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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
60/893,617	03/07/2007		100			

CONFIRMATION NO. 1849

32146
STEVE W. GOLDSTEIN
16390 MADOLENA PLACE
DEL RAY BEACH, FL33446

FILING RECEIPT

Date Mailed: 04/05/2007

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Applicant(s)

Stevem Wayne Goldstein, Delray Beach, FL;

Power of Attorney: None

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

Non-Publication Request: No

Early Publication Request: No

** SMALL ENTITY **

Title

Headwear Acoustic Equalization system (HEQS)

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	
		Application Number	
Title of Invention	AHeadwear Acoustic Equalization system (HEQS)		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

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Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117	☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Stevem	Wayne	Goldstein		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Delray Beach	State/Province	FI	Country of Residence i	US
Citizenship under 37 CFR 1.41(b) i		US			
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Address 1	16390 Maddalena Place				
Address 2					
City	Delray Beach	State/Province	FI		
Postal Code	33446	Countryi	US		
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Customer Number	32146		
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Email Address	mhbbehb@aol.com		Remove Email

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	
		Application Number	
Title of Invention	AHeadwear Acoustic Equalization system (HEQS)		

Application Information:

Title of the Invention	AHeadwear Acoustic Equalization system (HEQS)		
Attorney Docket Number		Small Entity Status Claimed	☒
Application Type	Provisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	9	Suggested Figure for Publication (if any)	
Publication Information:			
☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)			
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not been and will not be the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing.			

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Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	
		Application Number	
Title of Invention	AHeadwear Acoustic Equalization system (HEQS)		

			Remove
Application Number	Country ⁱ	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			☒ Yes ☐ No
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Signature	/stevegoldstein/		Date (YYYY-MM-DD)	2007-03-07
First Name	Steven	Last Name	Goldstein	Registration Number

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Headwear Acoustic Equalization System

Abstract:

A system to compensate for the acoustic filtering of headwear (hats, helmets, fire-proof headwear etc) is herein described. The Headwear Acoustic Equalization System (HEQS) empirically measures or determines the acoustic filtering properties of a head garment on a continuous, intermittent, or discrete basis. The acoustic filtering properties is used to compensate for the change in response of a microphone mounted on the user's head (e.g. at or near the entrance to the ear canals) from an external sound source (e.g. voice) by filtering the microphone signal with an audio signal filter (which may be adaptive or one from a pre-defined filter database).

Background

1. Field of the invention

This invention pertains to sound reproduction, sound recording, audio forensics and audio communications using headsets. Particularly, the new audio system describes a method for compensating the signal response of a sound sensor due to the frequency-dependant acoustic attenuation of external sound sources by headwear.

2. Background.

Two-way audio headsets provide the means for a user to monitor an audio signal and to detect sound in the users local environment (such as user-generated speech and ambient sounds) for transmission to a second person or a data storage system. US Pat, no. 7,110,551 describes a headset with a microphone for monitoring the Sound Pressure

Level (SPL) of a user's local ambient sound field so as to provide active noise control for an audio signal reproduced with a receiver transducer mounted on the same headset.

A problem with the system in US Pat. No. 7,110,551, which the present invention improves upon, is that the acoustic absorption properties of any material between the microphone sensor and receiver transducer is not considered. Furthermore, the signal may be affected by sound-reflections from headwear the user is wearing, e.g. reflections from the brim of a helmet or baseball cap.

Examples of headwear which may affect the sound received by an Ambient Sound Microphone positioned at or near an individual's ear are: a military helmet, a SWAT hood, balaclava, cold-weather face mask, helmet liner, neoprene camouflage face mask, religious headwear such as a burka or turban, or a fireproof face mask as typically worn by fighter pilots and fire-service workers (fire men/ women).

A particular use of the present invention is with emergency workers (particularly, fire-fighters) using the Personal Alert Safety System (PASS). This is commonly worn independently or as a part of the self contained breathing apparatus to acoustically alert others when a firefighter stops moving for a period of time or manually operates the device. The PASS device sounds an alarm that can assist another firefighter locating the firefighter in distress. A problem with the PASS is that firefighters and materials from a burning building may fall on top of the device, thus attenuating the acoustic radiation from the emergency sound beacon. Furthermore, due to headwear typically worn by firefighters such as helmets and fireproof (NOMEX) hoods, and the fact that firefighters often suffer from noise induced hearing loss (Reischl, 1981), it may be difficult for comrade firefighters to hear a PASS sound from a firefighter in distress. The HEQS addresses this problem of PASS device recognition by automatically equalizing for the sound attenuation of headwear the firefighter may use.

US Pat. No. 2006/0068857A1 describes a hybrid audio monitoring system with microphone and loudspeaker transducers for connecting with a communication device such as a cell phone or walky-talky. Similarly, US Pat. No. 2006/0182287 A1 describes an audio monitoring system which monitors sound in a User's local environment using one or two microphone sensors mounted at or the entrance to the user's ear canal- thereby

enabling a binaural audio recording, analysis, transmission to a second person, or monitoring by the user. However, if the user is wearing any headwear, such as a helmet or hat, then the sound field at the microphone sensors will be affected due to the acoustic absorption and diffraction of the headwear. The resulting affect of a monitored signal is that the binaural signal will sound muffled, with high frequencies attenuated. The present invention enables a signal from a microphone sensor occluded or partly occluded by headwear to be filtered using analog or digital signal processing circuitry and to equalize for the acoustic filtering effect. This allows for the monitored or recorded audio signal (which may be from one or more microphones) to be auditioned with a neutral sound character, to have a timbral quality as if the headwear was absent.

3. Brief summary of the invention

The present invention concerns an automatic, self-contained audio signal equalization system to compensate for the acoustic filtering effect of headwear, so that the audio signal monitored by one or more microphones mounted near the users head has a response similar to the microphone response with the headwear removed.

The HEQS is activated either manually in response to a user-generated command (e.g. a user voice command or with a switch interface), or automatically by monitoring changes in the user's ambient sound field on a continuous or intermittent basis. Alternatively, the HEQS may be activated manually by a second operator, e.g. a command officer in a remote location using a wireless data control system.

In the automatic activation mode, the presence of headwear on the HEQS user may be detected using a SONAR-based system, whereby the HEQS emits a sound from one or more External Receivers (ERs), and a sound reflection is detected by one or more Ambient Sound Microphones (ASMs); these transducer may be located on the HEQS device. Alternatively, the presence of headwear on the HEQS user may be detected in response to user-generated speech, whereby a change in the detected spectral profile of the ASM signal is used as an indication that headwear is worn by the user.

The acoustic absorption properties of the headwear are automatically determined by the HEQS, and the ASM signal is then electronically filtered to compensate for this

acoustic filtering so that the modified ASM signal is similar to the ASM signal if the headwear was not worn by the user.

The acoustic absorption properties of the headwear may be determined in a number of ways. One way is by an analysis of the sound reflection characteristics of the SONAR method described above, whereby a sound signal is emitted by an External Receiver. The sound signal for this SONAR method may be, for instance, one or more chirp signals; an MLS-type signal; one or more impulse signals. The signal detected by the Ambient Sound Microphones will therefore be modified by any headwear the user may be wearing, and this spectral and temporal modification can be determined by analysis of the transfer function or impulse response of the detected signal by the ASM compared with the signal emitted by the ER, using a deconvolution method familiar to those skilled in the art. The measured temporal impulse response (or its frequency domain transfer-function equivalent) can then be compared a look-up table stored in computer memory that maps the measured impulse response to particular materials or particular headwear.

Another way the acoustic absorption properties of the headwear is determined is by analysis of the ASM signals in response to specific or general user-generated speech. In this particular mode, a reference user speech spectral profile is first made whilst no headwear is worn. This is undertaken by the user verbally speaking either general speech or by repeating specific speech words (e.g. words which are chosen to be phonetically balanced with respect to each other), and the signal detected by the ASMs is recorded and stored in computer-memory. Alternatively, this reference user voice spectral profile may be obtained using non-speech sounds such as whistles. When the HEQS equalization system is activated, a second user voice spectral profile is obtained; which is made by analyzing the ASM signal. Again, this user voice spectral profile may be obtained as the user is uttering general speech or specific speech words. The first reference user voice spectral profile is then compared with this second user voice spectral profile to create a third difference spectral profile, and the difference spectral profile is analyzed. If this third spectral profile signal is indicative of headwear, then equalization is applied to the ASM signal using a digital or analog audio signal filter.

The specific signal equalization applied to the ASM signal may be constantly updated (i.e. using an adaptive filter); or may be empirically determined once using the voice stimulus method previously described; or thirdly, the specific equalization parameters may be recalled from a database stored in computer memory, e.g. an acoustic filter for a specific headwear such as a helmet.

References

Reischl, U., Hanks, T. G., & Reischl, P. (1981). Occupation related firefighter hearing loss. *American Industrial Hygiene Association Journal*, 42, 656-662

Headwear Acoustic Equalization system (HEQS)

Embodiments

- 1. A self-contained Headwear Acoustic Equalization system (HEQS) to compensate for the acoustic filtering of headwear (hats, helmets, fire-proof headwear etc) is herein described. The Headwear Acoustic Equalization System (HEQS) empirically measures or determines the acoustic filtering properties of a head garment on a continuous, intermittent, or discrete basis. The acoustic filtering properties is used to compensate for the change in response of a microphone mounted on the user's head (e.g. at or near the entrance to the ear canals) from an external sound source (e.g. voice) by filtering the microphone signal with an audio signal filter (which may be adaptive or one from a pre-defined filter database). The HEQS comprises:**

- A. An assembly to monitor the acoustic field in a Users immediate environment using one or more Ambient Sound Microphones (ASMs) located near to or at the entrance to one or both occluded ear canals.
- B. A signal processing circuit to amplify the signal from the ASMs in (A) and to equalize for the frequency sensitivity of the microphones and to low-pass filter (LPF) the signals prior to digital conversion to prevent aliasing (with the cut-off frequency of the LPF equal or less than half the sampling frequency of the digital sampling system).
- C. An analog-to-digital converter (ADC) to convert the filtered analog signals in (B) to a digital representation.
- D. An optional beam-forming platform that takes as its inputs the digital signals from the ASMs from one or both headsets to selectively affect the spatial sensitivity of the headset to sound in the user's local environment.
- E. An assembly to generate a desired SPL at or near the entrance to one or both occluded (or partly occluded) ear canals consisting of a loudspeaker receiver mounted in an earplug that forms an acoustic seal of the ear canal. (This is the External Receiver; ER).
- F. A signal processing circuit to amplify the signal to the ER to equalize for the frequency sensitivity of the transducer.
- G. An digital-to-analog convert (DAC) to convert a digital audio signal into an analog audio signal for reproduction with the ER.
- H. A HEQS initialization system to start the HEQS; which may be manually by the user with a voice-activation or with a physical switch, or may be remote activation by a second person, or may be automatically by a system which detects when headwear is adjusted or fitted, or may be on a continuous or intermittent basis.
- I. A system to detect whether the HEQS user is wearing headwear. Examples of headwear include: a military helmet, a SWAT hood, balaclava, cold-weather face mask, helmet liner, neoprene camouflage face mask, religious headwear such as a burka or turban, or a fireproof face mask as typically worn by fighter pilots and fire-service workers (fire men/ women).

- J. A system to determine the frequency-dependant acoustic attenuation of the headwear from an ambient sound source (such as the user's voice or a sound-creating object in the environment of the user) to the ASM(s). This attenuation transmission index is called ATI_HW.
- K. A system to filter the ASM signal with the inverse of the ATI_HW of the headwear, so as to give an ASM signal similar to that with the headwear absent.
- L. A system to update the ATI_HW automatically on a continuous basis.
- M. A system to update the ATI_HW manually from either a user-generated command or a command issued by a second remote person.
- N. A system to update the ATI_HW automatically on an intermittent basis (e.g. every 10 minutes).
- O. A system to transmit the ATI_HW to a data storage or analysis system using a wired or wireless data transmission system.

2. Another embodiment of the invention enables the HEQS to automatically determine if headwear is worn using a self-contained SONAR-based headwear detection platform. A SONAR test sound is emitted with an external receiver mounted on the headset device, and it's sound reflection is detected using one or more ambient sound microphones mounted on the same headset. The reflected sound is analyzed to determine the presence of headwear. This SONAR-based headwear detection platform comprises:

- A. An assembly to monitor the acoustic field in a Users immediate environment using one or more Ambient Sound Microphones (ASMs) located near to or at the entrance to one or both occluded ear canals.
- B. A signal processing circuit to amplify the signal from the ASMs in (A) and to equalize for the frequency sensitivity of the microphones and to low-pass filter (LPF) the signals prior to digital conversion to prevent aliasing (with the cut-off frequency of the LPF equal or less than half the sampling frequency of the digital sampling system).
- C. An analog-to-digital converter (ADC) to convert the filtered analog signals in (B) to a digital representation.
- D. An optional beam-forming platform that takes as its inputs the digital signals from the ASMs from one or both headsets to selectively affect the spatial sensitivity of the headset to sound in the user's local environment.
- E. An assembly to generate a desired SPL at or near the entrance to one or both occluded (or partly occluded) ear canals consisting of a loudspeaker receiver mounted in an earplug that forms an acoustic seal of the ear canal. (This is the External Receiver; ER).
- F. A signal processing circuit to amplify the signal to the ER to equalize for the frequency sensitivity of the transducer.
- G. An digital-to-analog convert (DAC) to convert a digital audio signal into an analog audio signal for reproduction with the ER.
- H. An initialization system to start the SONAR-based headwear detection platform; which may be manually by the user with a voice-activation or with a physical switch, or may be remote activation by a second person, or may be automatically by a system which detects when headwear is adjusted or fitted, or may be on a continuous or intermittent basis.
- I. A system to generate or retrieve from computer memory a SONAR audio data test signal. This signal may be one of the following types:
 - a. Swept sine "chirp" signal.
 - b. Maximum Length Sequence (MLS) test signal.
 - c. Dirac transient click signal.

- d. Music audio signal.
- e. Noise signal (white noise or link noise).
- J. Circuitry to reproduce the audio test signal in (I) with the external receiver.
- K. A system to simultaneously record the ASM signal whilst the test signal in (I) is reproduced with the ER.
- L. A system to repeat the reproduction of the test signal in (I).
- M. A system to analyze the recorded ASM signal in response to the SONAR test signal to determine if headwear is worn. This system comprises a method to deconvolve the recorded ASM signal to give a time domain impulse response or frequency domain transfer function with reference to the original SONAR test audio signal.
- N. A system to determine if headwear is worn by analysis of the deconvolved test impulse response (IR) or transfer function (TF) in (M) with respect to a reference IR or TF made with no headwear worn.

3. Another embodiment of the invention enables the HEQS to automatically determine the frequency-dependant acoustic absorption characteristics of the headwear worn by a user (this is the Headwear acoustic Attenuation Transmission Index or ATI_HW). Once obtained, the ASM signal is filtered with a filter corresponding to the inverse of ATI_HW. This self-contained SONAR-based headwear determination platform uses a SONAR test sound emitted with an external receiver mounted on the headset device, and it's sound reflection is detected using one or more ambient sound microphones mounted on the same headset. The reflected sound is analyzed to

determine the headwear using a look-up table analysis with previous measurements of known headwear. This SONAR-based headwear determination platform comprises:

- A. An assembly to monitor the acoustic field in a Users immediate environment using one or more Ambient Sound Microphones (ASMs) located near to or at the entrance to one or both occluded ear canals.
- B. A signal processing circuit to amplify the signal from the ASMs in (A) and to equalize for the frequency sensitivity of the microphones and to low-pass filter (LPF) the signals prior to digital conversion to prevent aliasing (with the cut-off frequency of the LPF equal or less than half the sampling frequency of the digital sampling system).
- C. An analog-to-digital converter (ADC) to convert the filtered analog signals in (B) to a digital representation.
- D. An optional beam-forming platform that takes as its inputs the digital signals from the ASMs from one or both headsets to selectively affect the spatial sensitivity of the headset to sound in the user's local environment.
- E. An assembly to generate a desired SPL at or near the entrance to one or both occluded (or partly occluded) ear canals consisting of a loudspeaker receiver mounted in an earplug that forms an acoustic seal of the ear canal. (This is the External Receiver; ER).
- F. A signal processing circuit to amplify the signal to the ER to equalize for the frequency sensitivity of the transducer.
- G. An digital-to-analog convert (DAC) to convert a digital audio signal into an analog audio signal for reproduction with the ER.
- H. An initialization system to start the SONAR-based headwear detection platform; which may be manually by the user with a voice-activation or with a physical switch, or may be remote activation by a second person, or may be automatically by a system which detects when headwear is adjusted or fitted, or may be on a continuous or intermittent basis.

- I. A system to generate or retrieve from computer memory a SONAR audio data test signal. This signal may be one of the following types:
 - a. Swept sine “chirp” signal.
 - b. Maximum Length Sequence (MLS) test signal.
 - c. Dirac transient click signal.
 - d. Music audio signal.
 - e. Noise signal (white noise or link noise).
- J. Circuitry to reproduce the audio test signal in (I) with the external receiver.
- K. A system to simultaneously record the ASM signal whilst the test signal in (I) is reproduced with the ER.
- L. A system to repeat the reproduction of the test signal in (I).
- M. A system to analyze the recorded ASM signal in response to the SONAR test signal to determine if headwear is worn. This system comprises a method to deconvolve the recorded ASM signal to give a time domain impulse response or frequency domain transfer function with reference to the original SONAR test audio signal.
- N. A system to determine if headwear is worn by analysis of the deconvolved test impulse response (IR) or transfer function (TF) in (M) with respect to a reference IR or TF made with no headwear worn.
- O. A system to determine what headwear is worn by the user by comparing the empirically obtained IR or TR with a library of measured IRs or TRs previously obtained. The empirically obtained IR or TR is matched with the particular previously measured IR or TR using, for example, the method of least-squared difference.
- P. A system to obtain the ATI_HW of the worn headwear using a look-up table of previously measured ATI_HW’s corresponding to particular headwear IR’s.
- Q. A system to filter the ASM signal with a filter corresponding to the inverse of the obtained ATI_HW. In the preferred embodiment, this filter is a digital FIR-type filter.

4. Another embodiment of the invention enables the HEQS to automatically determine if headwear is worn using a self-contained Voice-based headwear detection platform. A Voice test sound is generated by the HEQS user, and is simultaneously detected using one or more ambient sound microphones mounted on the same headset. In some embodiments the user-generated sound is a non-voice sound such as a hand-clap or mouth whistle. The measured sound is analyzed to determine the presence of headwear. This Voice-based headwear detection platform comprises:

- A. An assembly to monitor the acoustic field in a Users immediate environment using one or more Ambient Sound Microphones (ASMs) located near to or at the entrance to one or both occluded ear canals.
- B. A signal processing circuit to amplify the signal from the ASMs in (A) and to equalize for the frequency sensitivity of the microphones and to low-pass filter (LPF) the signals prior to digital conversion to prevent aliasing (with the cut-off frequency of the LPF equal or less than half the sampling frequency of the digital sampling system).
- C. An analog-to-digital converter (ADC) to convert the filtered analog signals in (B) to a digital representation.
- D. An optional beam-forming platform that takes as its inputs the digital signals from the ASMs from one or both headsets to selectively affect the spatial sensitivity of the headset to sound in the user's local environment.
- E. An digital-to-analog convert (DAC) to convert a digital audio signal into an analog audio signal for reproduction with the ER.

- F. An initialization system to start the Voice-based headwear detection platform; which may be manually by the user with a voice-activation or with a physical switch, or may be remote activation by a second person, or may be automatically by a system which detects when headwear is adjusted or fitted, or may be on a continuous or intermittent basis.
- G. A system to obtain a Reference User Voice Profile (rUVP); when activated by the system in (F), the rUVP acquisition system works by the user generating some general or predefined verbal messages (e.g. a collection of phonemically balanced words, prompted by a messaging system reproduced with the ear canal receiver). Alternatively, the user may be asked to generate non-verbal sound stimuli, such as hand claps or mouth-whistles. Whilst the user creates the Reference sound message, the ASM signals are simultaneously recorded. The resulting spectral profiles is the rUVP.
- H. A system to obtain a Current User Voice Profile (cUVP); when activated by the system in (F), the cUVP acquisition system works by the user generating some general or predefined verbal messages (e.g. a collection of phonemically balanced words, prompted by a messaging system reproduced with the ear canal receiver). Alternatively, the user may be asked to generate non-verbal sound stimuli, such as hand claps or mouth-whistles. Whilst the user creates the Reference sound message, the ASM signals are simultaneously recorded. The resulting spectral profiles is the cUVP.
- I. A system to compare the rUVP and cUVP, and thus determine if headwear is used. This comparison may be in the time domain, but in the preferred embodiment the comparison is in the frequency domain. If the frequency content of the cUVP is less than the rUVP at particular frequencies (e.g. $1/3^{\text{rd}}$ octave measurements made at 1 kHz and 4 kHz) by a pre-defined amount (e.g. 5 dB), then it may be deemed that headwear is currently being worn.

5. Another embodiment of the invention enables the HEQS to automatically determine the frequency-dependant

acoustic absorption characteristics of the headwear worn by a user (this is the Headwear acoustic Attenuation Transmission Index or ATI_HW). Once obtained, the ASM signal is filtered with a filter corresponding to the inverse of ATI_HW. This self-contained Voice-based headwear determination platform uses a Voice or non-voice (e.g. hand-clap) test sound created by the HEQS user, and is simultaneously recorded using one or more ambient sound microphones mounted on a headset near to or in the user's ear canal. The recorded sound is analyzed to determine the particular headwear and its corresponding ATI_HW using a look-up table analysis with previous measurements of known headwear. This Voice-based headwear determination platform comprises:

- A. An assembly to monitor the acoustic field in a Users immediate environment using one or more Ambient Sound Microphones (ASMs) located near to or at the entrance to one or both occluded ear canals.
- B. A signal processing circuit to amplify the signal from the ASMs in (A) and to equalize for the frequency sensitivity of the microphones and to low-pass filter (LPF) the signals prior to digital conversion to prevent aliasing (with the cut-off frequency of the LPF equal or less than half the sampling frequency of the digital sampling system).
- C. An analog-to-digital converter (ADC) to convert the filtered analog signals in (B) to a digital representation.

- D. An optional beam-forming platform that takes as its inputs the digital signals from the ASMs from one or both headsets to selectively affect the spatial sensitivity of the headset to sound in the user's local environment.
- E. An digital-to-analog convert (DAC) to convert a digital audio signal into an analog audio signal for reproduction with the ER.
- F. An initialization system to start the Voice-based headwear detection platform; which may be manually by the user with a voice-activation or with a physical switch, or may be remote activation by a second person, or may be automatically by a system which detects when headwear is adjusted or fitted, or may be on a continuous or intermittent basis.
- G. A system to obtain a Reference User Voice Profile (rUVP); when activated by the system in (F), the rUVP acquisition system works by the user generating some general or predefined verbal messages (e.g. a collection of phonemically balanced words, prompted by a messaging system reproduced with the ear canal receiver). Alternatively, the user may be asked to generate non-verbal sound stimuli, such as hand claps or mouth-whistles. Whilst the user creates the Reference sound message, the ASM signals are simultaneously recorded. The resulting spectral profiles is the rUVP.
- H. A system to obtain a Current User Voice Profile (cUVP); when activated by the system in (F), the cUVP acquisition system works by the user generating some general or predefined verbal messages (e.g. a collection of phonemically balanced words, prompted by a messaging system reproduced with the ear canal receiver). Alternatively, the user may be asked to generate non-verbal sound stimuli, such as hand claps or mouth-whistles. Whilst the user creates the Reference sound message, the ASM signals are simultaneously recorded. The resulting spectral profiles is the cUVP.
- I. A system to compare the rUVP and cUVP, and to determine the particular headwear worn by the user.. This comparison may be in the time domain, but in the preferred embodiment the comparison is in the frequency domain. If the frequency content of the cUVP is less than the rUVP at particular frequencies (e.g. $1/3^{\text{rd}}$ octave measurements made at 1 kHz and 4 kHz) by a

pre-defined amount (e.g. 5 dB), then it may be deemed that headwear is currently being worn. The transfer function of rUVP to cUVP is compared to a database of measurements made with particular headwear with a known Headwear acoustic Attenuation Transmission Index or ATI_HW.

- J. Alternative to the ATI_HW determination system in (I), a system to empirically to determine ATI_HW which is calculated as the ratio of rUVP to cUVP.
- K. A system to filter the ASM signal with a filter corresponding to the inverse of the obtained ATI_HW (i.e. obtained in process I or J). In the preferred embodiment, this filter is a digital FIR-type filter.

Headwear Acoustic Equalization system (HEQS)

Drawings:

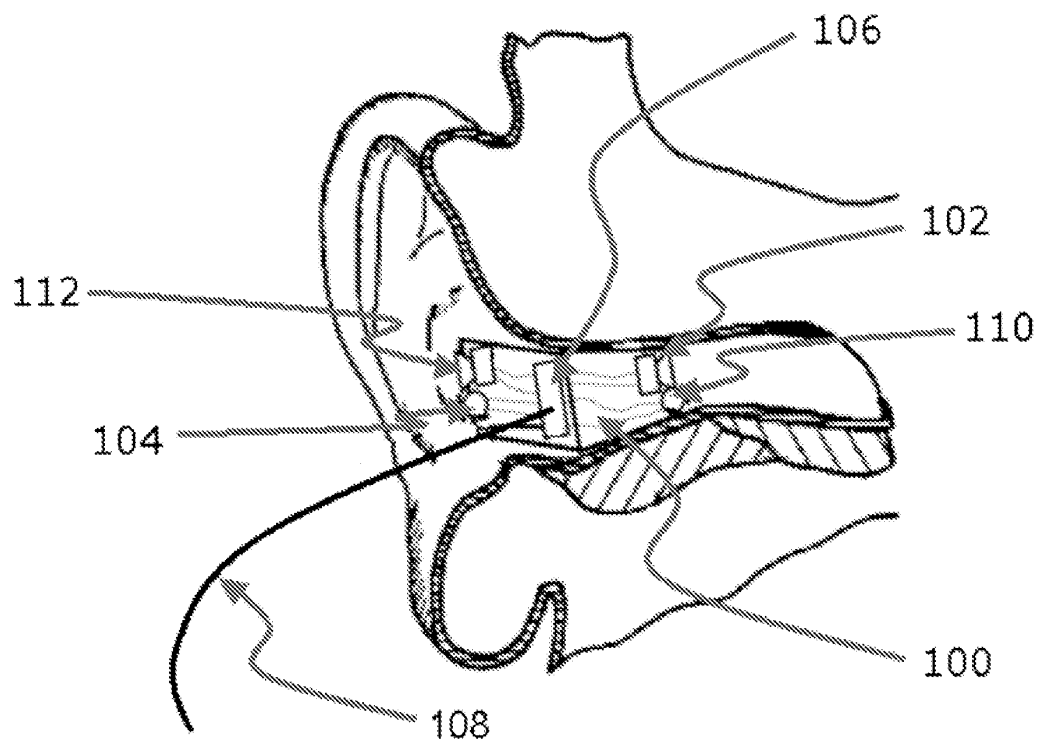


Figure 1: Preferred embodiment for headset.

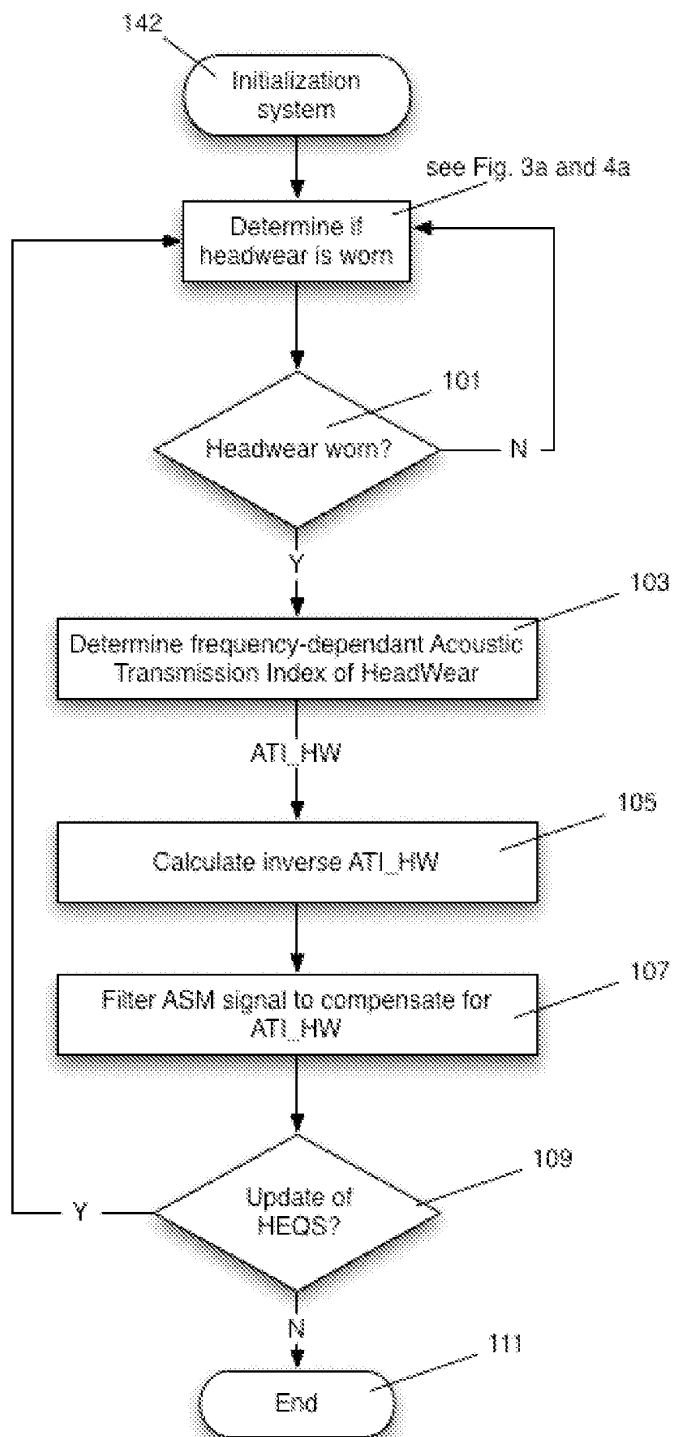


Figure 2a: Overview of HEQS.

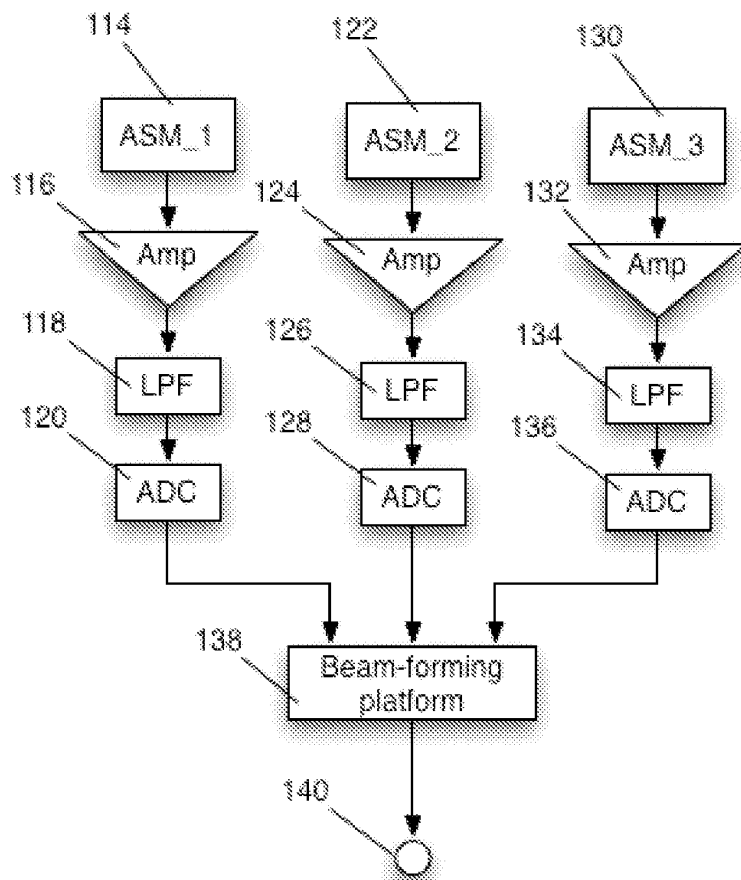


Figure 2b: ASM signal conditioner.

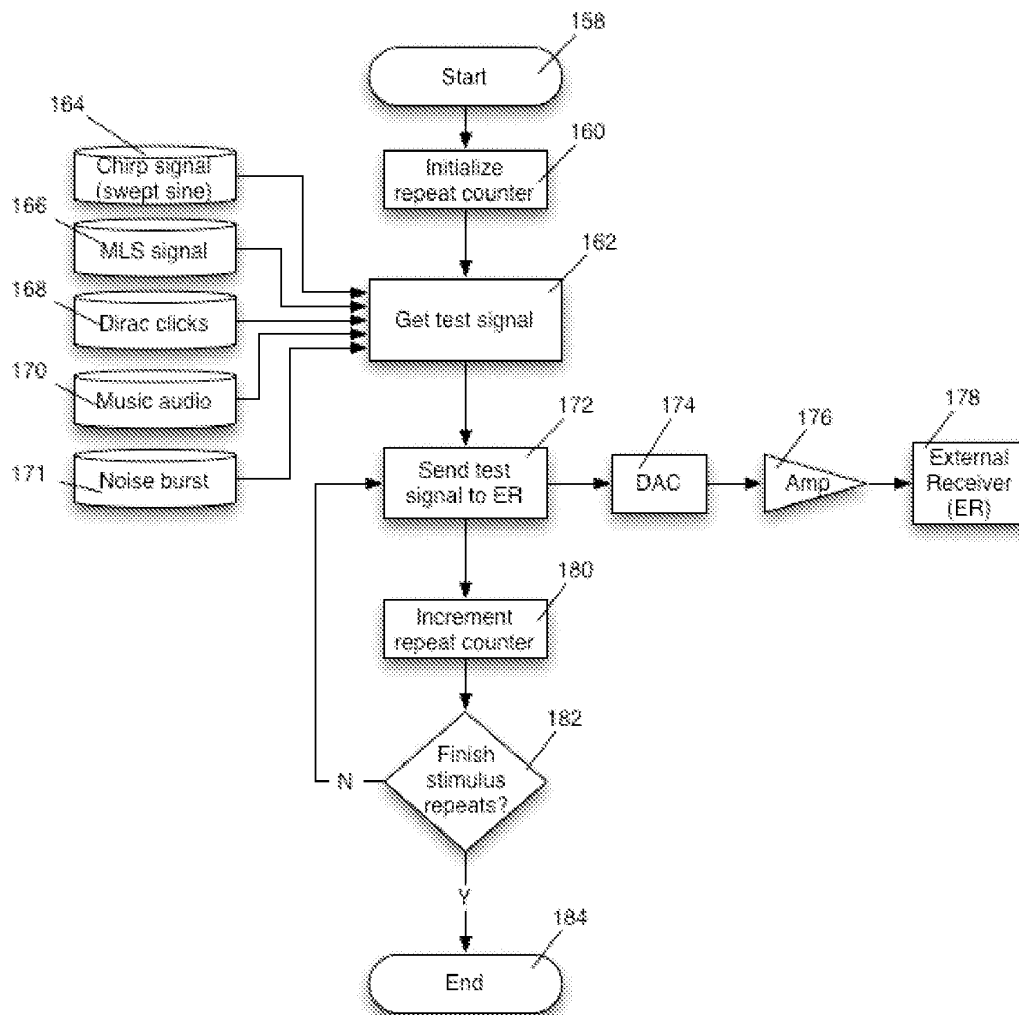


Figure 3b: SONAR-based headwear detection platform: stimulus production assembly.

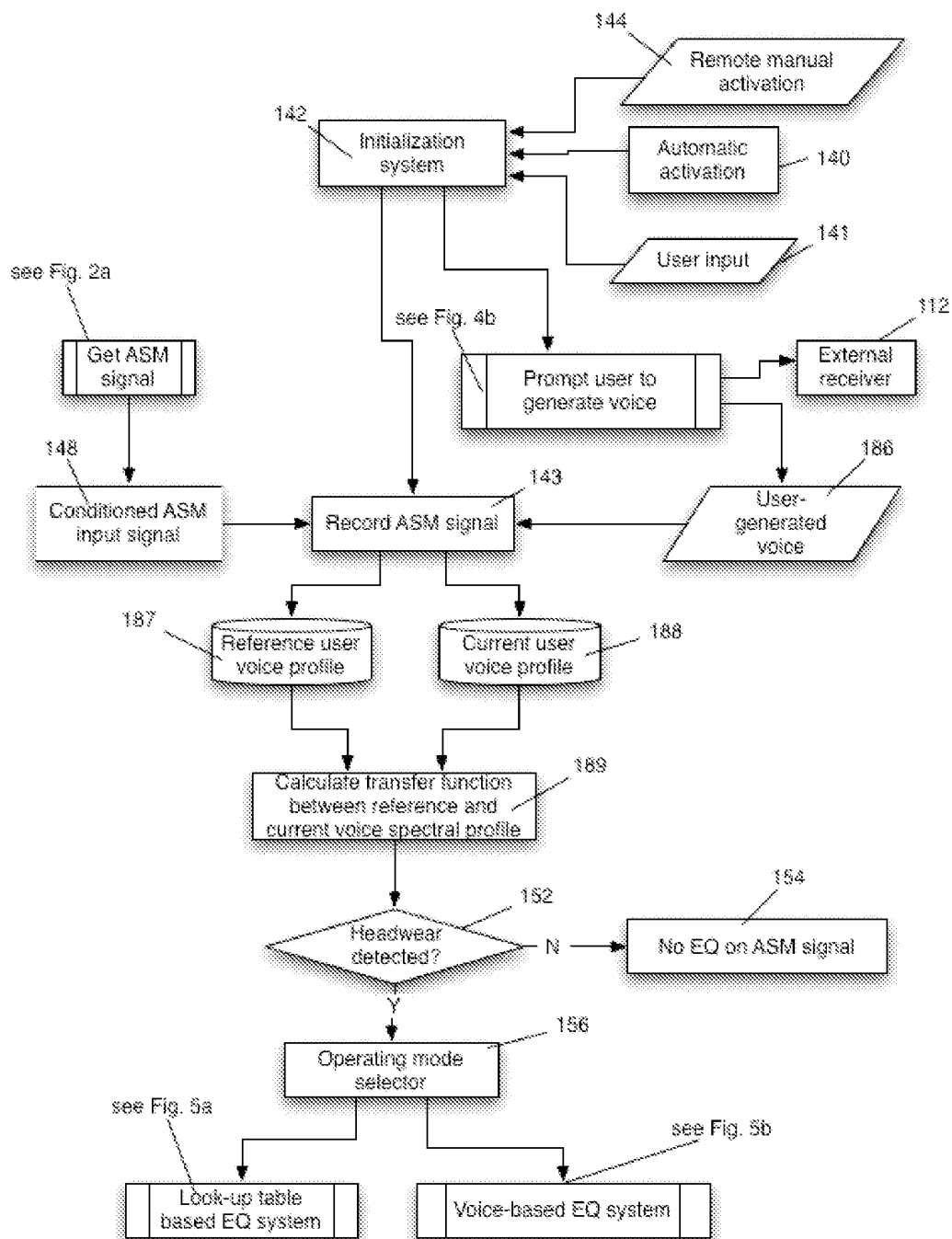


Figure 4a: Voice-based headwear detection platform.

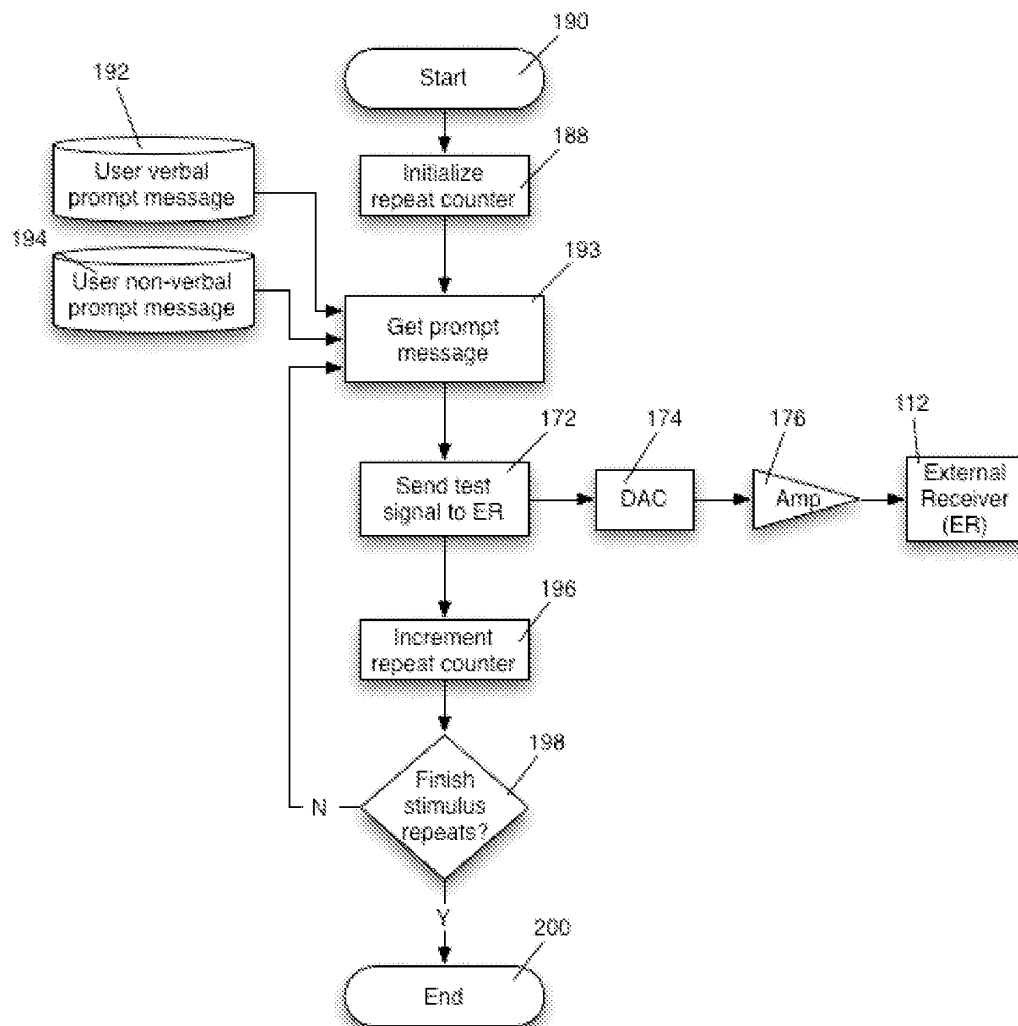


Figure 4b: User voice spectral profile acquisition system.

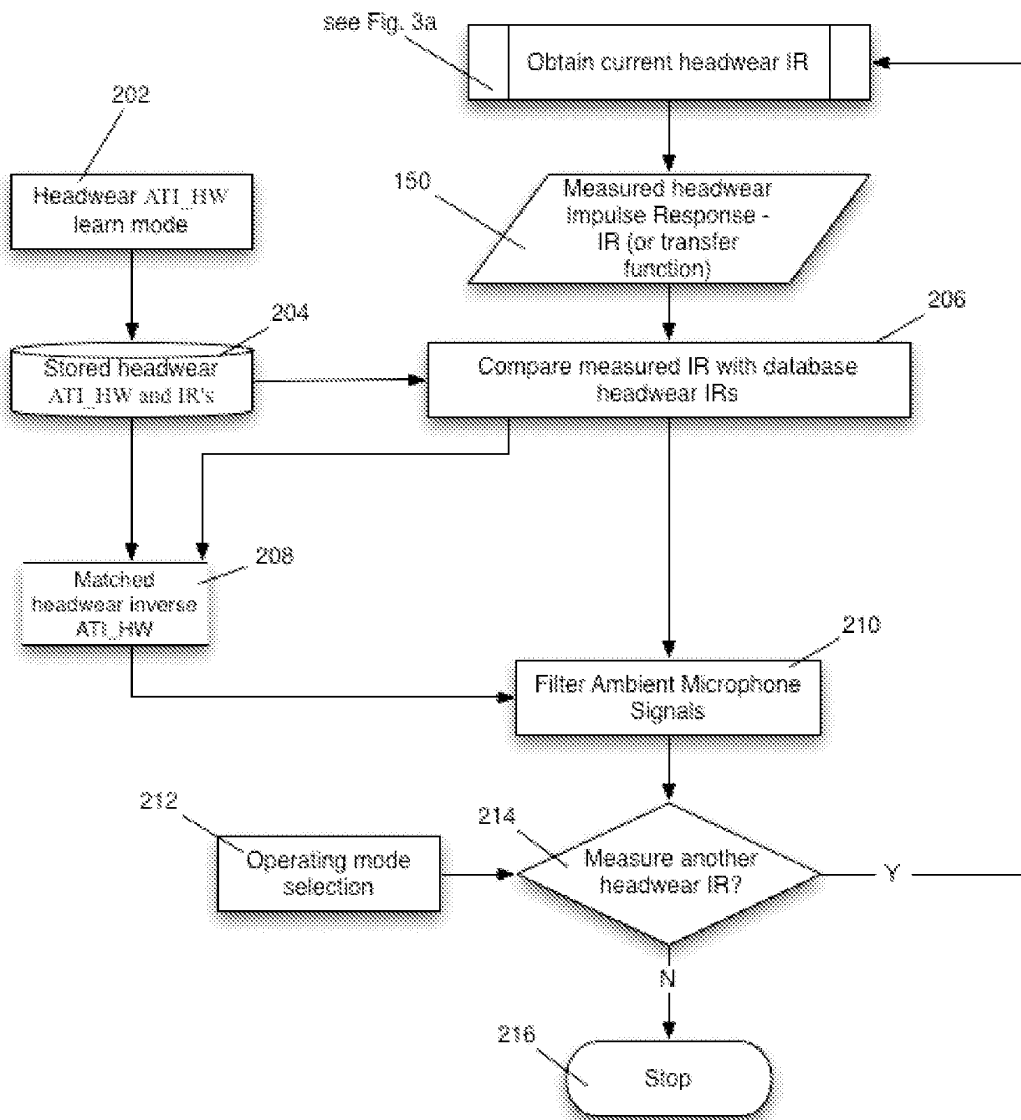


Figure 5a: Look-up table based Headwear EQ System.

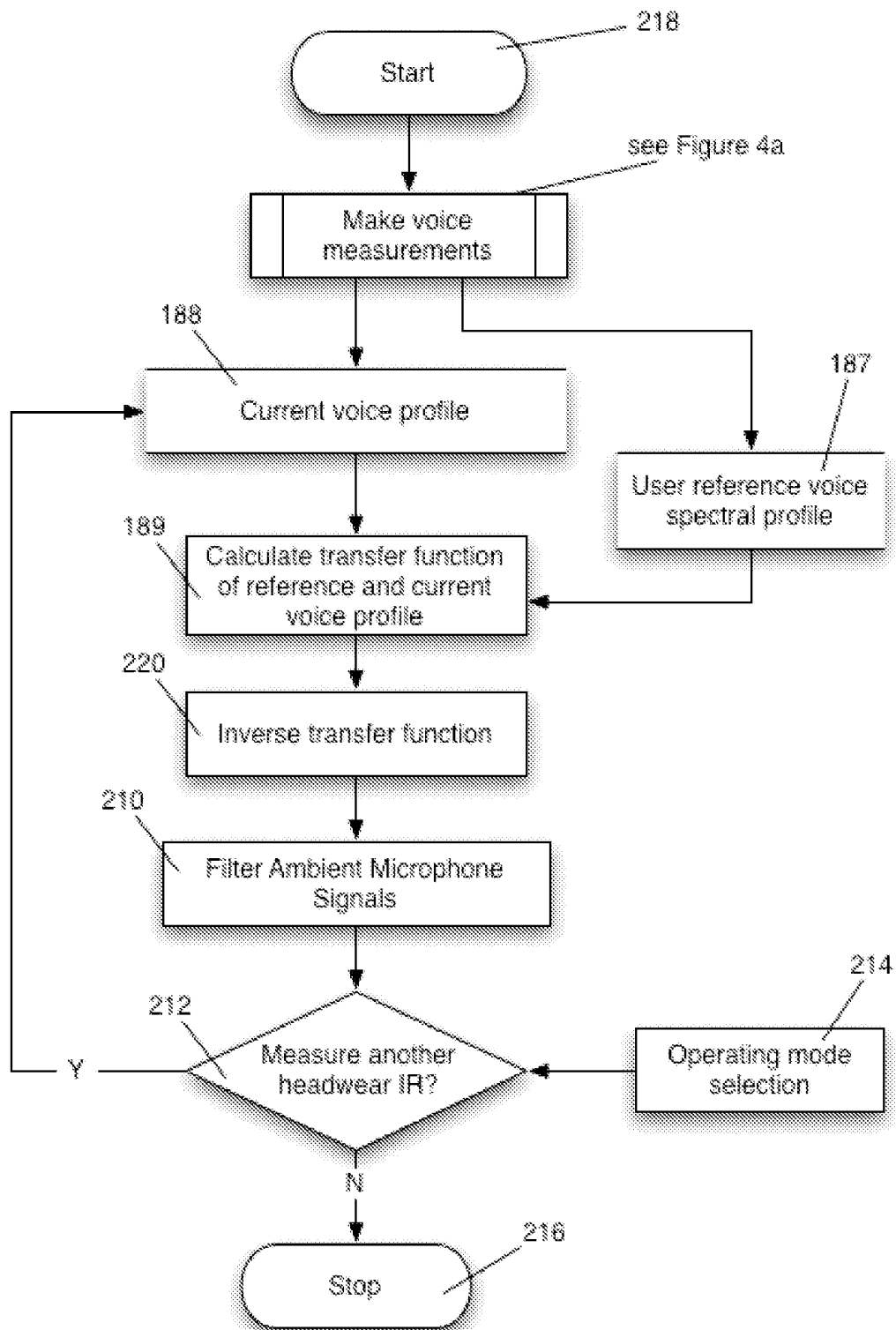


Figure 5b: Voice based headwear EQ system.

Headwear Acoustic Equalization system (HEQS)

Detailed description of drawings

A preferred embodiment of the present invention is illustrated in **Fig. 1**. The embodiment is a small headphone that is inserted in the ear of the user. The headphone consists of the sound-attenuating earplug **100** inserted into the ear. At the inner (eardrum-facing) surface of the plug, an ear-canal loudspeaker receiver **102** is located for delivering the audio signal to the listener. At the outer (environment-facing) surface of the plug, an ambient-sound microphone **104** is located. Both the loudspeaker **102** and the microphone **104** are connected to the electronic signal processing unit **106**. The signal processing unit **106** also has a connector **108** for input of the audio signal. Additionally, an ear-canal microphone **110** is placed at the inner (eardrum-facing) surface of the plug and an external loudspeaker **112** is placed on the outer (environment-facing) surface of the plug for performing other functions of the headphone system not described here (such as monitoring of sound exposure and ear health conditions, headphone equalization, headphone fit testing, noise reduction, and customization).

Fig. 2a depicts a general “top-level” overview of the Headwear acoustic Equalization System (HEQS). Initialization of the HEQS **142** may be manually invoked in a number of ways. One way is a manual activation; by either the HEQS user (i.e. that person wearing the headset system in **Fig. 1**), or manually by a second person in a local or remote location (e.g. a supervisor). Another activation method is with an automatic mode, for instance in response to a loud sound or when the user dons headwear (e.g. a helmet). There are a number of methods for detecting headwear, as disclosed by the systems in

Figs. 3a and 4a. When headwear detection systems determine that headwear is worn, then decision unit **101** invokes a system **103** to determine the frequency dependant acoustic transmission index of the headwear (ATI_HW); the method for to determine ATI_HW is described in **Fig. 5a and 5b**. The ASM signal is then filtered **107** with a filter with a response approximating the inverse of ATI_HW **105**. This gives a modified ASM signal which approximates that ASM signal with the headwear removed. The filter system **107** may use entirely analog circuitry or may use digital signal processing, e.g. using an FIR-type digital filter. Depending on the particular operating mode of the HEQS the ATI_HW may be updated on a continuous or intermittent basis, as determined by decision unit **109**. If the operating mode is such that ATI_HW is calculated just once, then the update sequence is terminated **111**.

Fig. 2b describes an optional beam-forming platform. The beam forming platform allows for the direction-dependant sensitivity of the microphones in the headset in **Fig. 1** to be electronically manipulated. For instance, the sensitivity may be increased in the direction of the HEQS users voice, and decreased in the direction of local noise sources, such as machine noise. The beam-forming platform **138** takes as its inputs at least three Ambient Sound Microphones (ASMs) **114, 122, 130**. The analog signal is then amplified **116, 124, 132**, and then filtered with a Low Pass Filter (LPF) **118, 126, 134** to prevent frequency aliasing by the Analog to Digital Converters (ADC) **120, 128, 136**. The beam-forming platform **138** may also take as its input signal the output signal from ASMs in both the left and right headsets worn by the HEQS user. The output signal **140** for each headset is considered the “conditioned ASM signal” in other figures in the present invention.

Fig. 3a depicts the SONAR-based headwear detection platform. This system detects the presence of headwear using a SONAR-based system. Activation of this system **142** may be manually by a remote second person **144** or by the HEQS user **141**, or may be automatic **140** e.g. with a computer timer. A SONAR test signal is reproduced with the External Receiver (ER) **112** whilst simultaneously recording **143** the conditioned ASM signal **148**. The SONAR test signal **144** may be one of a number of specific test signals, as described in **fig. 3b**. The recorded ASM signal is analyzed **146** to extract the time-

domain impulse response (IR) or frequency domain transfer function **150**. The frequency-domain transfer function may be obtained empirically by dividing the spectral frequency profile of the SONAR test signal **144** by the spectral frequency profile of the recorded ASM signal **143** (if the spectral frequency profile is logarithmic, then this would be a subtraction of the two profiles). Alternatively, an adaptive filter such as one based on the LMS algorithm may be used to iteratively approximate the time-domain impulse response or frequency domain transfer function. If a maximum-length sequence (MLS) SONAR test signal is used, then the time-domain IR may be obtained by cross-correlation of the MLS and recorded ASM signal **143**. The resulting IR is then analyzed to detect headwear. This is undertaken by detecting features in the IR representative of strong sound reflections at time delays consistent with headwear; for instance, if a helmet is worn, then a reflection from the brim is expected at about 0.6 ms for a brim that is 10 cm from the headset. If close-fitting headwear is worn, such as a balaclava or fire-proof hood, then a higher-level IR would be observed (especially at high frequencies) compared with the case when no headwear is worn. If no headwear is worn, then decision unit **152** determines that no additional filtering of the ASM signal is undertaken **154**. However, if the analysis of the obtained IR **146** predicts that headwear is worn, then depending on the particular operating mode **156** (which may be set with the initialization system **142**) filtering of the ASM signal may be invoked with either a look-up table based EQ system (**Fig. 5a**) or a voice-based EQ system (**Fig. 5b**).

Fig. 3b depicts the assembly for generating the SONAR test signal used by the SONAR-based headwear detection platform in **Fig. 3b**, and also for the system which determines the acoustic transmission index of the headwear described in **Fig. 5a**. When the SONAR test signal is needed, the activation command **158** initializes a counter **160** which keeps a record of the number of repetitions of the test stimulus (i.e. how many averages the analysis system makes). The particular test signal used may be one of a number of signals; a frequency sweep **164** (ideally this so-called chirp signal is from a lower frequency to a higher frequency with a logarithmic rather than linear incremental sweep). Single or multi-frequency sine-waves may also be used to give a frequency-dependant acoustic transfer function; a Maximum Length Sequence (MLS) signal **166** is often used

to measure acoustic impulse responses; transient (Dirac) impulses **168** give a IR directly; music audio **179** may be used to measure the transfer function, as well as noise bursts **171** which may be narrow-band filtered. Once the audio test signal is acquired **162**, the signal is sent to the ER **178** via digital to analog conversion **174** and analog amplification **176** (which may be frequency-dependant to compensate for the electroacoustic sensitivity of the loudspeaker). A digital counter **180** tracks the number of times the audio test signal is repeatedly reproduced with the ER, and decision unit **182** terminates reproduction of the test signal **184** when the number of repeats is sufficient.

Alternative to the SONAR-based system in **Fig. 3a** is the Voice-based headwear detection platform described in **Fig. 4a**. This system detects the presence of headwear using a user-generated voice. Activation of this system **142** may be manually by a remote second person **144** or by the HEQS user **141**, or may be automatic **140** e.g. with a computer timer. The headwear is detected by analyzing the conditioned ASM signal **148** in response to user-generated voice **186**. The prompting system for the user to speak is described in **fig. 4b**. The recorded ASM signal is analyzed by unit **143** when there is no headwear present to give a reference user voice spectral profile **187**. When the user dons headwear, they are prompted to speak (see **Fig. 4b**) and a second ASM recording is made to give a current user voice spectral profile **188**. The reference user voice spectral profile **187** and current user voice spectral profile **188** are compared with unit **189** to give a transfer function which is analyzed to predict if headwear is worn. This analysis system may, for instance, determine that headwear is worn if the transfer function indicates that high-frequency content (e.g. at particular frequencies such as 1 kHz and 4 kHz) are attenuated in the current user voice spectral profile **188** compared with the reference user voice spectral profile **187** (e.g. are <5 dB at these particular frequencies). If this analysis unit **189** determines that headwear is not worn, then decision unit **152** does not filter the ASM signal **154**. Alternately, if analysis unit **189** determines that headwear IS worn, then decision unit **152** further determines the frequency dependant acoustic transmission index of the headwear (ATI_HW) that is used to filter the ASM signal (i.e. with a filter response approximating the inverse of ATI_HW). ATI_HW is calculated depending on

the particular operating mode, as determined by unit **156**, these two operating modes are described in **Fig. 5a** and **fig. 5b**.

Fig. 4b describes the user-prompting system for the voice-based headwear detection platform. Either a pre-recorded verbal message **192** or non-verbal message **194** (e.g. a tone) is reproduced with the External Receiver **112** for the user to speak either a specific set of words (e.g. a phonetically balanced word list) or general words (e.g. normal conversation) or non-speech sounds (such as a whistle or hand-clap). This prompt may be repeated a number of times, according to the incremental repeat counter **196** and decision unit **198** which terminates the prompt message after a pre-defined number of repeated message prompts.

Fig. 5a describes a system for determining the acoustic transmission index of the headwear (ATI_HW). This is a frequency dependant value for the free-field acoustic absorption of the headwear from an external sound source to a measurement point on the other side of the headwear (specifically, measured at the entrance to the user's ear canal). The system uses the SONAR headwear detection platform described in **Fig. 3a** to obtain a headwear impulse response **150**. It should be noted that this is not the same as the ATI_HW; rather, it is the impulse response obtained by emitting a SONAR test signal from the external receiver (**112** in **Fig. 1**) and recording the sound response at the ASM **104** (or conditioned ASM signal **140** in **Fig. 2b**). In a particular optional learn mode **202**, the IR of different headwear may be measured empirically, and their corresponding ATI_HW is also measured and stored in computer memory **204**. The recently measured headwear IR **150** is then compared and match with measured IR's in the database **204** using matching unit **206** (matching may be accomplished using a standard least mean squares difference approach). When the current headwear has been matched to one in the database, then the ASM signals **140** is filtered with an impulse response (or frequency-domain transfer function) which approximates the inverse of the matched ATI_HW **208**. The filtering of the ASM signal by unit **210** may be accomplished using a digital FIR-type filter or an IIR-type digital filter, or a multi-band analog audio signal filter. Depending on the particular operating mode of the HEQS selected by the user (or

automatically selected) with selecting device **212**, the ATI_HW may be continually updated by decision unit **214**.

Fig. 5b describes an alternative method to that system in **Fig. 5a**, for determining the ATI_HW of the headwear worn by the HEQS user. The method in **Fig. 5b** uses a measure of the user's reference voice spectral profile **187**; this is spectral profile of the (conditioned) ASM signals when no headwear is worn in response to user-generated speech or non-speech (e.g. hand-claps). This is compared to the current ASM spectral profile when the user is wearing headwear **188**. The comparison is undertaken by unit **189**, which may be a simple spectral subtraction (in the logarithmic, or deci-Bel, domain), or may be a division of the linear spectral magnitude. The resulting transfer function approximates ATI_HW, and it's inverse is calculated by unit **220** to give a data vector which can be used to filter the ASM signals with filter unit **210** (as previously described for **Fig. 5a**).

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Filing Date:				
Title of Invention:		Headwear Acoustic Equalization system (HEQS)		
First Named Inventor/Applicant Name:		Steven Wayne Goldstein		
Filer:		Steven Wayne Goldstein		
Attorney Docket Number:				
Filed as Small Entity				
Provisional Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Provisional Application filing fee	2005	1	100	100
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				100

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Document Number	Document Description	File Name	File Size(Bytes)	Multi Part /.zip	Pages (if appl.)
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1	Application Data Sheet	US_ADS_Form_SB_14.pdf	901362	no	4
Warnings:					
Information:					
2	Abstract	Headwear_Acoustic_Equalization_System_HEQS_Abstract_and_Background.pdf	103585	no	5
Warnings:					
Information:					
3	Specification	HEQS_embodiments.pdf	149078	no	12
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4	Drawings	HEQS_drawings.pdf	496643	no	9
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Information:					
5	Specification	HEQS_detailed_description_of_drawings.pdf	102760	no	6
Warnings:					
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6	Fee Worksheet (PTO-06)	fee-info.pdf	8088	no	2
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