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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
61/098,250	09/19/2008		105	PERS-0071-PR		

CONFIRMATION NO. 2487

FILING RECEIPT

71158
PERSONICS HOLDINGS INC.
5100 Town Center Circle, Tower 11, Suite 510
BOCA RATON, FL 33486

OC000000032577931

Date Mailed: 10/15/2008

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

John Usher, Montreal, CANADA;

Power of Attorney:
Marc Boillot--56164

If Required, Foreign Filing License Granted: 10/14/2008

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 61/098,250**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

Acoustic Sealing System

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IPR2024-01015
Page 00001

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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PTO/SB/16 (08-08)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
John	Usher	Montreal, Canada

Additional inventors are being named on the _____ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max):

Acoustic Sealing System

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☑ The address corresponding to Customer Number: 71158

OR

☐ Firm or Individual Name

Address

City	State	Zip
Country	Telephone	Email

ENCLOSED APPLICATION PARTS *(check all that apply)*

☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number of CDs _____

☑ Drawing(s) *Number of Sheets* 10

☐ Other (specify) _____

☑ Specification (e.g. description of the invention) *Number of Pages* 34

Fees Due: Filing Fee of $210 ($105 for small entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

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☑ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fee and application size fee (if applicable).

☐ Payment by credit card. Form PTO-2038 is attached

☑ The Director is hereby authorized to charge the filing fee and application size fee (if applicable) or credit any overpayment to Deposit Account Number: 504284.

105

TOTAL FEE AMOUNT ($)

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____

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SIGNATURE /Marc Boillot/ Date September 19, 2008

TYPED or PRINTED NAME Marc Boillot REGISTRATION NO. 56,164
(if appropriate)

TELEPHONE _____ Docket Number: PERS-0071-PR

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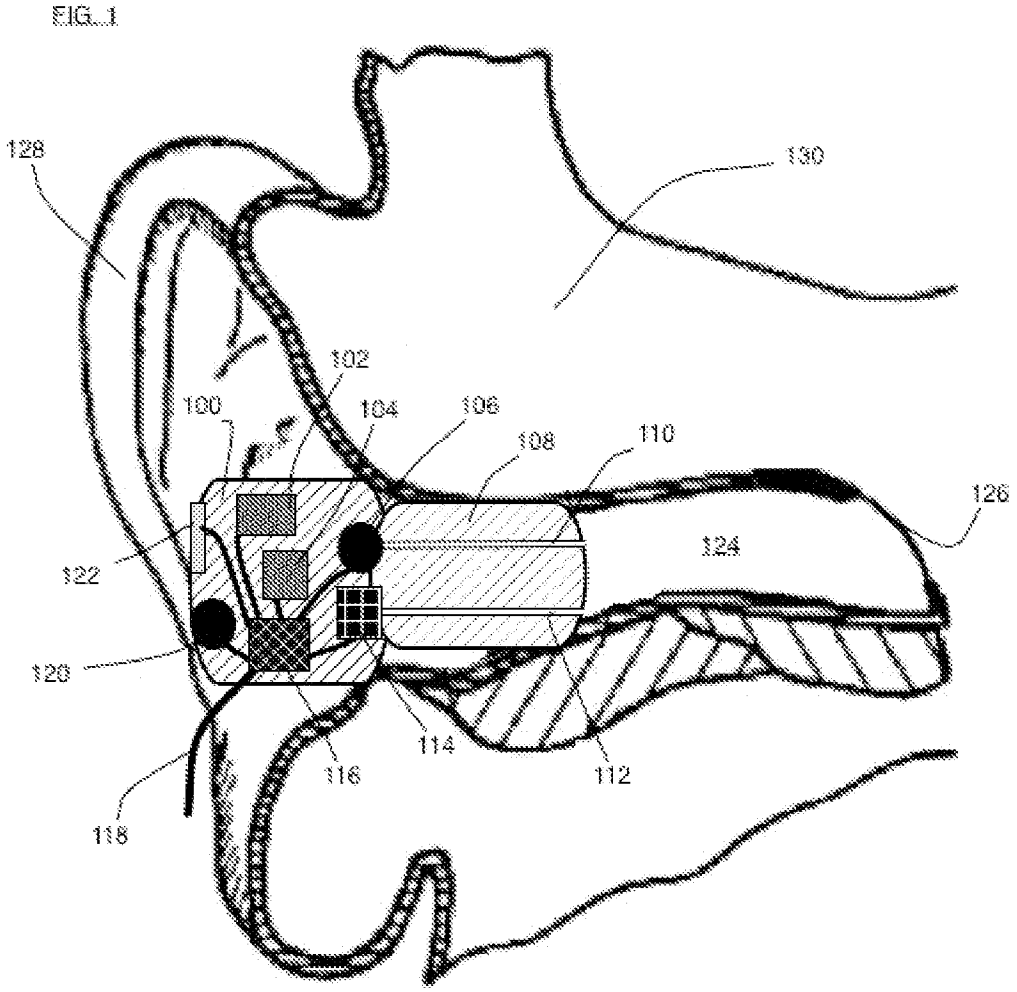
FIG. 1
128
130
102
100
104
106
108
110
126
124
122
120
114
116
112
118

FIG. 1

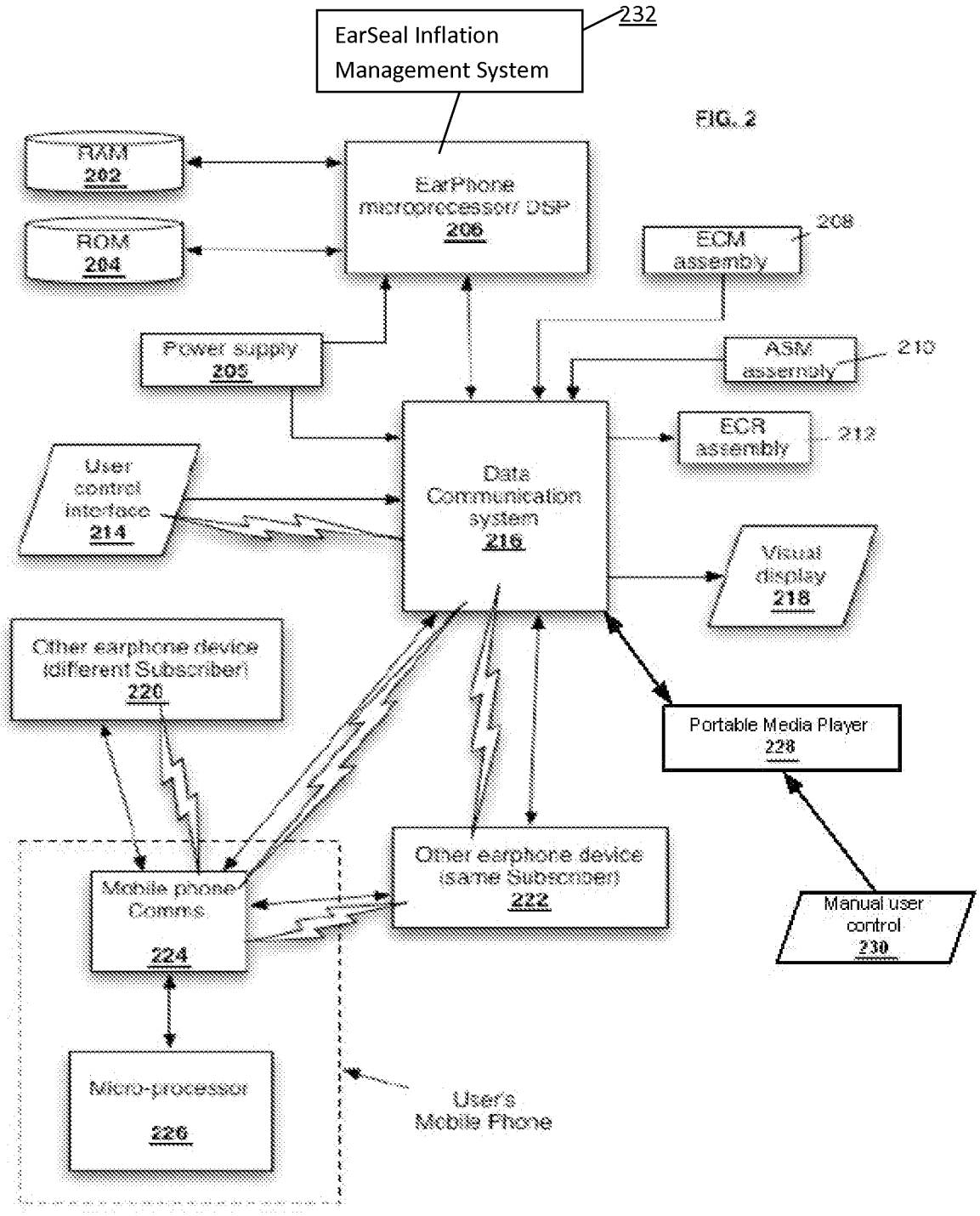
EarSeal Inflation Management System
232
FIG. 2
RAM 202
ROM 204
EarPhone microprocessor/ DSP 206
ECM assembly
208
Power supply 203
ASM assembly
210
ECR assembly
212
User control interface 214
Data Communication system 216
Visual display 218
Other earphone device (different Subscriber) 220
Portable Media Player 228
Other earphone device (same Subscriber) 222
Mobile phone Comms 224
Manual user control 230
Micro-processor 226
User's Mobile Phone

FIG. 2

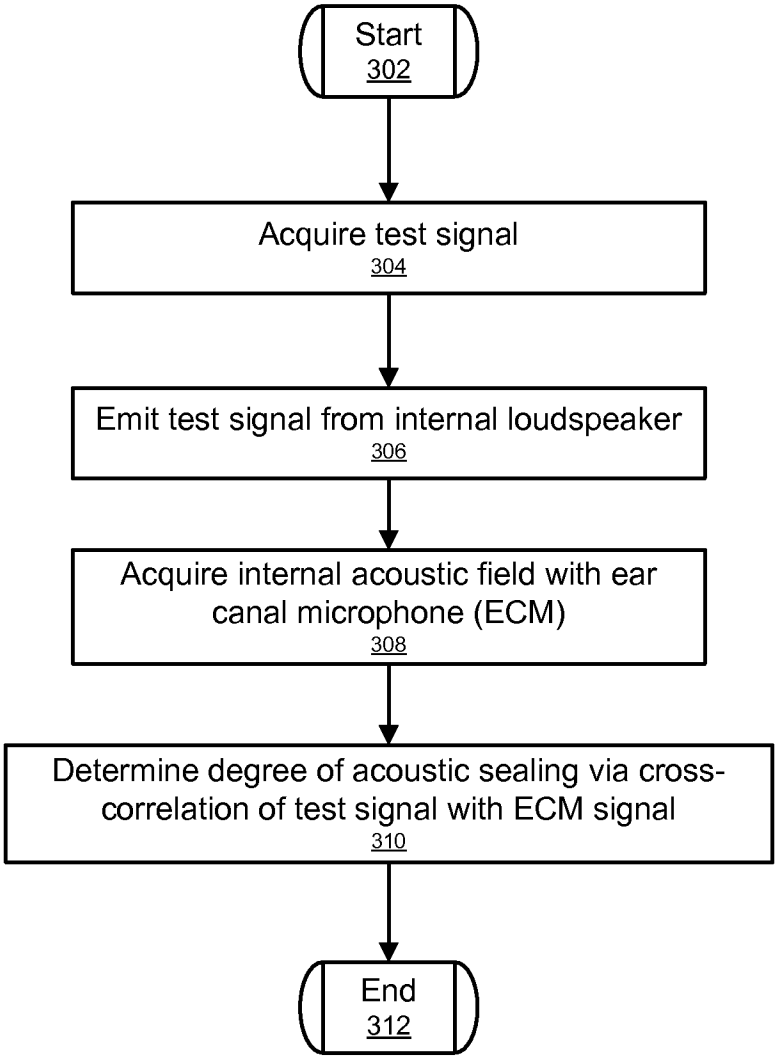
Start
302
Acquire test signal
304
Emit test signal from internal loudspeaker
306
Acquire internal acoustic field with ear canal microphone (ECM)
308
Determine degree of acoustic sealing via cross-correlation of test signal with ECM signal
310
End
312

FIG. 3

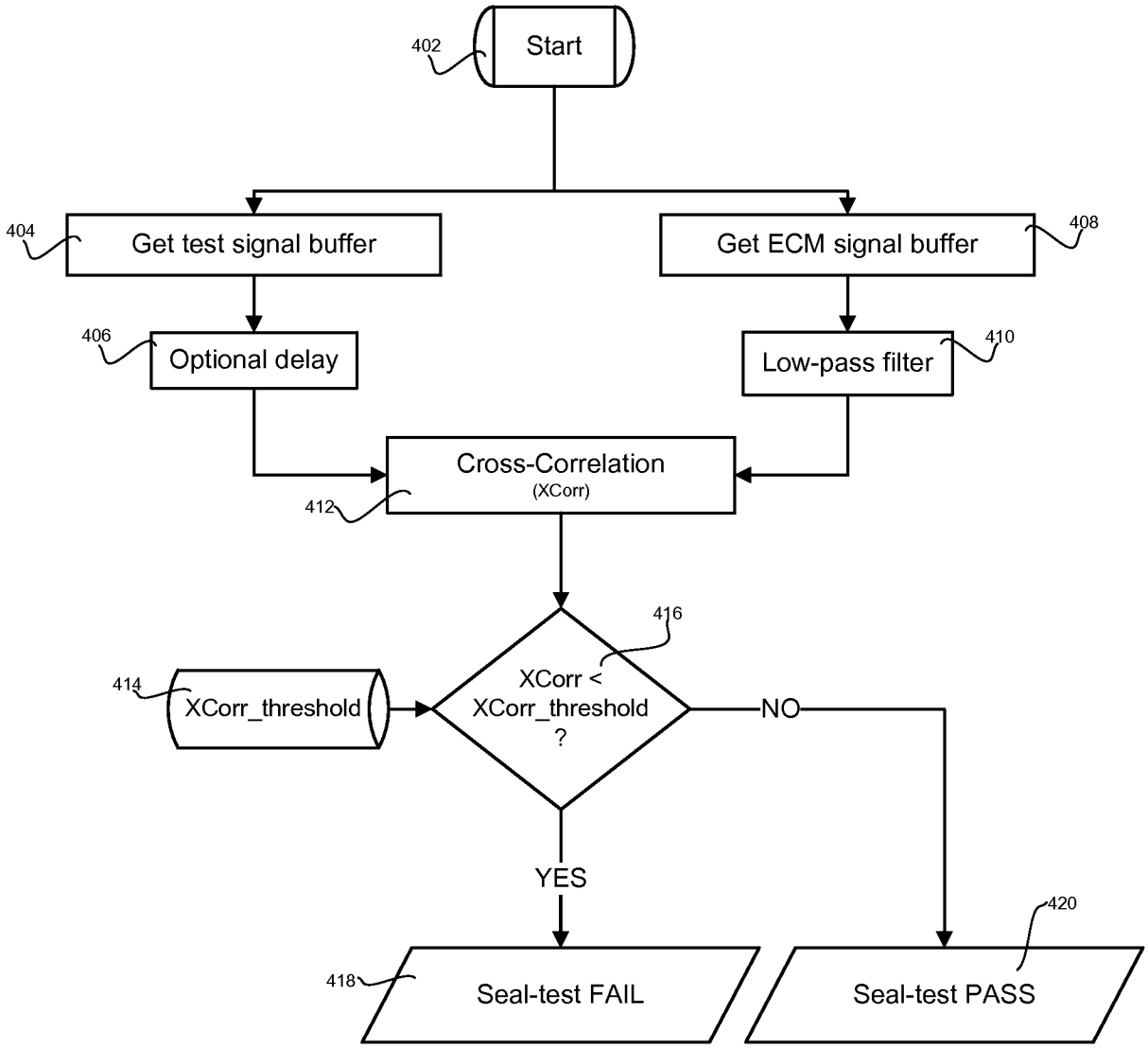
402
Start
404
Get test signal buffer
408
Get ECM signal buffer
406
Optional delay
410
Low-pass filter
Cross-Correlation
(XCorr)
412
416
414
XCorr_threshold
XCorr <
XCorr_threshold
?
NO
YES
420
418
Seal-test FAIL
Seal-test PASS

FIG. 4

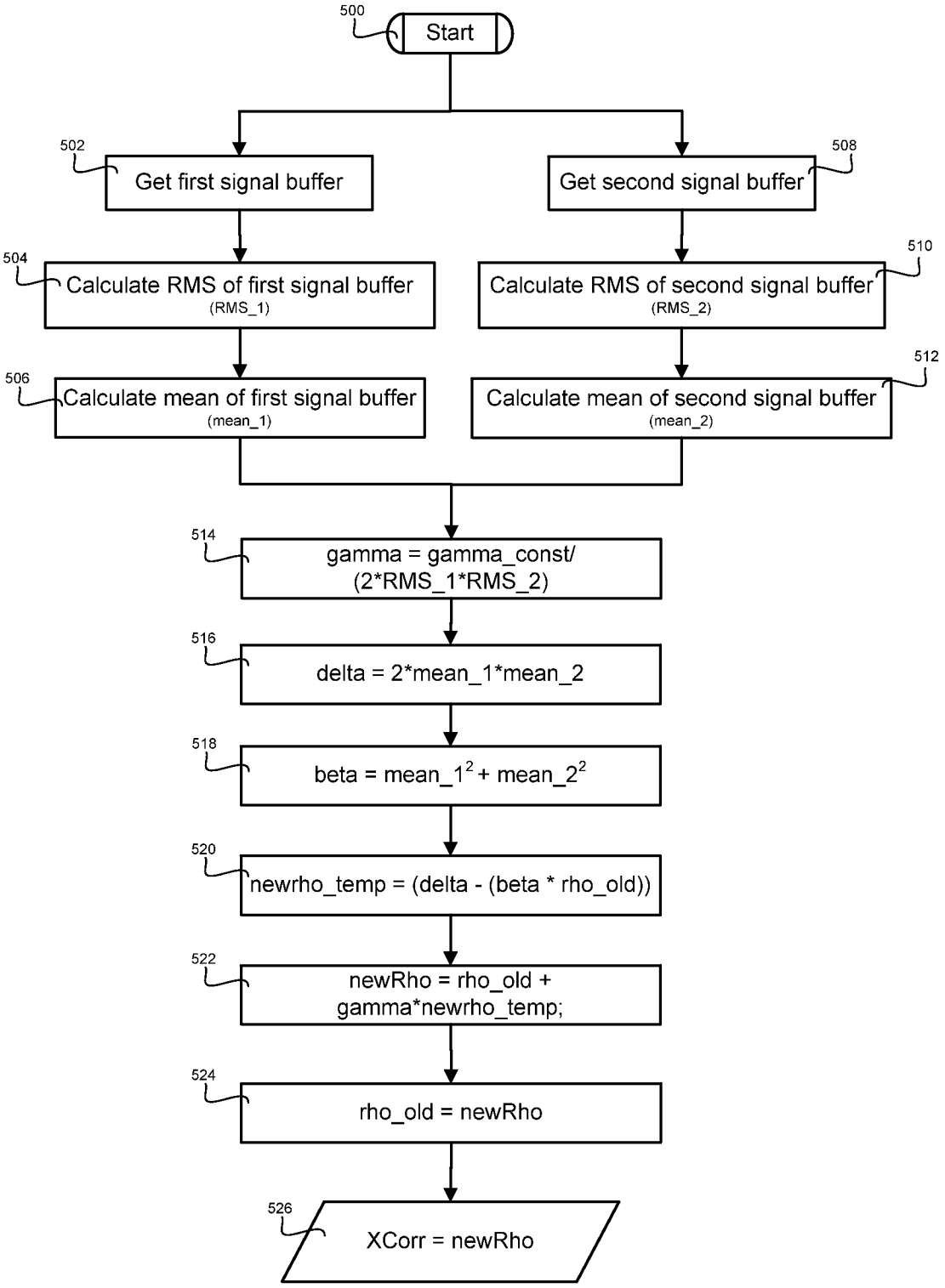
500
Start
502
Get first signal buffer
508
Get second signal buffer
504
Calculate RMS of first signal buffer
(RMS_1)
510
Calculate RMS of second signal buffer
(RMS_2)
506
Calculate mean of first signal buffer
(mean_1)
512
Calculate mean of second signal buffer
(mean_2)
514
gamma = gamma_const/
(2*RMS_1*RMS_2)
516
delta = 2*mean_1*mean_2
518
beta = mean_1^2 + mean_2^2
520
newrho_temp = (delta - (beta * rho_old))
522
newRho = rho_old +
gamma*newrho_temp;
524
rho_old = newRho
526
XCorr = newRho

FIG.5

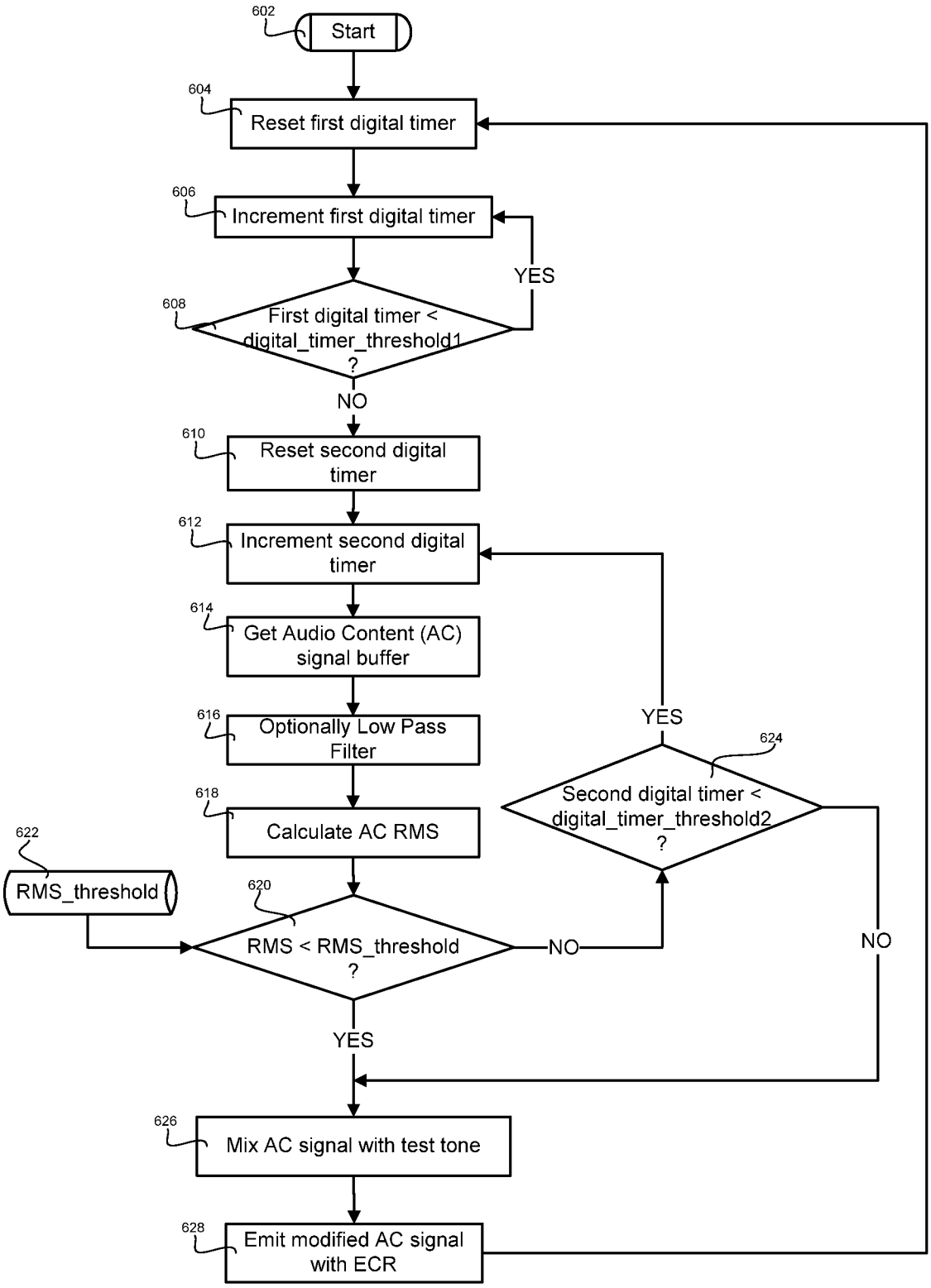
602
Start
604
Reset first digital timer
606
Increment first digital timer
YES
608
First digital timer < digital_timer_threshold1 ?
NO
610
Reset second digital timer
612
Increment second digital timer
614
Get Audio Content (AC) signal buffer
616
Optionally Low Pass Filter
618
Calculate AC RMS
YES
624
Second digital timer < digital_timer_threshold2 ?
622
RMS_threshold
620
RMS < RMS_threshold ?
NO
NO
YES
626
Mix AC signal with test tone
628
Emit modified AC signal with ECR

FIG. 6

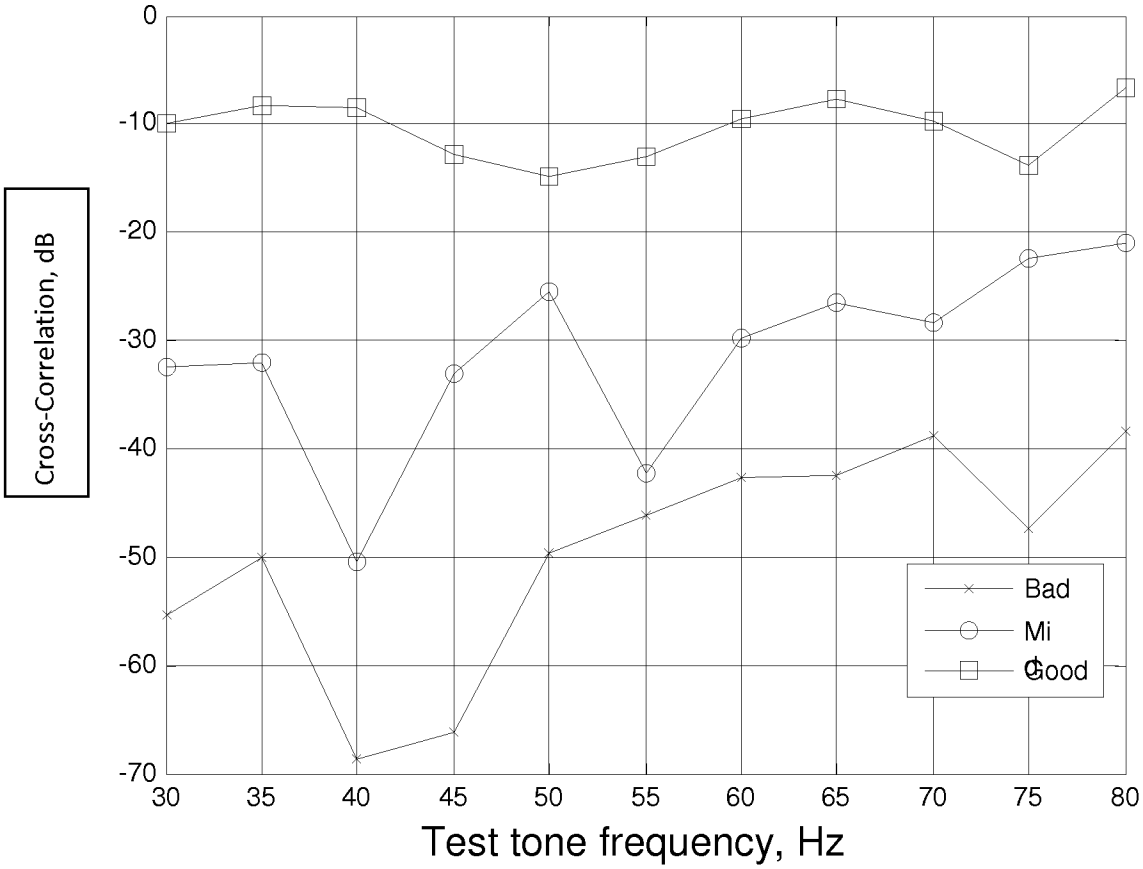
Cross-Correlation, dB
0
-10
-20
-30
-40
-50
-60
-70
30
35
40
45
50
55
60
65
70
75
80
Test tone frequency, Hz
Bad
Mi
d
Good

FIG. 7

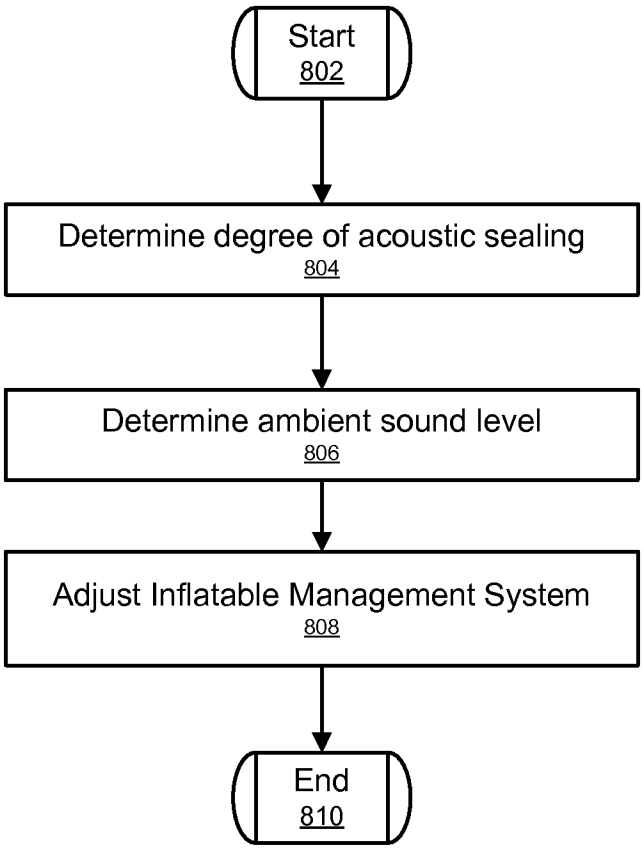
Start
802
Determine degree of acoustic sealing
804
Determine ambient sound level
806
Adjust Inflatable Management System
808
End
810

FIG. 8

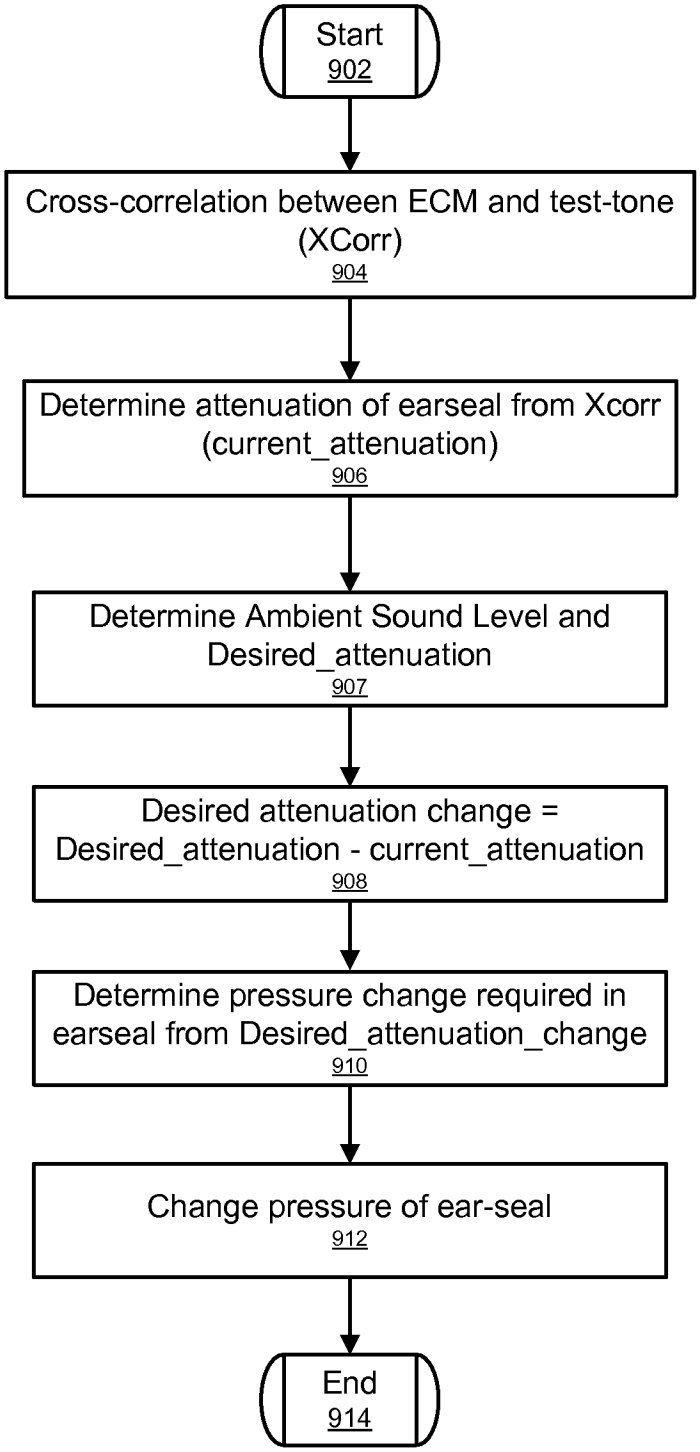
Start
902
Cross-correlation between ECM and test-tone (XCorr)
904
Determine attenuation of earseal from Xcorr (current_attenuation)
906
Determine Ambient Sound Level and Desired_attenuation
907
Desired attenuation change = Desired_attenuation - current_attenuation
908
Determine pressure change required in earseal from Desired_attenuation_change
910
Change pressure of ear-seal
912
End
914

FIG. 9

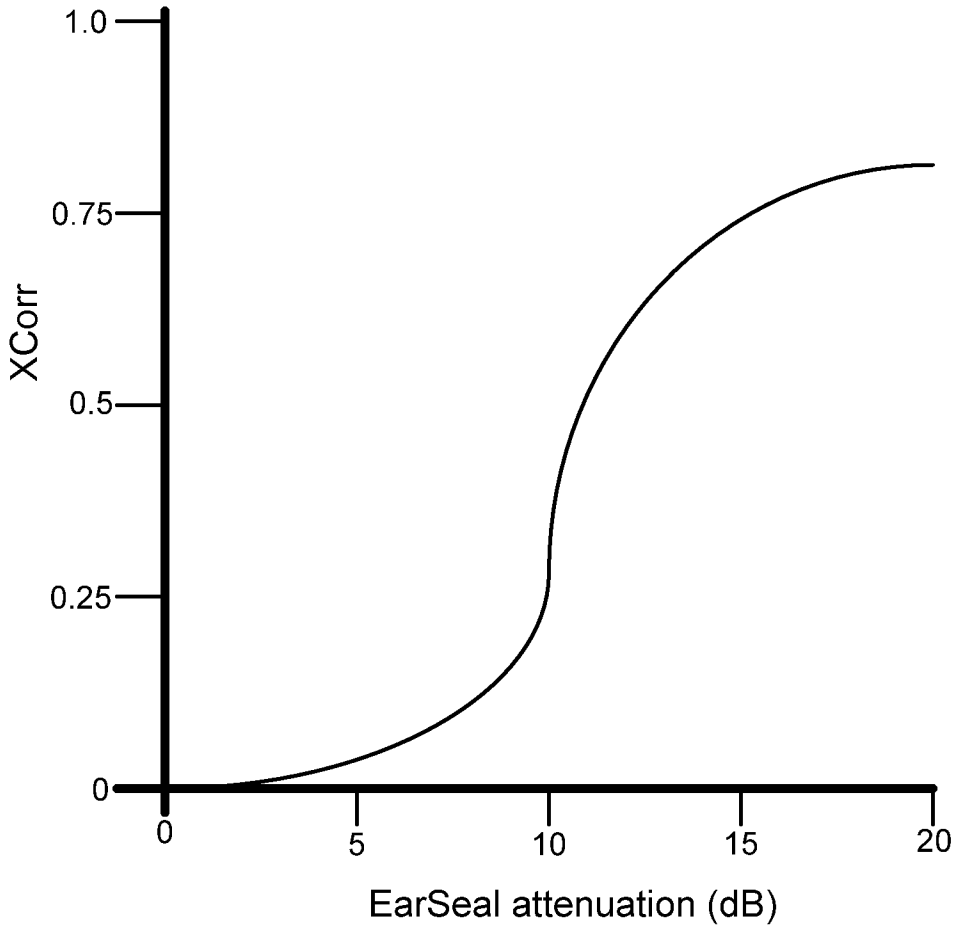

FIG. 10

APPLICATION FOR LETTERS PROVISIONAL PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

FOR:

ACOUSTIC SEALING ANALYSIS SYSTEM

By:
John Usher

FIELD OF THE INVENTION

[0001] The present invention relates to testing the seal of an orifice inserted device, and more particularly, though not exclusively, to a device and method for determining if an earpiece is sealed correctly in an ear canal.

BACKGROUND

[0002] It can be difficult to communicate using an earpiece or earphone device in the presence of high-level background sounds. In many earpiece designs a transducer is suspended over the ear canal opening. Ambient sound from the surrounding environment enters the ear canal with the audio content from the transducer. Environmental sounds such as traffic, construction, and nearby conversations can degrade the quality of the communication experience.

[0003] Although audio processing technologies can adequately suppress noise, the earpiece is generally sound agnostic and cannot differentiate sounds. Thus, one method to prevent ambient sound from entering the ear is to seal or provide

an acoustic barrier at the opening of the ear canal. Sealing ensures minimum background noise entering the ear canal under high background noise conditions. Earpiece systems may require some minimum noise isolation from the ambient to provide adequate performance to the user. User conditions may change substantially during the operation of the earpiece. In some circumstances, the earpiece may become misaligned or may be fit incorrectly such that it is not sealed correctly.

SUMMARY

[0004] Broadly stated, embodiments are directed to a device and method to determine if an earpiece is operating within the design specification of the device.

[0005] In one embodiment,. the device can include a sealing section forming acoustic barrier between a first volume and a second volume. An ear canal receiver (ECR) can be configured to generate an acoustic signal in the first volume. An Ear Canal Microphone (ECM) in the first volume can be configured to measure the acoustic signal in the first volume. The first acoustic signal emitted by the ECR can be cross-correlated with the first acoustic signal detected with the ECM to determine if the sealing section is sealed properly.

[0006] Further areas of applicability of exemplary embodiments of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Exemplary embodiments of present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0008] FIG. 1 is a diagram of an earpiece inserted in an ear canal in accordance with an exemplary embodiment;

[0009] FIG. 2 is a block diagram of the earpiece in accordance with an exemplary embodiment;

[0010] FIG. 3 is a flowchart of a method for checking an ear seal in accordance with an exemplary embodiment;

[0011] FIG. 4 is a flowchart to determine acoustic seal integrity of an earpiece in accordance with the exemplary embodiment.

[0012] FIG. 5 is a flowchart of a method to estimate the instantaneous cross-correlation between a first and second audio signal.

[0013] FIG. 6 is a flowchart to determine when to emit a test signal in accordance with an exemplary embodiment; and

[0014] FIG. 7 is a graph illustrating different seal measurements in accordance with the present invention.

DETAILED DESCRIPTION

[0015] The following description of exemplary embodiment(s) is merely illustrative in nature and is in no way intended to limit the invention, its application, or uses.

[0016] Exemplary embodiments are directed to or can be operatively used on various wired or wireless orifice inserted devices for example earpieces devices (e.g., earbuds, headphones, ear terminal, behind the ear devices or other acoustic devices as known by one of ordinary skill, and equivalents).

[0017] Processes, techniques, apparatus, and materials as known by one of ordinary skill in the art may not be discussed in detail but are intended to be part of the enabling description where appropriate. For example specific computer code may not be listed for achieving each of the steps discussed, however one of ordinary skill would be able, without undo experimentation, to write such code given the enabling disclosure herein. Such code is intended to fall within the scope of at least one exemplary embodiment.

[0018] Additionally exemplary embodiments are not limited to earpieces, for example some functionality can be implemented on other systems with speakers and/or microphones for example computer systems, PDAs, Blackberrys, cell and mobile phones, and any other device that emits or measures acoustic energy. Additionally, exemplary embodiments can be used with digital and non-digital acoustic systems. Additionally various receivers and microphones can be used, for example MEMs transducers, diaphragm transducers, for examples Knowle's

FG and EG series transducers.

[0019] Notice that similar reference numerals and letters refer to similar items in the following figures, and thus once an item is defined in one figure, it may not be discussed or further defined in the following figures.

[0020] In all of the examples illustrated and discussed herein, any specific values, for example the sound pressure level change, should be interpreted to be illustrative only and non-limiting. Thus, other examples of the exemplary embodiments could have different values.

[0021] Note that herein when referring to correcting or preventing an error or damage (*e.g.,* hearing damage), a reduction of the damage or error and/or a correction of the damage or error are intended.

[0022] At least one exemplary embodiment of the invention is directed to an earpiece for sealing or partially sealing an ear. **FIG. 1** is a diagram of an earpiece inserted in an ear canal 124 in accordance with at least one exemplary embodiment of the invention. As illustrated, the earpiece comprises an electronic housing unit 100 and a sealing unit 108. The earpiece depicts an electro-acoustical assembly for an in-the-ear acoustic assembly, as it would typically be placed in an ear canal 124 of a user 130. The earpiece is an in-ear earpiece, behind the ear earpiece, receiver in the ear, partial-fit device, or any other suitable earpiece type. The earpiece can be partially or fully occlude ear canal 124, and is suitable for use with users having healthy or abnormal auditory functioning.

[0023] The earpiece includes an Ambient Sound Microphone (ASM) 120 to capture ambient sound, an Ear Canal Receiver (ECR) 114 to deliver audio to an ear canal 124, and an Ear Canal Microphone (ECM) 106 to capture and assess a sound exposure level within the ear canal 124. The earpiece partially or fully occludes the ear canal 124 to provide various degrees of acoustic isolation. The assembly is designed to be inserted into the user's ear canal 124, and to form an acoustic seal with the walls of the ear canal 124 at a location between the entrance to the ear canal 124 and the tympanic membrane (or ear drum). In general, such a seal is typically achieved by means of a soft and compliant housing of sealing unit 108.

[0024] Sealing unit 108 is an acoustic barrier having a first side corresponding to ear canal 124 and a second side corresponding to the ambient environment. In at least one exemplary embodiment, sealing unit 108 includes an ear canal microphone tube 110 and an ear canal receiver tube 114. Sealing unit 108 creates a closed cavity of approximately 5cc or less between the first side of sealing unit 108 and the tympanic membrane in ear canal 124. As a result of this sealing, the ECR (speaker) 114 is able to generate a full range bass response when reproducing sounds for the user. This seal also serves to significantly reduce the sound pressure level at the user's eardrum resulting from the sound field at the entrance to the ear canal 124. This seal is also a basis for a sound isolating performance of the electro-acoustic assembly.

[0025] In at least one exemplary embodiment and in broader context, the second side of sealing unit 108 corresponds to the side adjacent to electronic

housing unit 100. Ambient sound microphone 120 is housed in housing unit 100 and is exposed to the ambient environment for receiving sound from the ambient environment around the user.

[0026] Electronic housing unit 100 houses system components such as a microprocessor 116, memory 104, battery 102, ECM 106, ASM 120, ECR, 114, and user interface 120. Microprocessor 116 (or processor 116) can be a logic circuit, a digital signal processor, controller, or the like for performing calculations and operations for the earpiece. Microprocessor 116 is operatively coupled to memory 104, ECM 106, ASM 120, ECR 114, and user interface 120. A wire 118 provides an external connection to the earpiece. Battery 102 powers the circuits and transducers of the earpiece. Battery 102 can be a rechargeable or replaceable battery.

[0027] In at least one exemplary embodiment, electronic housing unit 100 is adjacent to sealing unit 108. Openings in electronic housing unit 100 receive ECM tube 110 and ECR tube 112 to respectively couple to ECM 106 and ECR 114. ECR tube 112 and ECM tube 110 acoustically couple signals to and from ear canal 124. For example, ECR outputs an acoustic signal through ECR tube 112 and into ear canal 124 where it is received by the tympanic membrane of the user of the earpiece. Conversely, ECM 114 receives an acoustic signal present in ear canal 124 though ECM tube 110.

[0028] One function of ECM 106 is that of measuring the sound pressure level in the ear canal cavity 124 as a part of testing the hearing acuity of the user as well as confirming the integrity of the acoustic seal and the working condition of

the earpiece. In one arrangement, ASM 120 is housed in an ear seal of the earpiece to monitor sound pressure at the entrance to the occluded or partially occluded ear canal 124. All transducers shown receive or transmit audio signals to a processor 116 that undertakes audio signal processing and provides a transceiver for audio via the wired (wire 118) or a wireless communication path.

[0029] The earpiece can actively monitor a sound pressure level both inside and outside an ear canal 124 and enhance spatial and timbral sound quality while maintaining supervision to ensure safe sound reproduction levels. The earpiece in various embodiments can conduct listening tests, filter sounds in the environment, monitor warning sounds in the environment, present notification based on identified warning sounds, maintain constant audio content to ambient sound levels, and filter sound in accordance with a Personalized Hearing Level (PHL).

[0030] The earpiece can generate an Ear Canal Transfer Function (ECTF) to model the ear canal 124 using ECR 114 and ECM 106, as well as an Outer Ear Canal Transfer function (OETF) using ASM 120. For instance, the ECR 114 can deliver an impulse within the ear canal 124 and generate the ECTF via cross correlation of the impulse with the impulse response of the ear canal 124. The earpiece can also determine a sealing profile with the user's ear to compensate for any leakage. It also includes a Sound Pressure Level Dosimeter to estimate sound exposure and recovery times. This permits the earpiece to safely administer and monitor sound exposure to the ear.

[0031] Referring to **FIG. 2**, a block diagram of an earpiece in accordance with an exemplary embodiment is shown. A power supply 205 powers components of the earpiece including microprocessor 206 (or processor 206) and a data communication system 216. As illustrated, the earpiece includes the processor 206 operatively coupled to data communication system 216, ASM 210, ECR 212, and ECM 208. Data communication system 216 may include one or more Analog to Digital Converters and Digital to Analog Converters (DAC). The processor 206 can utilize computing technologies such as a microprocessor, Application Specific Integrated Chip (ASIC), and/or digital signal processor (DSP) with associated Random Access Memory (RAM) 202 and Read Only Memory 204. Other memory types such as Flash, non-volatile memory, SRAM, DRAM or other like technologies can be used for storage with processor 206. The processor 206 can also include a clock to record a time stamp.

[0032] In general, data communication system 216 is a communication pathway to components of the earpiece and components external to the earpiece. The communication link can be wired or wireless. In at least one exemplary embodiment, data communication system 216 is configured to communicate with ECM assembly 208, ASM assembly 210, visual display 218, and user control interface 214 of the earpiece. As shown, user control interface 214 can be wired or wirelessly connected. In at least one exemplary embodiment, data communication system 216 is capable of communication to devices exterior to the earpiece such as the user's mobile phone, a second earpiece 222, and a

portable media player 228. Portable media player 228 can be controlled by a manual user control 230.

[0033] The user's mobile phone includes a mobile phone communication system 224. A microprocessor 226 is operatively coupled to mobile phone communication system 224. As illustrated multiple devices can be wirelessly connected to one another such as an earpiece 220 worn by another person to the user's mobile phone. Similarly, the user's mobile phone can be connected to the data communication system 216 of earpiece 201 as well as the second earpiece 222. This connection would allow one or more people to listen and respond to a call on the user's mobile phone through their respective earpieces.

[0034] As illustrated, a data communication system 216 can include a voice operated control (VOX) module to provide voice control to one or more subsystems, such as a voice recognition system, a voice dictation system, a voice recorder, or any other voice related processor. The VOX module can also serve as a switch to indicate to the subsystem a presence of spoken voice and a voice activity level of the spoken voice. The VOX can be a hardware component implemented by discrete or analog electronic components or a software component. In one arrangement, the processor 206 can provide functionality of the VOX by way of software, such as program code, assembly language, or machine language.

[0035] The RAM 202 stores program instructions for execution on the processor 206 as well as captured audio processing data. For instance, memory RAM 202 and ROM 204 can be off-chip and external to the processor 206 and include a

data buffer to temporarily capture the ambient sound and the internal sound, and a storage memory to save from the data buffer the recent portion of the history in a compressed format responsive to a directive by the processor. In at least one exemplary embodiment, the data buffer can be a circular buffer that temporarily stores audio sound at a current time point to a previous time point. It should also be noted that the data buffer is configured operably with processor 206 to provide high speed data access. The storage memory can be non-volatile memory such as SRAM to store captured or compressed audio data.

[0036] Data communication system 216 includes an audio interface operatively coupled to the processor 206 and the VOX to receive audio content, for example from portable media player 228, cell phone, or any other communication device, and deliver the audio content to the processor 206. The processor 206 responsive to detecting voice-operated events from the VOX can adjust the audio content delivered to the ear canal of the user of the earpiece. For instance, the processor 206 (or the VOX of data communication system 216) can lower a volume of the audio content responsive to detecting an event for transmitting the acute sound to the ear canal of the user. The processor 206 by way of the ECM 208 can also actively monitor the sound exposure level inside the ear canal and adjust the audio to within a safe and subjectively optimized listening level range based on voice operating decisions made by the VOX of data communication system 216.

[0037] The earpiece and data communication system 216 can further include a transceiver that can support singly or in combination any number of wireless

access technologies including without limitation Bluetooth™, Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), and/or other short or long range communication protocols. The transceiver can also provide support for dynamic downloading over-the-air to the earpiece. It should be noted also that next generation access technologies can also be applied to the present disclosure.

[0038] Data communication system 216 can also include a location receiver that utilizes common technology such as a common GPS (Global Positioning System) receiver that can intercept satellite signals and therefrom determine a location fix of the earpiece 201.

[0039] The power supply 205 utilizes common power management technologies such as replaceable batteries, supply regulation technologies, and charging system technologies for supplying energy to the components of the earpiece and to facilitate portable applications. A motor (not shown) can be a single supply motor driver coupled to the power supply 205 to improve sensory input via haptic vibration. As an example, the processor 206 can direct the motor to vibrate responsive to an action, such as a detection of a warning sound or an incoming voice call.

[0040] Microprocessor 206 is operatively connected with an EarSeal Inflation Management System 232 to control the degree to which the sealing unit 108 is inflated or deflated. In one exemplary embodiment, sealing unit 108 comprises an inflatable balloon mechanism, whereby a cavity can be filled with air or a liquid to change the degree of acoustic isolation between the internal ear canal space

124 and the ambient environment. Alternately, a passive system for sealing ear canal 124 is used such as a flexible rubber or silicon sealing unit or a foam plug. In one exemplary embodiment, the passive system is a balloon mechanism that is filled with air or liquid. The balloon mechanism conforms to the shape and size of an ear canal and includes a restorative force module that applies a pressure to the balloon mechanism for sealing the ear canal cavity.

[0041] The earpiece is a single operational device or a family of devices configured in a master-slave arrangement, for example, a mobile device and an earpiece. In the latter embodiment, the components of the earpiece are reused in different form factors for the master and slave devices.

[0042] Referring to **FIG. 3**, a flowchart illustrates a method for an acoustic sealing analysis system in accordance with an exemplary embodiment. In general, a first volume is acoustically isolated from a second volume. The test determines if the two volumes have sufficient acoustic isolation from one another. For example, cars are designed to have a quiet interior. Users of an automobile do not want to be subjected to the noise of the external environment. Thus, a car interior (first volume) is acoustically isolated from the external environment outside of the automobile. Similarly, an earpiece having a sealing unit such as described in FIG. 1 will create a first volume (the ear canal) that is acoustically isolated from the ambient environment of the user (second volume). In either example, the acoustic sealing analysis system determines if there is sufficient acoustic isolation for the application. In the earpiece example, random or periodic testing of the seal may be beneficial because a new seal is formed in the

ear canal when the device is put in the ear or it may shift over time depending on user activity.

[0043] A test signal is acquired in a step 304. For example, the test signal can be stored in memory or generated by a microprocessor. The test signal is provided to the acoustic transducer. The acoustic transducer or loudspeaker emits an acoustic signal corresponding to the test signal within the first volume. The acoustic field in the first volume is detected by an Ear Canal Microphone (ECM) in a step 308. The acoustic loading on both the ECR and ECM will change depending on the degree of acoustic sealing, thereby affecting the degree magnitude of the radiated ECR signal detected by the ECM. In general, as the degree of ear seal decreases, the effect lumped air mass coupled to the ECR and ECM will decrease thereby increasing in Thevenin capacitance, which effectively reduces the transfer of low-frequency emitted sound from the ECR to the ECM.

[0044] In one exemplary embodiment, the test signal and the acoustic signal emitted by the loudspeaker into the first volume is a single frequency sine wave signal for testing leakage from one volume to another.

[0045] The degree of sealing between the first and second acoustic volumes is determined in a step 310. The cross-correlation between the emitted test signal and detected ECM signal is taken. In at least one exemplary embodiment, the test signal and the measured acoustic signal emitted by the loudspeaker are conditioned using a time delay and frequency dependent filter. The ear-seal is determined to be low (or “leaky”) if the cross-correlated signals are below a

predetermined value. In at least one exemplary embodiment, automatic adjustments to the sealing section are made (such as deflating and re-inflating the sealing balloon to reseal the sealing section including retesting). Alternately, an audible sound, vocal response, or visual response can be provided to let the user know that the earpiece is sealed correctly or incorrectly.

[0046] Referring to FIG. 1, the earpiece is used as an example to illustrate a test sequence as disclosed in **FIG. 3**. Sealing unit 108 occludes an opening of ear canal 124 creating a first volume (ear canal 124) and a second volume (the ambient environment). Sealing unit 108 has a first side exposed to ear canal 124 and a second side is exposed to or corresponds to the ambient environment external to the ear.

[0047] In at least one exemplary embodiment, processor 116 is configured to receive a test signal in memory 104. Processor 116 generates the test signal and provides the test signal to Ear Canal Receiver 114 (ECR 114). ECR 114 emits the test signal into Ear Canal Receiver Tube (ECR Tube 112). The test signal propagates through ECR tube 112 and into ear canal 124. Ear Canal Microphone tube 110 (ECM tube 110) is configured to receive an acoustic signal incident on the first side of sealing unit 108. The test signal in ear canal 124 propagates through ECM tube 110 and is received by Ear Canal Microphone 106 (ECM 106). ECM 106 is configured to measure the test signal in ear canal 124 and provide the measured test signal to processor 116.

[0048] As shown, electronic housing unit 100 of earpiece 90 is adjacent to the second side of sealing unit 108. Electronic housing unit 100 is exposed to the

ambient environment and for purposes of acoustic sealing analysis is considered the second side of sealing unit 108. Electronic housing unit 100 includes Ambient Sound Microphone 120 (ASM 120) which is configured to measure sounds in the ambient environment. Thus, ASM 120 receives and measures an ambient signal corresponding to a signal incident on the second side of sealing unit 108. ASM 120 provides the measured ambient signal to processor 116.

[0049] Ideally, sealing unit 108 is an acoustic barrier preventing the test signal or very little of the test signal from getting past sealing unit 108 and into the ambient environment. Conversely, sealing unit 108 if improperly sealed will pass some of the test signal. Processor 116 compares the test signal to the signal provided by ECM 106 corresponding to the acoustic signal in ear canal 124. In particular, processor 116 undertakes the cross-correlation between emitted test signal and the ECM signal.

[0050] Referring to **FIG. 4**, a flowchart of an exemplary method to determine the acoustic seal integrity of an earpiece in accordance with an exemplary embodiment is illustrated. In at least one embodiment of an acoustic sealing analysis system, the test signal is masked or used in a manner undetectable by the user. This allows unobtrusive (periodic or non-periodic) testing to determine if a device is sealed correctly ensuring optimum system performance and more importantly user safety.

[0051] In at least one exemplary embodiment, an audio content is provided in a step 402. A step 404 stores the test signal in a test signal data buffer. For example, a single frequency sine wave is stored in the test signal data buffer.

The output (or alternatively- input) of the test signal data buffer is optionally delayed by digital delay unit 406. The function of delay unit 406 is to time-align the emitted test signal with the ECM signal so the cross-correlation is sensitive to changes in ear seal.

[0052] A step 408 stores the test ECM signal in a test signal data buffer. The output (or alternatively- input) of the ECM signal buffer is filtered with a low-pass filter 410. The low pass filter is configured so that the pass-band covers the frequency of the test signal. In one exemplary configuration, the low-pass filter is a cascaded bi-quad IIR type filter with the cut-off frequency equal to 10 Hz greater than the test signal frequency.

[0053] A step 412 cross-correlates the optionally delay test signal buffer with the low-pass filtered ECM signal buffer. An exemplary method for the cross-correlation algorithm is described in figure 5. The instantaneous cross-correlation (i.e. the cross-correlation at zero-lag) value from step 412 is compared with the cross-correlation threshold value 414 using comparator unit 416. If the instantaneous cross-correlation of the two signal buffers is less than the threshold value 414, then the seal test status is set to FAIL 418 (i.e. an ear-seal leak is detected); otherwise, if the cross-correlation is suitably high, the seal test status is set to PASS 420.

[0054] Referring to **FIG. 5**, a flowchart of an exemplary embodiment to determine the instantaneous cross-correlation between a first and second audio signal. In at least one exemplary embodiment, the first audio signal is the test

signal (i.e. a sine wave) and the second signal is the low-pass-filtered ECM signal.

[0055] The correlation between two signals x and y at time k using an exponential window is defined as:

[0056] $$\rho(k) = \frac{S_{xy}(k)}{\sqrt{\left(S_{xx}(k) S_{yy}(k)\right)}} \qquad (1)$$

[0057] Where

[0058] $$S_{xx}(k) = \sum_{l=0}^{\infty} c e^{-\eta l} x_{k-l} y_{k-l} \qquad (2)$$
$$c = 1 - e^{-\eta}$$

[0059] And S_{xx} and S_{yy} are defined similarly as in (2) (replacing y with x for S_{xx} etc.).

[0060] It can be shown (see Aarts et al, 2001) that (1) can be approximated with the recursion:

[0061] $$\hat{\rho}(k) = \hat{\rho}(k-1) + \gamma\left[\partial_k - \beta_k \hat{\rho}(k-1)\right]$$
$$\partial_k = 2 x_k y_k \qquad (3)$$
$$\beta_k = \alpha x_k^2 \alpha^{-1} y_k^2$$

[0062] Where

[0063] $$\alpha = \frac{y_{RMS}}{x_{RMS}} \qquad (4)$$
$$\gamma = \frac{c e^{\eta}}{2 x_{RMS} y_{RMS}}$$

[0064] The cross-correlation estimate using the above recursion is modified for block-wise processing rather than the sample-by-sample basis. This modification

replaces the sample values (i.e. x(k) and y(k)) with values for the *N*-length block mean, i.e.

[0065] $$x(k) = \frac{1}{N}\sum_{l=0}^{N-1} x(k-l)$$

[0066] Furthermore, the numerator for γ is replaced with a small constant and so is α (replacing α with a constant effectively un-normalizes the correlation estimate). It is found that the modified un-normalized block-wise cross-correlation accurately estimates the cross-correlation compared with using the standard cross-correlation for two signals.

[0067] The modified block-wise fast cross-correlation algorithm, as summarized in figure 5, comprises the following steps:

1. A first signal buffer 502 is accumulated. This signal buffer corresponds to the emitted test signal (i.e. the sine wave).
2. The RMS level of the first buffer is calculated 504 (x_{RMS}).
3. The mean level of the first buffer is calculated 506.
4. A second signal buffer 508 is accumulated. This signal buffer corresponds to the filtered ECM signal.
5. The RMS level of the second buffer is calculated 510 (y_{RMS}).
6. The mean level of the second buffer is calculated 512.
7. In step 514, γ (gamma) is approximated as:

   $$\gamma = \frac{\Gamma}{2x_{RMS}\, y_{RMS}}$$

   Where Γ is a small constant, e.g. 10E-3.

8. In step 516, ∂_k (delta) is calculated as twice the product of the first signal buffer mean and the second signal buffer mean.
9. In step 518, beta is calculated as the sum of the square of the mean value of the first buffer with the sum of the square of the mean value of the second buffer.
10. In step 520, the new temporary estimate of the correlation newRho_temp is calculated as: newRho_temp = (delta – beta*rho_old))
11. In step 522, the new estimate of the correlation newRho is updated by summing the previous estimate of the correlation with the product of gamma and the temporary estimate of the correlation newRho_temp.
12. In step 524, the "old" value of the correlation is set to the newest correlation estimate, ready for the next iteration of the update algorithm.
13. In step 526, the current correlation estimate between the emitted test signal and the received and filtered ECM signal is set as equal to the value of newRho.

[0068] Referring to **FIG. 6**, a flowchart of a method to determine when to emit the test signal. The test signal is emitted when the test can be performed unobtrusively to the user and also provides an accurate test. In at least one exemplary embodiment, a test event to determine if an earpiece is sealed correctly is initiated via a timing methodology. In a first timing scenario, the test

event occurs after a delay of a first predetermined time period when the RMS of the Audio Content (AC) is less than a RMS threshold. In a second timing scenario, the delay of the first predetermined time period is allowed to lapse without the test event occurring when the RMS of the audio content is greater than the RMS threshold. A second predetermined time period is started where the test event occurs when the RMS of the audio content is less than RMS threshold. The test event is then initiated when the second predetermined time period is exceeded independent of the RMS of the audio content.

[0069] A test sequence is initiated in a step 602. The previous seal test event resets the first digital timer in a step 604. A time delay is generated by the loop comprising steps 606 and 608. The first digital timer is time incremented in the step 606. After each added time increment, the first digital timer is compared against a digital_timer_threshold1. The first digital timer is time incremented (after the time has advanced another increment) after the comparison in the step 606 if the first digital timer is less than the digital_timer_threshold1.

[0070] A second digital timer is reset in a step 610 when the first digital timer is greater than the digital_timer_threshold1. The second digital timer is time incremented in a step 612. Audio content (AC) from a signal buffer is retrieved in a step 614. The audio content can be filtered through a low pass filter in an optional step 616. The RMS of the audio content is calculated in a step 618. The calculated RMS of the audio content is compared against an RMS_threshold 622 in a step 620. The second digital timer is compared against a digital_timer_threshold2 in a step 624 if the RMS of the audio content is greater

than the RMS_threshold. The second digital timer is time incremented (after the time has advanced another increment) when the second digital timer is less than digital_timer_threshold2 in the step of 624.

[0071] The audio content signal is mixed with the test signal when the RMS of the audio content is less than the RMS_threshold in a step 626. Also, the audio content signal is mixed with the test signal when the second digital timer is greater than digital_timer_threshold2 in the step 626. The modified audio signal (having the test signal mixed in) is emitted by the ECR in a step 628 for testing the sealing section of the earpiece. The first digital timer is then reset in the step 604 to begin a timing sequence for another sealing section test.

[0072] **FIG. 7** is a graph illustrating different seal measurements in accordance with the present invention. The estimated un-normalized cross-correlation between the ECM signal and the test signal (i.e. sine wave) is shown for different sine wave frequencies from 30-80 Hz. Three different curves are provided corresponding to a good fit (i.e. a tight optimal seal providing approximately 20-30 dB of acoustic attenuation), mid or partial seal (i.e. an ear-seal that could be characterized as “half in” providing approximately 10-15 dB of acoustic attenuation), and a poor seal (i.e. an ear-seal providing less than 10 dB of acoustic attenuation). At lower test frequencies, the change in correlation is more pronounced as the degree of ear seal fitting is changed from “good” to “mid” and “poor”. From the data, the threshold used to determine whether the ear seal can be characterized as “good” is approximately -20 dB, (i.e. 0.85 of FIG. 10 which corresponds to the value for XCorr_threshold 414 in FIG. 4**).**

[0073]

In at least one exemplary embodiment, the test signal for testing a seal of a sealing section is less than 200 hertz. The frequency of the emitted test signal is chosen to satisfy the requirements of being able to reveal small degradations in ear seal quality. It is also beneficial if the selected test signal frequency can be acoustically masked by reproduced audio to minimize detection of the test by an earpiec user. Both of these criteria are met using a test signal frequency below 200 Hz. The sensitivity is highest from the measured data at frequencies below 50 Hz. Conversely, as the test signal frequency increases the cross-correlation difference between a “good” and “bad” acoustic seal decreases. For example, with a 40 Hz test tone, the cross-correlation for a “good” ear seal is -8 dB, and for a bad ear seal it is -68 dB (i.e. a 60 dB difference). At a test signal frequency of 80 Hz, the cross-correlation for a “good” ear seal is -8 dB and for a bad ear seal it is -38 dB (i.e. a 30 dB difference). Thus, above 200 Hz the cross-correlation difference between a “good” and “bad” acoustic seal is further reduced thereby reducing the sensitivity of the test.

[0074] Using the cross-correlation rather than a level differencing approach improves the accuracy and minimizes errors which occur due to user non-speech body noise, such as teeth chatter; sneezes, coughs, etcetera. Furthermore, such non-speech user generated noise would generate a larger sound level in the ear canal than on the outside of the same ear canal producing inaccurate results.

[0075] **FIG. 8** is a flowchart to adjust the degree of acoustic sealing of an Inflation Management System (IMS) in accordance with an exemplary

embodiment. The IMS is adjusted depending on the degree of acoustic sealing provided by an earpiece is shown. The acoustic sealing is measured as disclosed in FIG. 7 and the result provided in a step 804. to determine the cross-correlation (XCorr) between a test signal and corresponding ECM signal. In general, the higher the cross-correlation, the higher the degree of acoustic sealing. An exemplary graph showing the relationship between XCorr and acoustic sealing is given in **FIG. 10.** The degree of acoustic sealing is determined from known XCorr using a look-up (or "hash") table or using a formula (e.g. of a polynomial form) that maps the acoustic sealing to the known XCorr value. The ambient sound level is measured in a step 806. The ambient sound level corresponds to the noise level in proximity to the user. In general, a higher degree of attenuation is desired when the ambient sound levels are high. Conversely, at low ambient sound levels the attenuation level of the IMS may be less of an issue and comfort more of a factor. The IMS is adjusted in a step 808 to meet the attenuation needs. In general, inflating the IMS to increases attenuation while deflating the IMS decreases attenuation.

[0076] Referring to **FIG. 9**, is a more detailed flowchart to adjust the degree of acoustic sealing of an Inflation Management System (IMS). In general, the attenuation increases when the pressure in the IMS is raised thereby allowing a degree of control to make adjustments. For example, an adjustment is made to increase attenuation when the background noise level rises or a seal check produces a failed result. Adjustments are made until the seal check passes. The pressure level adjustments of the IMS will fall within a comfort range of a user.

Typically, the pressure level is set at a minimum level to achieve a predetermined attenuation level.

[0077] The degree of acoustic sealing is determined from cross-correlation between the ECM signal and the test signal generating. The XCorr value is provided in a step 906. The attenuation provided by the IMS is calculated (equation) or looked up (table) from data such as that shown in FIG. 10. In one exemplary embodiment, the desired attenuation value is dependant on the ambient sound level of the user. In another exemplary embodiment, the desired attenuation value is dependant on the ear-canal sound level of the user. In yet another exemplary embodiment, the desired attenuation value is dependant on the level of audio content (e.g. speech or music audio) reproduced with the earphone device. In all of the above examples, the desired attenuation value is determined by one or more of the embodiments in a step 907.

[0078] The difference between the degree of acoustic sealing determined in step 906 and the desired attenuation value determined in step 907 is calculated in step 908. The difference value in step 908 is used to determine the change in pressure of the IMS necessary to minimize the difference value in a step 910. In at least one exemplary embodiment, the difference value of the attenuation is converted into a corresponding pressure value change (e.g. in milli-Bars) using a similar look-up table or equation method as described previously. The pressure change in the IMS is then affected with step 912 to meet the desired attenuation level.

[0079] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all modifications, equivalent structures and functions of the relevant exemplary embodiments. For example, if words such as “orthogonal”, “perpendicular” are used the intended meaning is “substantially orthogonal” and “substantially perpendicular” respectively. Additionally although specific numbers may be quoted in the claims, it is intended that a number close to the one stated is also within the intended scope, i.e. any stated number (e.g., 90 degrees) should be interpreted to be “about” the value of the stated number (e.g., about 90 degrees).

[0080] Thus, the description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the exemplary embodiments of the present invention. Such variations are not to be regarded as a departure from the spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. A device comprising:

a sealing section configured to seal a user's orifice, where the sealing section is configured to produce an acoustic seal between a first side of the sealing section and a second side of the sealing section;

a transducer configured to emit a test signal incident on the first side of the sealing section; and

a microphone configured to measure an acoustic signal incident on the first side of the sealing section, where the acoustic signal includes the test signal emitted from the transducer where the acoustic signal is cross-correlated to the test signal to determine if the sealing section is sealed.

2. The device of claim 1, where the orifice is an ear canal and where the sealing section is configured to reduce acoustic energy passing through the sealing section between the first side of the sealing section and the second side of the sealing section when the sealing section is sealed.

3. The device of claim 1, further including a processor operatively coupled to the transducer and operatively coupled to the first microphone where the processor has been configured to compare the test signal to the acoustic signal to determine if the sealing section is sealed.

4. -The device of claim 1 where the sealing section has passed a sealing test when the cross-correlation is equal to or greater than a threshold.

5. The device according to claim 1,where the sealing section has failed a sealing test when the cross-correlation is less than a threshold.

6. The device according to claim 4 where the threshold corresponds to an attenuation level of the sealing section.

7. The device according to claim 7 where an indication is provided to the user indicating the sealing section is improperly sealed.

8. The device according to claim 1 where a volume on the first side of the sealing section is less than 5 cubic centimeters.

9. A method of detecting sealing integrity of an earpiece comprising the steps of:

providing a test signal;

generating an acoustic signal corresponding to the test signal incident on an ear canal side of a sealing section;

converting the acoustic signal incident on a first side of the sealing section to an electrical signal; and

cross-correlating the test signal to the electrical signal where the earpiece is sealed correctly when a cross-correlation between the test signal and the

electrical signal is above a threshold.

10. The method of claim 9 further including a step of using a single frequency tone to test sealing integrity of the earpiece where the single frequency tone is less than 200 hertz.

11. The method of claim 10 further including a step of filtering the electrical signal with a low pass filter having a cut-off frequency less than or equal to 10 Hertz greater than the single frequency tone for testing sealing integrity.

12. The method of claim 9 further including the steps of:

testing the sealing integrity of the earpiece when the sealing section is initially inserted in an ear canal of a user

periodically testing the sealing integrity of the earpiece while in use by the user.

13. The method of claim 12 where the step of periodically testing the sealing integrity of the earpiece further includes the steps of:

initiating a first timing sequence;

comparing a time of the first timing sequence against a first predetermined time period;

retrieving audio content from a signal buffer when the time of the first timing sequence is greater than the first predetermined time period;

initiating a second timing sequence for a second predetermined time period;

calculating the RMS of the audio content;

comparing the RMS of the audio content to a RMS threshold where the test signal is mixed with the audio content for providing a modified test signal if the audio content RMS is less than the RMS threshold;

emitting the modified test signal; and

resetting the first and the second timing sequence.

14. The method of claim 13 where the step of calculating audio content RMS further includes a step of filtering the audio content with a low pass filter.

15. The method of claim 13 further including the steps of:

periodically retrieving audio content from the signal buffer after the second timing sequence has been intitiated;

calculating the RMS of the audio content;

comparing the RMS of the audio content to a RMS threshold where the test signal is mixed with the audio content for providing a modified test signal if the audio content RMS is less than the RMS threshold;

emitting the modified test signal; and

resetting the first and the second timing sequence.

16. The method of claim 14 further including the steps of:

comparing a time of the second timing sequence against a second predetermined time period;

mixing the test signal with audio content for providing a modified test signal when the time of the second timing sequence is greater than the second predetermined time period;

emitting the modified test signal; and

resetting the first and the second timing sequence.

17. A method of adjusting attenuation of an earpiece comprising the steps of:

relating cross-correlation of a test signal and a measured acoustic signal in an ear canal of a user to an attenuation level of a sealing section of the earpiece;

comparing the attenuation level of the sealing section of the earpiece to a minimum attenuation value; and

adjusting a pressure of the sealing section to meet the minimum attenuation value.

18. The method of claim 17 further including a step of increasing the pressure of the sealing section to raise the attenuation level of the sealing section of the earpiece.

19. The method of claim 17 further including a step of decreasing the pressure of the sealing section such that the attenuation level of the sealing section is equal to or greater than the minimum attenuation level to improve comfort to the user of the earpiece.

20. The method of claim 17 further including a step of limiting the sealing section to a predetermined maximum pressure level.

21. The method of claim 17 further including a step of adjusting the sealing section to meet the minimum attenuation level as a background noise level changes.

22. The method of claim 17 further including a step of adjusting the minimum attenuation level by the Ear-Canal Sound Level of the earphone device.

23. The method of claim 17 further including a step of adjusting the minimum attenuation level by the level of audio content reproduced with the earphone device.

ABSTRACT

An earpiece for sealing to an ear canal is provided. The earpiece includes a sealing section (108) that is an acoustic barrier between the ear canal and the ambient environment. A transducer (114) generates a test signal in the ear canal to determine if the sealing section (108) is sealing correctly. A microphone (106) is configured to measure an acoustic signal in the ear canal volume. The acoustic signal includes the test signal. The test signal is cross-correlated against the acoustic signal to determine if the sealing section is sealed properly. The degree of acoustic sealing is used to adjust the attenuation level of a sealing section of the earpiece or alert the user that the sealing section (108) of the seal status.

Electronic Patent Application Fee Transmittal

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Filing Date:	
Title of Invention:	Acoustic Sealing System
First Named Inventor/Applicant Name:	John Usher
Filer:	Marc Andre Boillot
Attorney Docket Number:	PERS-0071-PR

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Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Provisional Application filing fee	2005	1	105	105
Pages:				
Claims:				
Miscellaneous-Filing:				
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Warnings:					
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3		PERS0071-PR_Spec.pdf	138212 666cf404c05b7e20f38307b49b439054b7b7d886	yes	34

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	27
Claims	28	33
Abstract	34	34

Warnings:					
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4	Fee Worksheet (PTO-06)	fee-info.pdf	28841 384e4cc86c4c04d60fef81c0732d5796898a2649	no	2
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