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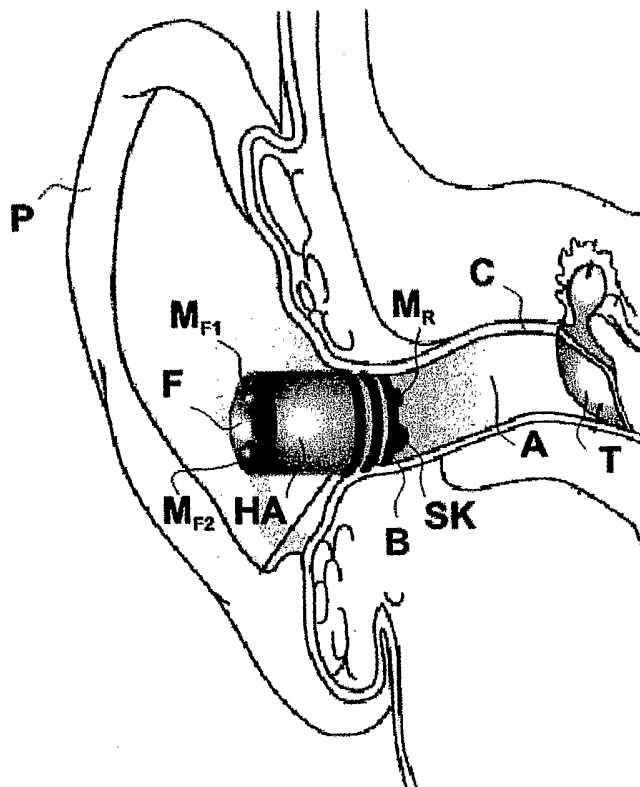
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[Continued on next page]

(54) Title: HEARING AID WITH ELECTRO-ACOUSTIC CANCELLATION PROCESS



(57) Abstract: A complete-In-canal hearing aid (HA) for facilitating concealment, the hearing aid employs electro-acoustic cancellation processes (PA) whereby an occlusion effect is minimized. Said processes simultaneously minimize unwanted hearing-aid-driven acoustic resonance in a sealed segment of the canal (A). Natural open canal resonant modes may then be effectively emulated electronically for further enhancement of speech intelligibility.



SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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Hearing Aid with Electro-Acoustic Cancellation Process

By Mike Petroff, Marina Del Rey, CA

PRIORITY

Benefit is claimed under 35 U.S.C. 119 (e) of pending provisional patent application no. 60/564,462 filed 04/22/2004.

FIELD

This writing relates to the field of hearing aids, and more specifically to an electro-acoustic cancellation processes for the minimization of the occlusion effect and ear canal resonances. This writing describes at least a hearing aid with electro-acoustic cancellation process for minimization of occlusion effect and ear canal resonances.

BACKGROUND

A common problem associated with conventional hearing aids is the occlusion effect, in which the hearing aid user hears an undesirable accentuation of his or her voice caused by bone conduction of the voice to acoustically trapped air between the hearing aid seal and the tympanic membrane. The severity of the occlusion effect varies as a function of the degree to which the hearing aid occludes the ear canal, which is largely determined by the size and Helmholtz resonant frequency of the vent between such acoustically trapped air and the outside. Recent hearing aid designs accommodate relatively large vents having correspondingly high Helmholtz resonant frequencies and reduced occlusion affect, however such designs do not eliminate the occlusion effect entirely and decrease the maximum allowable amplification without feedback. Other recent hearing aid designs reduce the occlusion effect by locating only the speaker component (receiver) of the hearing aid in the ear canal, thereby accommodating even larger vents, and by locating the remaining hearing aid components in a separate behind-the-ear case, however this approach also decreases the

~~maximum allowable amplification without~~ feedback and, very importantly, does not enable concealment of the entire hearing aid device in the ear. Completely-In-Canal hearing aids may be designed in such as manner as to occupy virtually all air space within the canal thereby reducing the occlusion effect, however when designed in such a manner such hearing aids are not optimally comfortable to wear and can be irritating to the ear canal when worn for extended periods of time. What is needed therefore is a hearing aid, preferably but not limited to the Completely-In-Canal type to facilitate concealment, which does not occupy virtually all air space within the canal to optimize comfort, utilizes a relatively small vent to enable high amplification without feedback but therefore also introduces substantial occlusion effect, and employs novel electro-acoustic cancellation processes whereby the occlusion effect is minimized. Such cancellation processes simultaneously minimize unwanted hearing aid driven acoustic resonances in the sealed segment of the canal, and effectively enable open canal resonant modes to be electronically emulated for further enhancement of speech intelligibility without requiring in the canal audiology measurement and calibration procedures.

SUMMARY OF THE INVENTION

The present invention is a novel hearing aid, preferably Completely-In-Canal to facilitate concealment, which does not occupy virtually all air space within the canal to optimize comfort, utilizes a relatively small vent to enable high amplification without feedback but therefore also introduces substantial occlusion effect, and employs electro-acoustic cancellation processes whereby the occlusion effect is minimized. Such processes simultaneously minimize unwanted hearing aid driven acoustic resonances in the sealed segment of the canal. Natural open canal resonant modes may then be effectively emulated electronically for further enhancement of speech intelligibility.

The electro-acoustic cancellation processes of the present invention comprises at least a first front microphone disposed on a front side of the hearing aid exposed to the outside, a rear microphone disposed on a back side of the hearing aid substantially adjacent to a speaker (receiver) and exposed to the sealed segment of the canal and to the tympanic membrane, and a vent between the sealed segment of the canal and the outside. A signal from the first

front microphone, which monitors outside speech and sound, is applied to the input of a first signal process typically comprising at least one prior art function of high frequency compression, personalized hearing curve compensation, or adaptive feedback cancellation (based on different principles than the electro-acoustic cancellation processes of the present invention), and which preferably also comprises frequency response emulation of natural open canal resonant modes. The first signal process provides an output signal to a first input of a power amplifier that drives the speaker, thereby providing modified sound originally monitored by the first front microphone. In a second step, a signal from the rear microphone, which monitors sound present in the sealed segment of the canal, including occlusion effect related bone conducted sound from the user's voice and unwanted hearing aid driven acoustic resonances in the sealed segment of the canal, is applied to a second signal process comprising phase and amplitude compensated negative feedback. The second signal process provides an output to a second input of the power amplifier that drives the speaker, which by virtue of such phase and amplitude compensated negative feedback, provides a signal component to the speaker and a sound field in the sealed segment of the canal that is substantially equal and opposite the occlusion effect sound and the hearing aid driven resonances. In the above manner, the occlusion effect and hearing aid driven acoustic resonances are electro-acoustically minimized, and natural open canal resonant modes are emulated, in a hearing aid that may be of the CIC type not occupying virtually all air space within the canal for optimum user comfort.

As an optional feature, a second front microphone may be disposed on a front side of the hearing aid exposed to the outside and displaced from the first front microphone along one of (i) a line that is substantially coincident with the user's mouth, (ii) a line that is substantially coincident with the back of the user's head, or (iii) a line that lies in a compromise direction between the lines described in (i) and (ii) above. The output of the second front microphone is applied to a third signal process comprising a time, phase and amplitude compensated signal cancellation function for the purpose of providing a polar response null in the direction of the applicable line described in (i), (ii) or (iii). The output of the third signal process is applied to a third input of the power amplifier that drives the speaker. In this manner, a reduction in at least one of air conducted sound from user's voice, and speech and sound emanating from behind

the user, is reduced in amplitude. A single bipolar or directional microphone, in which the direction of polar nullification aligns the applicable line described in (i), (ii) or (iii), may substitute or be utilized with the first and second microphone and third signal process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a three dimensional view of a hearing aid representing a preferred embodiment of the present invention, shown inserted in an ear canal.

FIG. 2 is a functional block diagram illustrating first, second and third signal processes of the hearing aid of FIG. 1, including a first, second and third microphone and speaker.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the preferred embodiment of the present invention in which hearing aid **HA** is inserted in ear canal **C** which opens to Pinna **P** (the outer ear). **HA** comprises first front microphone **Mf1** disposed on front side **F** of **HA**, second front microphone **Mf2** disposed on **F** and displaced in distance from **Mf1**, speaker **S** disposed on rear side **R** of **HA**, and rear microphone **Mr** disposed on **R** adjacent to speaker **S**.

FIG. 2 illustrates signal processes of the preferred embodiment of the present invention, in which signal **S1** from first front microphone **Mf1** is applied to the input of first signal process **SP1**, typically comprising at least one of high frequency compression, personalized hearing curve compensation, or adaptive feedback cancellation, and which preferably also comprises frequency response emulation of natural open canal resonant modes. **SP1** provides output signal **S3** applied to a first input of a power amplifier **PA**, which provides signal **S7** which drives speaker **SK**. Signal **S5** from the rear microphone **Mr** is applied to second signal process **SP2** comprising phase and amplitude compensated negative feedback. **SP2** provides output signal **S6** is applied to a second input of the power amplifier **PA**, which by virtue of phase and amplitude compensated negative feedback provides a signal component to speaker **SK** and a sound field in the sealed segment of the canal that is substantially equal and opposite

occlusion effect sound and hearing aid driven resonances. Signal **S2** from second front microphone **Mf2** is applied to third signal process **SP3** comprising a time, phase and amplitude compensated signal cancellation function for the purpose of providing a polar response null in a preferred the direction. The output of **SP3** is applied to a third input of power amplifier **PA**.

As a broad summary, this writing discloses in one embodiment a hearing aid. The hearing aid is completely in canal but does not occupy virtually all of the air space in the canal. The hearing aid utilizes a relatively small vent to enable high amplification without feedback and introduces a substantial occlusion effect. The hearing aid employs electro-acoustic cancellation to minimize the occlusion as well as minimizes unwanted hearing aid driven acoustic resonances in the sealed segment of the canal.

Claims

What is claimed is:

1. A hearing aid, worn by a user having an ear and ear canal, comprising:

a front surface of the hearing aid that is acoustically exposed to outside sound and acoustically isolated from the ear canal of the user;

a first microphone disposed on the front surface of the hearing aid and providing a first audio signal corresponding to the outside sound;

a rear surface of the hearing aid that is acoustically coupled to the ear canal and acoustically isolated from the outside sound;

a speaker disposed on the rear surface of the hearing aid and generating sound within the ear canal.

a second microphone disposed on the rear surface of the hearing aid and providing a second audio signal corresponding to sound, within the ear canal, comprising components of direct sound generated by the hearing aid speaker, the occlusion effect, and hearing aid speaker driven acoustic resonances in the ear canal;

a first signal process receiving as input the first audio signal from the first microphone and providing at least one of high frequency compression, hearing curve compensation, adaptive feedback cancellation, and emulation of natural open canal resonant modes, and providing as output a first signal process output signal;

a second signal process receiving as input the second audio signal from the second microphone and providing a phase and amplitude compensated negative feedback function

providing cancellation of the occlusion effect and hearing aid driven acoustic resonances in the ear canal, and providing as output a second signal process output signal; and,

an audio power amplifier receiving as inputs the first and second signal process output signals and providing as output a power audio signal that is applied to the speaker.

2. A hearing aid, worn by a user having an ear and ear canal, comprising:

a front surface of the hearing aid that is acoustically exposed to outside sound and acoustically isolated from the ear canal of the user;

a first microphone disposed on the front surface of the hearing aid and providing a first audio signal corresponding to the outside sound;

a rear surface of the hearing aid that is acoustically coupled to the ear canal and acoustically isolated from the outside sound;

a speaker disposed on the rear surface of the hearing aid and generating sound within the ear canal.

a second microphone disposed on the rear surface of the hearing aid and providing a second audio signal corresponding to sound, within the ear canal, comprising components of direct sound generated by the hearing aid speaker, the occlusion effect, and hearing-aid-speaker-driven acoustic resonances in the ear canal;

a third microphone disposed on the front surface of the hearing aid and displaced from the first microphone along one of (i) a line that is substantially coincident with the user's mouth, (ii) a line that is substantially coincident with the back of the user's head, and (iii) a line that lies in a compromise direction between lines (i) and (ii), the third microphone providing a third audio signal corresponding to the outside sound;

a first signal process receiving as input the first audio signal from the first microphone and providing at least one of high frequency compression, hearing curve compensation, adaptive feedback cancellation, and emulation of natural open canal resonant modes, and providing as output a first signal process output signal;

a second signal process receiving as input the second audio signal from the second microphone and providing a phase and amplitude compensated negative feedback function providing cancellation of the occlusion effect and hearing aid driven acoustic resonances in the ear canal, and providing as output a second signal process output signal;

a third signal process receiving as input the third audio signal and providing a time, phase and amplitude compensated signal cancellation function providing a polar response null in the direction of the line between the third and first microphone along the front surface of the hearing aid, and providing as output a third signal process output signal; and,

an audio power amplifier receiving as inputs the first, second and third signal process output signals and providing as output a power audio signal that is applied to the speaker.

FIG. 1.

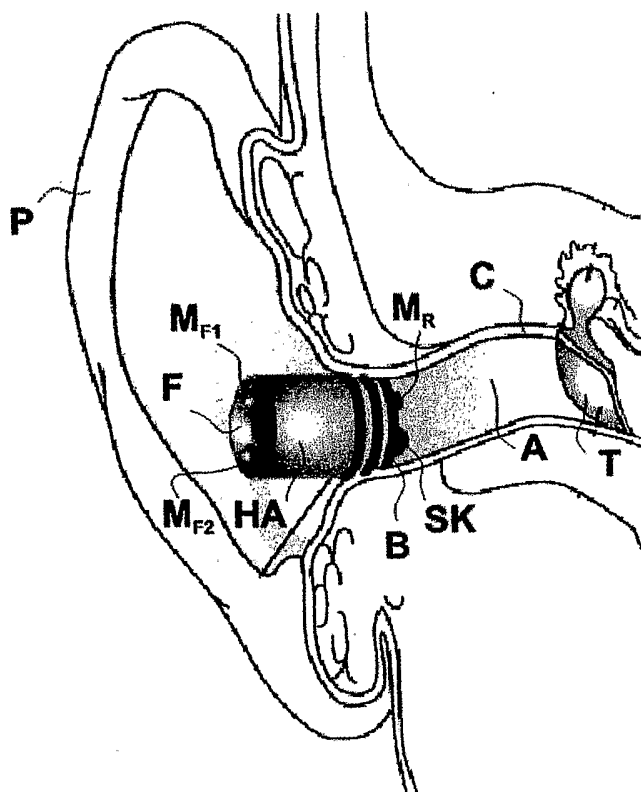
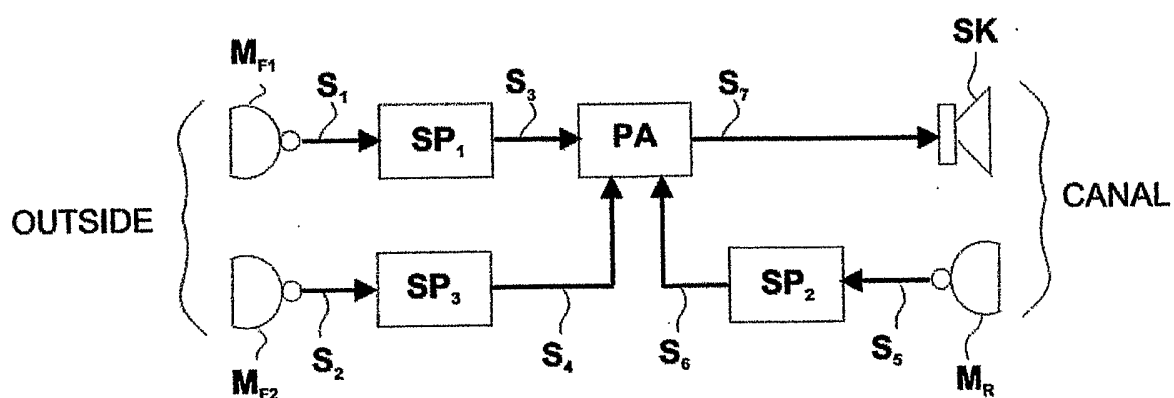


FIG. 2.



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04R 25/00

US CL : 381/312, 317, 318, 328

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)

U.S. : 381/312, 317, 318, 328 71.1, 93, 95

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
East**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,647,123 B2 (Kandel et al.) 11 November 2003 (11.11.2003), col. 7 line 20 to col. 12, line 17.	1
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Y		2
A	US 5,033,090 A (Weinrich) 16 July 1991 (16.07.1991), see entire document.	1-2
A,P	US 6,831,986 B2 (Kates) 14 December 2004 (14.12.2004), see entire document.	1-2



Further documents are listed in the continuation of Box C.



See patent family annex.

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