Referring to FIG. 1, the part for both EEG analysis and hearing threshold determination is firstly illustrated 100.

[43]

[44] If evoked EEG analysis data indicates that hearing threshold is not determined, next stimulus is presented 102.

[45]

[46] Concerning the method of stimulus presentation, unpredictable stimulus to both a user and a subject is presented in the present invention. This is accomplished by random processing of stimulus presenting part and is totally different from the conventional method. Generally used frequencies of tone-pip (or tone-burst) stimuli for objective hearing test are as follows; 250Hz, 500Hz, 1000Hz, 2000Hz, and 8000Hz. The number of tone-pip stimulus can be increased by applying subdivided frequency interval.

[47] Wide range of stimulus intensity from maximum of 130dBSPL to minimum can be used for the test.

[48]

[49] Test stimulus is presented to a subject's ear not directly through a speaker but after passing trigger part 104. The trigger part transmits synchronization signal (114) of stimulus onset time to the EEG analysis part 100, which is needed to define initial time for averaging, and at the same time presents the stimulus to a subject through a speaker 106.

[50]

[51] Concerning the location of electrodes placed to a subject, it is recommended to place an electrode on the upper part of subject's frontal lobe in the preferred embodiment of the present invention performing objective automated hearing test. The frontal lobe is a proper spot for minimizing difficulties accompanied by electrode placement. In addition, even when diverse methods suggested in the present invention for improving signal-to-noise ratio are applied to hearing test, evoked EEG with excellent signal-

to-noise ratio can be drawn out from the frontal lobe without any deterioration.

[52]

[53] EEG influxed from the subject's frontal lobe is transmitted to EEG sampling part 112 through electrode connecting part 110.

[54]

[55] Both EEG data and synchronization signal of stimulus onset time, which are drawn out by EEG sampling part and inputted by trigger part, respectively, are simultaneously transmitted to EEG analysis & hearing threshold determination part 100. After real-time analyzing, the subject's final hearing threshold of each stimulus frequency is determined.

[56]

[57] FIG. 2 is a flow chart illustrating whole process of objective automated hearing test according to a preferred embodiment of the present invention.

[58]

[59] Referring to FIG. 2, in advance of performing objective automated hearing test, test condition is set 200.

[60]

[61] Test condition setting comprises the steps of: choosing the number of testing frequency; setting filtering frequency of notch filter to eliminate electrical artifacts influxed from electrical source; setting frequencies of high-pass band filter and low-pass band filter to eliminate low-frequency artifact from brain and high-frequency electrical harmonics, respectively; setting the number of averaging; setting time range to randomize the time intervals between sequentially presented stimuli (i.e., inter-stimulus interval, ISI); setting both time range and critical intensity value of potential change, which is needed to classify an abrupt potential change during the test as an artifact and to exclude the epoch with the abrupt potential change from averaging process; setting a critical value which means a significant potential difference between section A containing positive peak of wave V and section B containing negative peak of SN10; and setting standards for both coordinates and graphic images which are visualized in a user interface.

[62]

[63] After setting test condition, subject's spontaneous EEG, which is influxed from electrodes attached to the subject's head before testing, can be converted into a real-time graphic image. This step is the same as the conventional methods 202.

[64]

[65] Next step 204 is a quantitative visualization of FFT analysis data on periodic artifacts among subject's spontaneous EEG. In this step, many number of notch filters are needed to completely eliminate minute artifacts influxed from electrical harmonics,

because the minute artifacts cannot be completely eliminated by a small number of notch filters, which are generally used for elimination of electrical harmonics. For accurate filtering of minute artifacts influxed from electrical harmonics, real-time frequency spectrum analysis of influx potential is required, and it is desirable to use FFT analysis.

[66]

[67] Based on the FFT analysis data, distinctive periodic artifacts are arbitrarily filtered by a user 206. In this step, it is desirable to use notch filters considering the frequency and intensity of electrical harmonics, and the same frequency as that of the corresponding harmonics artifact is applied as the frequency of a notch filter.

[68]

[69] The accuracy and reliability of hearing test can be increased by a preliminary test followed by a main test. In this step, once a user presses the start button, standard test stimulus is presented 208. Though 2KHz, 90dBHL (or 60dBnHL) tone-pip stimulus is usually used as a standard test stimulus, it can be arbitrarily set by a user. All the test stimulus containing standard test stimulus are presented to a subject with random time interval fixed in the step of test condition setting.

[70]

[71] While standard test stimulus is presented to a subject, an abrupt potential change, which distorts the final data of averaging, can be generated together with evoked potential by tone-pip stimulus. During ensemble averaging process, it is desirable to completely eliminate the epochs, which are containing the abrupt potential change 210. The elimination of epochs is accomplished according to the criteria fixed in the step of test condition setting, which includes time section and critical intensity.

[72]

[73] The epochs without abrupt potential change are averaged by the conventional method 212.

[74]

[75] By band-pass filtering of averaged data, wave form is changed sharply or softly and low-frequency artifacts from brain and high-frequency electrical harmonics are eliminated 214.

[76]

[77] As stimulus artifact, which is generated in concert with the presented stimulus, can be reflected to the final averaged data, notch filtering applying the same frequency as that of the test stimulus is included 216.

[78]

[79] The peak of wave V is found out from the final averaged data 218.

[80]

[81] After searching the wave V peak, both A and B sections, which contain the positive peak of wave V and negative peak of SN10 respectively, are set 220. An example of conditional sentences used to set the A and B sections is as follows; "if the generation time of wave V peak, which is between 6 ms and 9 ms of averaged EEG section, is set to X, A section is (X - 0.5) ms ~ (X + 0.5) ms and B section is (X + 1.5) ms ~ (X + 3.5) ms."

[82]

[83] By gradually decreasing (e.g. 90, 85, 80, 75 dBHL) or increasing (e.g. 95, 100, 105 dBHL) stimulus intensity, the minimal intensity, at which the potential difference between A and B section does not exceed the previously fixed critical value, is found out and set to Y. The initial stimulus intensity of a main test is set to Y + Z dB 222.

[84]

[85] In a main test 224 ~ 232, after presenting test stimulus of each frequency to a subject and searching the minimal intensity of each frequency where the potential difference between A and B section does not exceed the previously fixed critical value, the objective hearing threshold of each stimulus frequency is determined. Detail methods and processes applied to the main test are the same as that of a preliminary test except diversity of test stimulus frequency.

[86]

Industrial Applicability

[87] As described above, according to the preferred embodiment of the method and device for objective automated hearing test, users can shorten testing time by automatically performing tone-pip (or tone-burst) ABR test without both manual operation and user's subjective judgment. Further, according to the preferred embodiment of the present invention, in spite of minimization of the averaging number, reliable hearing test data with excellent signal-to-noise ratio is obtained by applying a decision method of objective hearing thresholds based on the gap between wave V and SN10.

Claims

[1] A method and device for objective automated hearing test comprising the steps of:
(a) setting test conditions, which is arbitrarily done by a user before starting test;
(b) converting subject's spontaneous EEG, which is influxed from electrodes placed on a subject's head right before starting test, into a real-time graphic image;
(c) quantitative visualization of FFT analysis data on periodic artifacts among subject's spontaneous EEG;
(d) filtering distinctive periodic artifacts based on the FFT analysis data, which is arbitrarily done by a user;
(e) as a preliminary test, presenting standard test stimulus (e.g. 2KHz, 90dBHL) to a subject according to the test condition with random time interval which is set in step (a), searching the wave V peak, and setting time section, which is the A and B section containing wave V peak and SN10 peak, respectively;
(f) setting initial intensity of the test stimulus, which is the minimal intensity where the potential difference between A and B section does not exceed the critical value fixed in advance in step (a); and
(g) as a main test, presenting test stimulus of each frequency, searching the minimal intensity where the potential difference between A and B section does not exceed the critical value fixed in advance in step (a), and determining objective hearing threshold of each frequency.

[2] The method and device of claim 1, wherein the step (a) comprises the steps of:
choosing the number of testing frequency;
setting filtering frequency of notch filter to eliminate electrical artifacts influxed from electrical source;
setting frequencies of high-pass band filter and low-pass band filter to eliminate low-frequency artifact from brain and high-frequency electrical harmonics, respectively;
setting the number of averaging;
setting time range to randomize the time intervals between sequentially presented stimuli;
setting both time range and critical intensity value of potential change, which is needed to classify an abrupt potential change during the test as an artifact and to exclude the epoch with the abrupt potential change from averaging process;
setting a critical value which means a significant potential difference between section A containing positive peak of wave V and section B containing negative

peak of SN10; and
setting standards for both coordinates and graphic images which are visualized in a user interface.

[3] The method and device of claim 1, wherein the step (c) and (d) comprise the steps of:
quantitative visualization of FFT analysis data on periodic artifacts among subject's spontaneous EEG and filtering of distinctive periodic artifacts appeared in the real time FFT analysis data of spontaneous EEG. This filtering step is arbitrarily performed by applying the frequency of corresponding periodic artifact as the frequency of a notch filter.

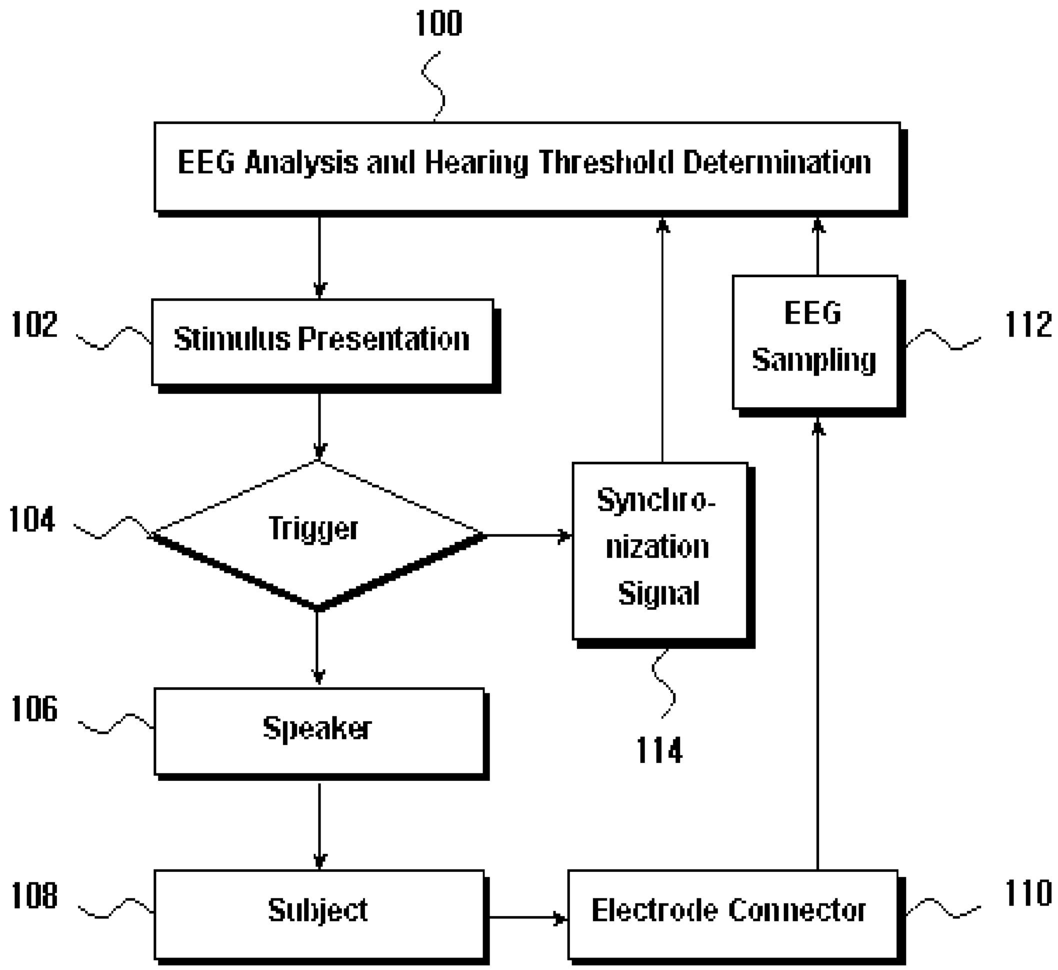
[4] The method and device of claim 1, wherein the step (e) comprises the steps of:
presenting standard test stimulus (e.g. 2KHz, 90dBHL, standard stimulus can be arbitrarily set by a user) to a subject according to the test condition with random time interval fixed in step (a);
real-time counting and notifying the number of epochs included for averaging and the number of epochs excluded from averaging process according to the criteria of epoch fixed in step (a);
averaging the epochs where there seems to be no abrupt potential change;
band-pass filtering of averaged data by applying the frequencies determined in step (a) to eliminate low-frequency artifact from brain and high-frequency electrical harmonics;
notch filtering of stimulus artifact generated in concert with the presented stimulus, by applying the same frequency as that of the test stimulus ;
real-time imaging of the averaged EEG data on coordinates according to the number of averaging and coordinates standard fixed in step (a); and
after searching the positive peak of evoked wave V, setting time section, which is the A and B section containing wave V positive peak and SN10 negative peak, respectively.
An example of conditional sentences used to set the A and B section is as follows; "if the generation time of wave V peak, which is between 6 ms and 9 ms of averaged EEG section, is set to X, A section is (X - 0.5) ms ~ (X + 1.5) ms and B section is (X + 1.5) ms ~ (X + 3.5) ms."

[5] The method and device of claim 1, wherein by gradually decreasing (e.g. 90, 85, 80, 75 dBHL) or increasing (e.g. 95, 100, 105 dBHL) stimulus intensity, the minimal intensity, at which the potential difference between A and B section does not exceed the previously fixed critical value, is found out and set to Y. The initial stimulus intensity of a main test is set to Y + Z dB in step (f).

[6] The method and device of claim 1, wherein after presenting test stimulus of each

frequency to a subject and searching the minimal intensity of each frequency where the potential difference between A and B section does not exceed the previously fixed critical value, the objective hearing threshold of each stimulus frequency is determined in step (g).

[Fig. 1]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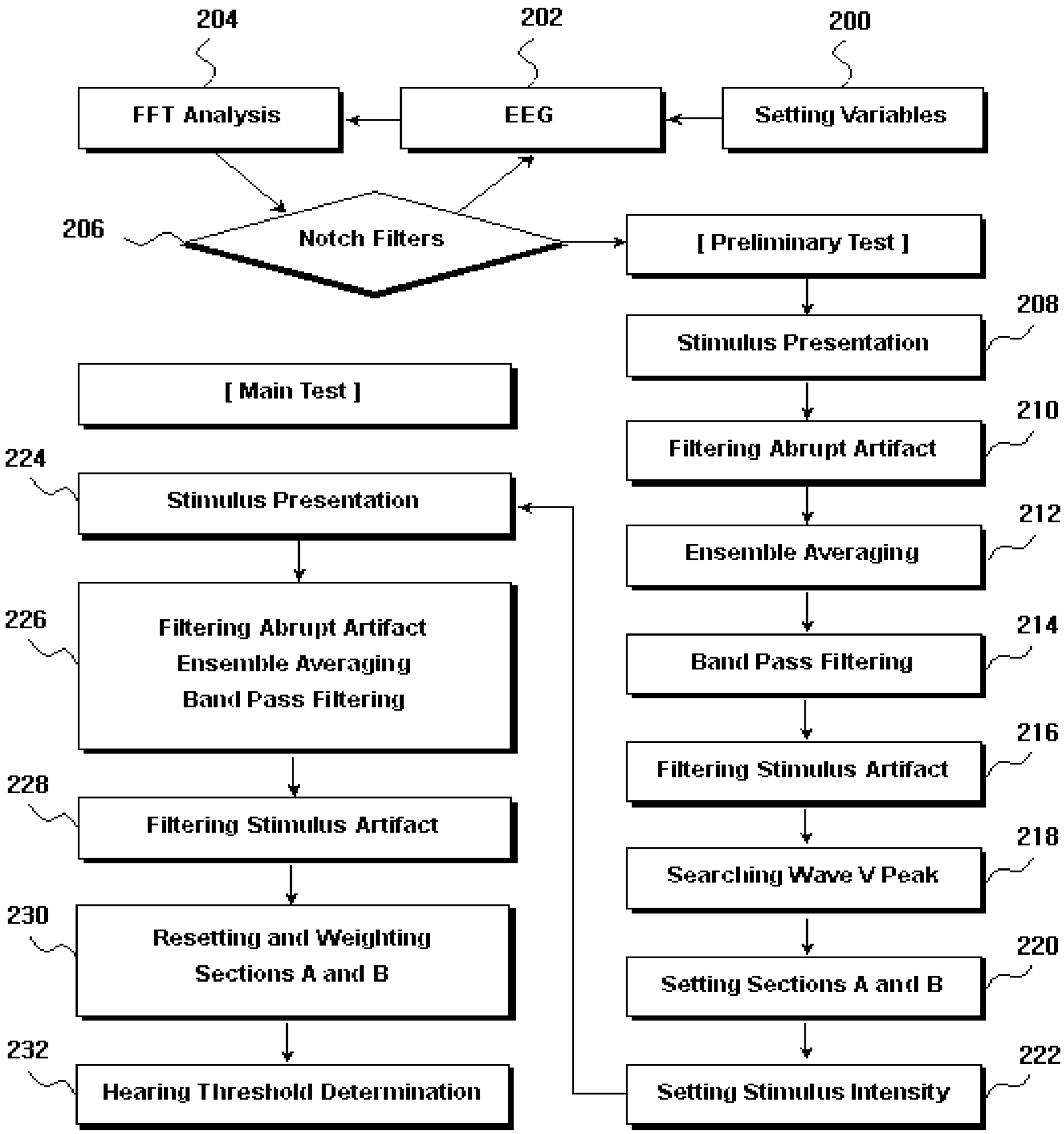
102
Stimulus Presentation
104
Trigger
106
Speaker
108
Subject
Electrode Connector
110
EEG
Sampling
112
Synchro-
nization
Signal
114

[Fig. 2]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EEG
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[Preliminary Test]
208
Stimulus Presentation
[Main Test]
210
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224
Stimulus Presentation
212
Ensemble Averaging
226
Filtering Abrupt Artifact
Ensemble Averaging
Band Pass Filtering
214
Band Pass Filtering
216
Filtering Stimulus Artifact
228
Filtering Stimulus Artifact
218
Searching Wave V Peak
230
Resetting and Weighting
Sections A and B
220
Setting Sections A and B
232
Hearing Threshold Determination
222
Setting Stimulus Intensity

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2007/003661

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/05(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 : A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) " auditory brainstem response"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6080112 A (DON, MANUEL) 27 June 2000 See figure 2 and claims	1-6
A	US 6200273 B1 (SININGER. Y.S. et al.) 13 March 2001 See figure 2 and claims	1-6
A	US 6196977 B1 (SININGER. Y.S. et al.) 06 March 2001 See figure 4 and claims	1-6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

27 NOVEMBER 2007 (27.11.2007)

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Name and mailing address of the ISA/KR

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Telephone No. 82-42-481-8458

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2007/003661

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patsnap

专利名称(译)	用于客观自动测听的方法和装置		
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摘要(译)

本发明涉及基于听觉诱发电位（AEP）评估的客观听力测试自动化方法，用于缩短测试时间，以及用于由此产生的不准确性和错误的最小化。自动缩短和缩短时间。该方法包括以下步骤：作为初步测试，向受试者提供标准测试刺激;搜索波V峰值和SN1 0峰值;并且作为测试，呈现每个频率的测试刺激，搜索最小强度并确定每个频率的客观听力阈值。