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(54) **OPTICALLY DRIVEN AUDIO SYSTEM**

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(52) **U.S. Cl.** **381/74**; 381/370

(57) **ABSTRACT**

An audio system includes an earplug with a speaker to deliver sound to the ear, and/or a microphone which captures sound in the ear canal, and an earmuff is worn over the earplug. The earplug receives sound signals from the earmuff (and/or transmits captured sound signals to the earmuff) by translating such sound signals into light signals which are transmitted over a free space situated between the earmuff and earplug. The light signals are then received at the earplug and/or earmuff and converted to electrical signals which may be further transmitted (e.g., from the earmuff to some external communications device) or converted to sound (e.g., in the earplug by having the electrical signals drive an earplug speaker). If power is required by the earplug, the need for on-board power sources may be avoided by converting light transmitted from the earmuff into power at the earplug. Electrical shock and physical snag hazards are avoided, and the earmuff is easily put on and removed, owing to the lack of wires or other physical connections between the earplug and earmuff. Additionally, by avoiding wires or radio transmission between the earplug and earmuff, electromagnetic interference may be reduced.

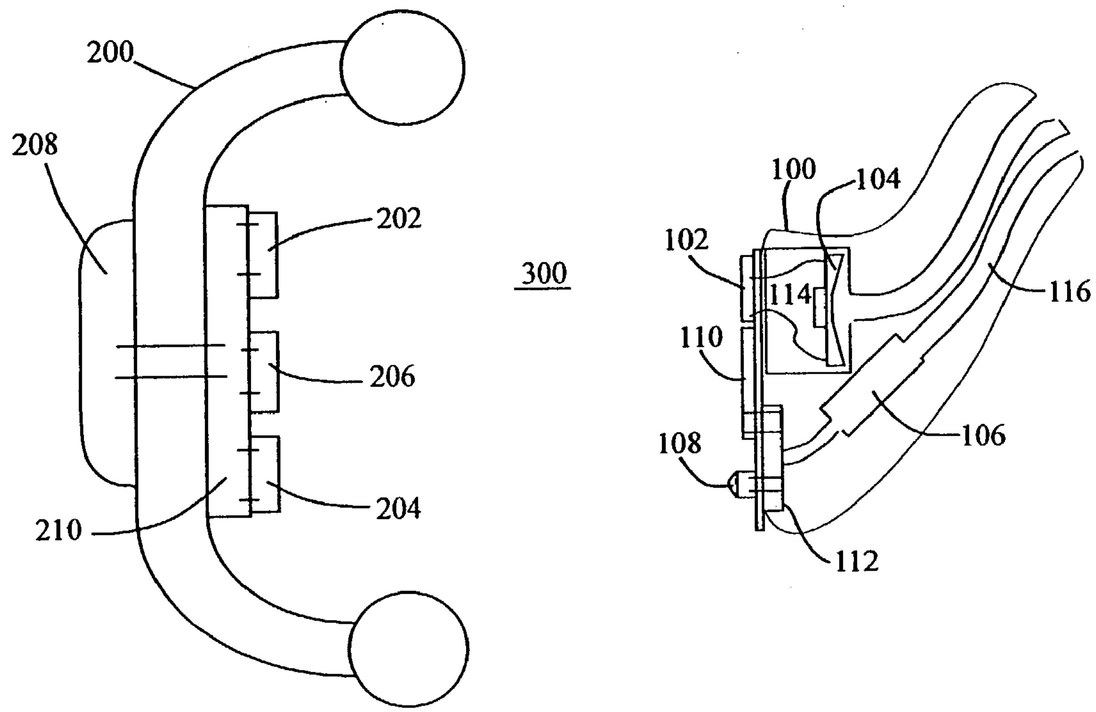


Fig. 1

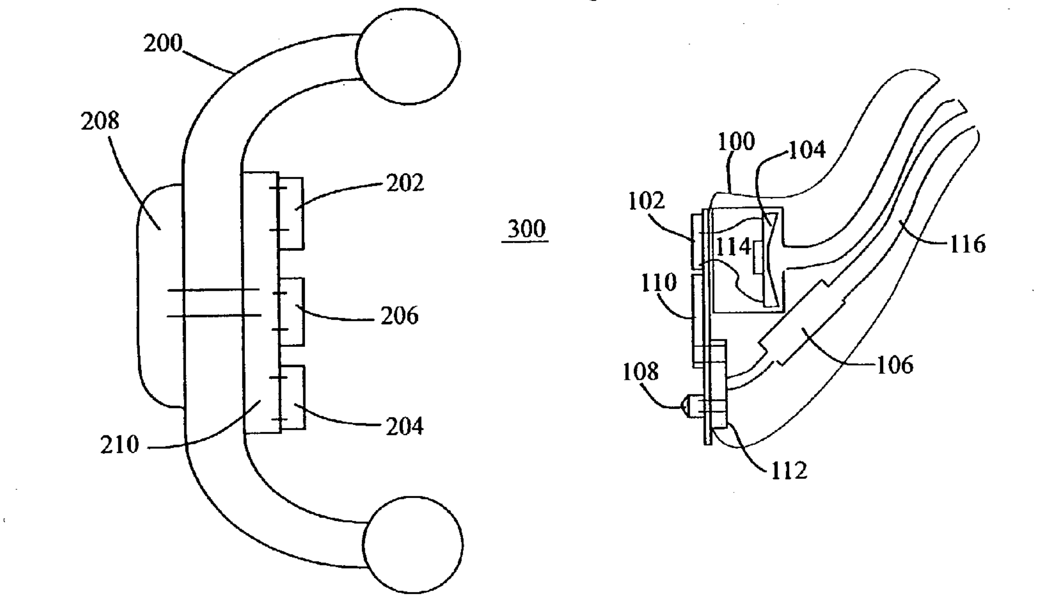
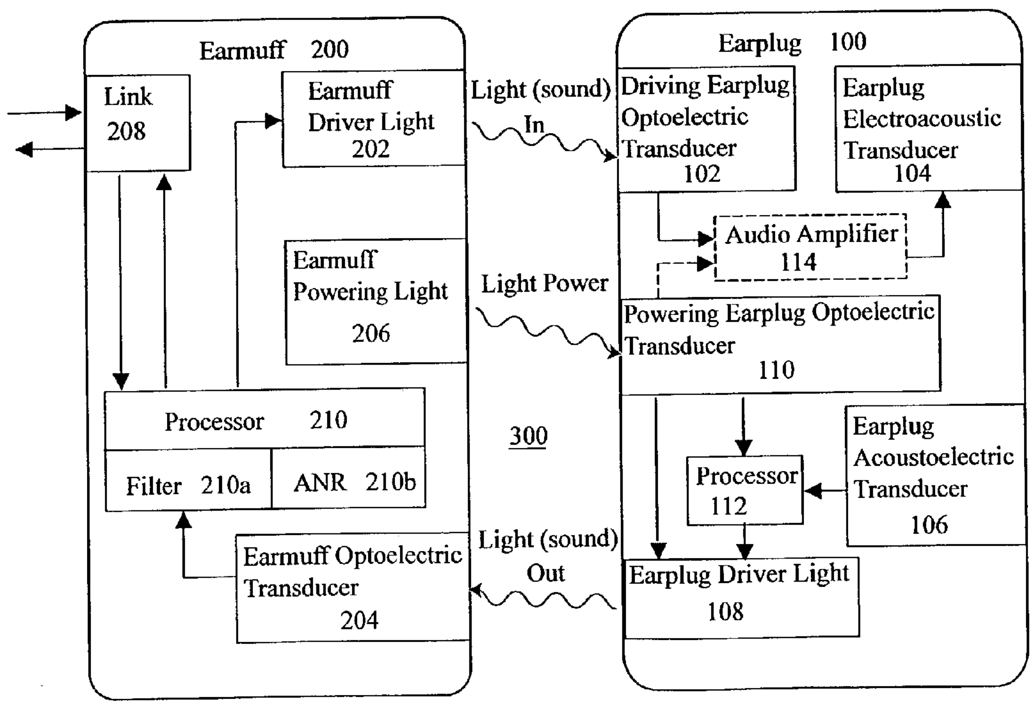

200
208
202
206
204
210
300
100
104
102
114
116
110
106
108
112

Fig. 2


Earmuff 200
Link 208
Earmuff Driver Light 202
Earmuff Powering Light 206
Processor 210
Filter 210a
ANR 210b
Earmuff Optoelectric Transducer 204
Light (sound) In
Light Power
300
Light (sound) Out
Earplug 100
Driving Earplug Optoelectric Transducer 102
Earplug Electroacoustic Transducer 104
Audio Amplifier 114
Powering Earplug Optoelectric Transducer 110
Processor 112
Earplug Acoustoelectric Transducer 106
Earplug Driver Light 108

OPTICALLY DRIVEN AUDIO SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 USC §119(e) to U.S. Provisional Patent Application 60/368,467 filed 27 Mar. 2002, the entirety of which is incorporated by reference herein.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] This invention was made with United States government support awarded by the United States Navy (Naval Air Warfare Center Aircraft Division), Contract No. N68335-02-C-3040. The United States has certain rights in this invention.

FIELD OF THE INVENTION

[0003] This disclosure concerns an invention relating generally to personal audio equipment, and more specifically to headsets, earplugs, and similar personal audio listening equipment.

BACKGROUND OF THE INVENTION

[0004] In high noise environments, in-the-ear active earplugs—wherein speakers deliver sound directly to the ear canal—help improve signal to noise, and thus the intelligibility of transmitted music or speech. The earplug serves as a passive attenuator of ambient noise to provide the ear with protection from dangerous sound levels, and reduces the ambient noise's interference with sound generated by the earplug speaker. Active earplugs usually only include sound output devices, such as electroacoustic speakers (i.e., speakers which generate sound output from electrical input). However, active earplugs may also include sound input devices in the earplug—such as acoustoelectric microphones, which generate electrical output from input sounds—to generate output signals representing the level of ambient noise "leaked" into the ear canal, and/or signals representing the wearer's speech sounds (which can be picked up in the ear canal). The ambient noise signals can then be used to provide active noise cancellation in the ear canal, or detected speech sounds can be used to allow two-way communication (i.e., the wearer of the earplugs can both hear transmitted sounds and can transmit his/her own speech). See, for example, U.S. Pat. Nos. 4,985,925 and 5,692,059.

[0005] However, the prior systems tend to suffer from certain disadvantages. Where they receive and/or send sound signals via wire, they can be subject to electromagnetic interference, and they tend to "tether" the wearer to a fixed location. Where wireless technologies are used, they are also subject to interference, and additionally they tend to be heavy and bulky owing to the presence of the transmitter and/or receiver for sound signals, and owing to the need for onboard battery power.

SUMMARY OF THE INVENTION

[0006] The invention involves audio systems which are intended to at least partially solve the aforementioned problems. To give the reader a basic understanding of some of the advantageous features of the invention, following is a brief summary of preferred versions of the earplugs. As this is merely a summary, it should be understood that more details regarding the preferred versions may be found in the Detailed Description set forth elsewhere in this document. The claims set forth at the end of this document then define the various versions of the invention in which exclusive rights are secured.

[0007] The audio system of the present invention includes an earplug which may include sound delivery and/or sound capture features as discussed above, and an earmuff is worn over the earplug to provide added noise protection in a high noise environment. The need for wire connections between the earmuff and earplug, and for onboard power sources in the earplug (i.e., batteries), may be avoided by providing both sound signals and power between the earplug and earmuff over a free space optical link: sound-encoded light signals may be delivered by light sources situated on the earplug and/or earmuff, and may be received by the other component by appropriate photoreceivers and then converted back into sound, if desired. Additionally, power may effectively be delivered over the free space by having a light source on the earmuff and/or earplug illuminate a powering photoreceiver on the other component, thereby powering that other component. The lack of wires between the earplug and earmuff removes electrical shock and physical snag hazards; reduces transmission of ambient noise from the earmuff to the earplug through vibration or other acoustic leakage; and allows easy don-and-doff since the earplug is not physically constrained to the earmuff. The problems with earplugs that communicate with remote wireless transceivers, such as the need for power sources onboard such earplugs and the problem of electromagnetic interference, are also avoided.

[0008] Further advantages, features, and objects of the invention will be apparent from the following detailed description of the invention in conjunction with the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a simplified cross-sectional view of an exemplary audio system including an earplug **100** which is worn by a user with an earmuff **200** placed over the earplug **100**, with sound-encoded light signals being transmitted across a free space therebetween to allow the earmuff **200** to transmit sounds to, and/or receive sounds from, the earplug **100**.

[0010] **FIG. 2** is a schematic diagram of the exemplary audio system of **FIG. 1**.

DETAILED DESCRIPTION OF PREFERRED VERSIONS OF THE INVENTION

[0011] An exemplary version of the invention is illustrated in **FIGS. 1 and 2**, wherein an audio system includes an earplug **100** and an earmuff **200**, wherein the earplug **100** receives sound signals from (and/or sends sound signals to) the earmuff **200** across a free space **300**. The earplug **100** may be adapted for mounting within an ear (as depicted in **FIG. 1**) or on an ear (as by including an over-the-ear hook), and the earmuff preferably has an earmuff interior sized to fit over the ear which bears the earplug **100**. The lack of any physical connection between the earmuff **200** and earplug **100** across the free space **300** allows the earmuff **200** to provide passive noise reduction—it reduces the ambient noise received by the ear canal (such reduction also being assisted by the earplug **100**)—while preventing direct conduction of ambient sound vibration between the earmuff **200** and earplug **100**. The presence of the free space **300** also allows easy "don-and-doff," whereby a user may wear the earplug **100** while readily taking the earmuff **200** on and off at any time. Such a capability is particularly useful for military applications, wherein a user may need to (for example) be able to rapidly don and remove a helmet wherein the earmuff **200** is provided.

[**0012**] To briefly preview the components and functionality of the preferred audio system of **FIGS. 1 and 2** (with a more detailed description being provided later in this document), the earplug **100** preferably includes an earplug sound input means **102**/**104** for inputting sound transmitted from the earmuff **200** to the ear, and/or an earplug sound output means **106**/**108** for outputting a sound measurement taken within the ear to the earmuff **200**. It can additionally be useful to include an earplug powering means **110** for powering the earplug sound input means and/or earplug sound output means (if such power is necessary). The earmuff **200** then preferably includes an earmuff sound output means **202** which outputs sound signals to the earplug sound input means **102**/**104**, and/or an earmuff sound input means **204** which receives sound signals from the earplug sound output means **106**/**108**. An earmuff powering means **206** for remotely powering the earplug powering means **110** can also be useful. Each of these components and their functionality will now be discussed at greater length.

[**0013**] Looking initially to the interrelationship between the earmuff sound output means **202** and the earplug sound input means **102**/**104**, the earmuff sound output means includes an earmuff driver light **202** which transmits sound-encoded light signals to the driving earplug optoelectric transducer **102**, which provides electrical output upon receipt of the light input. When it is stated that the earmuff driver light **202** transmits "sound-encoded" light signals, this means that the light signal is an optical signal bearing sound information —for example, a light signal carrying sound information via encoding schemes such as amplitude modulation, pulse width modulation (PWM), or pulse frequency modulation (PFM). The earmuff driver light **202** may take the form of (for example) a light emitting diode, a laser diode, a fiberoptic terminal (which emits light emitted by a separate light source), or any other appropriate light source. The driving earplug optoelectric transducer **102** may take the form of any appropriate photoreceiver, such as a Si, GaAs, or Ge photocell having an optimal power generation range coinciding with the wavelength(s) at which the earmuff driver light **202** emits light. The driving earplug optoelectric transducer **102** converts the received sound-encoded light signal into a sound-encoded electrical signal. This sound-encoded electrical signal is then provided to the earplug electroacoustic transducer **104** (e.g., a common electrically-driven diaphragm, piezoelectric, or other suitable speaker) to provide acoustic output into the ear canal upon receipt of the electrical input. Thus, the sound signal travels as light from the earmuff driver light **202** to the driving earplug optoelectric transducer **102** across the free space **300**, then as an electrical signal to the earplug electroacoustic transducer **104**, at which point it is converted back into sound and delivered to the ear canal.

[**0014**] As depicted by the exemplary embodiment of **FIGS. 1 and 2**, the sound signal optically transmitted by the earmuff driver light **202** may initially be received by the earmuff **200** as a sound-encoded electrical signal at link **208**, which may be a radio receiver or a wire input. The link **208** then provides the sound-encoded electrical signal to a processor **210**—a circuit board or chip containing appropriate circuitry—which may translate the electrical signal into a desired format (e.g., PWM, PFM) to drive the earmuff driver light **202** to generate analogous sound-encoded optical signals. However, the link **208** may initially receive sound-encoded optical signals rather than sound-encoded electrical signals. For example, the link **208** may receive sound information via a light signal transmitted over a fiberoptic cable input, as opposed to a wire or radio communication. In this case, the processor **210** might simply pass the sound-encoded optical signals to the earmuff driver light **202** without alteration. Thus, the link **208** may simply be a fiberoptic input terminal which passes sound-encoded optical signals directly to the earmuff driver light **202**, which in this case might merely be a terminal end of a fiberoptic cable transmitting the sound-encoded optical signals from the link **208**. Alternatively, the processor **210** could translate a sound-encoded optical signal coming in from the link **208** to another encoding scheme prior to passing the signal to the earmuff driver light **202**; for example, if the link **208** receives a sound-encoded optical signal in PFM format, the processor **210** might convert it to PWM format prior to passing it to the earmuff driver light **202**.

[**0015**] Where the foregoing arrangement is used, the audio system allows the earmuff **200** to communicate sound information to the earplug **100** via a light signal traveling through the free space **300**, with the earplug **100** then converting the light signal back into sound for delivery to the wearer's ear. In some cases, it may additionally or alternatively be desirable to use the earplug sound output means **106**/**108** to transmit sound signals from the earplug **100** to the earmuff sound input means **204** in the earmuff **200**. As one example, it might be useful to capture the ambient sound level within the ear canal and use it to provide feedback of active noise reduction signals, i.e., to combine any sound signals from the link **208** with the inverse of the measured ear canal ambient noise, thereby effectively cancelling out the ambient noise within the ear canal and making the ambient noise effectively inaudible. As another example, it may be useful to collect voice signals from the wearer of the earplug **100** by picking up such voice signals within the ear canal and transmitting them back to the earmuff **200** and link **208**. When such arrangements are provided, the earplug sound output means **106**/**108** may include an earplug acoustoelectric transducer **106**, which may take the form of an electret or other suitable microphone which obtains acoustic input from within the ear canal and generates a sound-encoded electrical output signal. The sound-encoded electrical signal is then passed to an earplug driver light **108**, which may take the form of an LED, laser diode, or other appropriate light source whereby the sound-encoded electrical signal is converted to a sound-encoded light signal transmitted to the earmuff **200**. If desired, a processor **112** may be included between the earplug acoustoelectric transducer **106** and earplug driver light **108** to provide amplification and/or format translation (e.g., translation of the sound-encoded electrical signal from the earplug acoustoelectric transducer **106** into PWM, PFM, or other formats).

If amplification is provided, it might be powered by batteries within the earplug **100**, or by other earplug powering means **110** to be discussed later in this document.

[**0016**] The earplug driver light **108** transmits the sound-encoded light signal across the free space **300** to the earmuff optoelectric transducer **204**, which converts the sound-encoded light signal back into a sound-encoded electrical signal. The earmuff optoelectric transducer **204**, like the driving earplug optoelectric transducer **102**, may take the form of any appropriate photovoltaic element or other optoelectric transducer. However, if all of the earmuff driver light **202**, the earplug driver light **108**, the driving earplug optoelectric transducer **102**, and the earmuff optoelectric transducer **204** are present, the earplug driver light **108** and earmuff optoelectric transducer **204** are preferably chosen to operate over a different wavelength range than the earmuff driver light **202** and the driving earplug optoelectric transducer **102**, so as to avoid crosstalk. The sound-encoded electrical signal generated by the earmuff optoelectric transducer **204** may then be passed to the link **208** for transmission from the earmuff **200**.

[**0017**] However, the sound-encoded electrical signal generated by the earmuff optoelectric transducer **204** may first undergo processing within a processor **210** before being passed to the link **208**. The processor **210** could perform a variety of functions; for example, it might include a voice filter **210***a* which specifically attenuates all components of the sound-encoded electrical signal save for a voice signal. This could be done by passive filtration of frequencies outside those corresponding to human speech, or by active filtration (active noise reduction), e.g., by subtracting out any signals corresponding to ambient noise measured outside the earmuff **200** (since such ambient noise might also be present in attenuated form within the ear canal). The filtered voice signal could then be passed to the link **208** for delivery from the earmuff **200**. Alternatively or additionally, the processor might include an active noise reduction processor **210***b* which takes the components of the sound-encoded electrical signal and inverts them to generate cancellation signals. The cancellation signals can then be passed to the earmuff driver light **202** (in conjunction with any signals passed from the link **208**) for transmission to the driving earplug optoelectric transducer **102** and earplug electroacoustic transducer **104**, thereby canceling out the ambient noise in the ear canal and presenting the wearer of the earplug **100** with a safer sound level (one less likely to cause hearing damage), as well as effectively clearer sound transmissions from the link **208**.

[**0018**] If it is necessary or useful for the earplug **100** to have power—for example, if the processor **112** requires power for amplification of signals transmitted from the earplug acoustoelectric transducer **106**, or if the earplug driver light **108** requires a supplementary power source in order to generate a sound-encoded signal of sufficient magnitude—the earmuff powering means **206** and earplug powering means **110** may be provided. The earmuff powering means might be provided by situating an earmuff powering light **206** (e.g., an LED, laser diode, or other suitable light source) on the interior of the earmuff **200**. The earmuff powering means **206** may transmit light across the free space **300**. Such light may be received by earplug powering means provided as a powering earplug optoelectric transducer **110** (i.e., a photocell or other suitable optoelectric transducer), which provides electrical output upon receiving light. Thus, the earmuff powering light **206** will stimulate the powering earplug optoelectric transducer **110** to generate power, which may in turn power the earplug driver light **108** or other components of the earplug **100**.

[**0019**] The foregoing arrangement has been constructed and successfully tested with use of the following components and modes of operation, though other choices are possible. Regarding the earmuff sound output means **202** and the earplug sound input means **102**/**104**, the earmuff driver light **202** is an LED which transmits an amplitude modulated infrared light signal to the driving earplug optoelectric transducer **102**. The driving earplug optoelectric transducer **102** is a Si solar cell/photovoltaic element having peak conversion efficiency at 850-900 nm (infrared) wavelength and an area of approximately 100 square mm, and having a low internal impedance which is closely matched with the earplug electroacoustic transducer **104**, a 13 mmm-diameter speaker with impedance of 32 ohms. The driving earplug optoelectric transducer **102** and earplug electroacoustic transducer **104** are connected via 30 gauge wires.

[**0020**] As for the earmuff powering means **206** and the earplug powering means **110**, the earmuff powering light **206** is a constantly on 660 nm wavelength (red) LED which transmits light to the powering earplug optoelectric transducer **110**, a 2-junction GaAs-based solar cell photoreceiver having approximately 180 square mm area. Note that to avoid crosstalk, different wavelength ranges are used for transmitted information and for power generation in the foregoing components—in other words, the earmuff driver light **202** and driving earplug optoelectric transducer **102** operate on different wavelengths or wavelength ranges than the earmuff powering light **206** and the powering earplug optoelectric transducer **110**, thereby preventing the earmuff powering light **206** from driving the driving earplug optoelectric transducer **102**, and preventing the earmuff driver light **202** from driving the powering earplug optoelectric transducer **110**.

[**0021**] The processor **112**, which assists in powering the earplug sound output means **106**/**108** (and thus the earmuff sound input means **204**), includes a single transistor preamplifier connected to a low voltage class-d audio amplifier to amplify the sound-encoded electrical signal generated by the earplug acoustoelectric transducer **106**. The resulting output then directly drives the earplug driver light **108** (an LED) with a PWM drive current, resulting in a PWM sound-encoded light signal. The earmuff optoelectric transducer **204**, a Si photocell, then receives the sound-encoded light signal from the earplug driver light **108**. The earplug acoustoelectric transducer **106** is an electret microphone having 4.5 mm diameter, and is connected to the processor **112** by 30 gauge wire.

[**0022**] In an alternative arrangement, the driving earplug optoelectric transducer **102** is a Si photodiode operating in photoconductive mode (though photovoltaic mode is also possible), and it therefore does not provide significant voltage response. The earplug electroacoustic transducer **104** is not driven directly from the earplug optoelectric transducer **102** in this scheme, but is rather controlled by a class-d amplifier circuit (shown in phantom at **114** in **FIG. 2**), which is powered by the earplug optoelectric transducer **110** and which receives its input signal from the earplug optoelectric transducer **102**. The earplug acoustoelectric transducer **106** may again use a class-d amplifier within the processor **112** to drive the earplug driver light **108**, as in versions of the invention described previously. Alternatively or additionally, the earplug optoelectric transducer **110** may use a boost-type DC—DC converter within the processor **112** to drive the LED of the earplug driver light **108** in PWM or PFM modes in accordance with the output of the earplug acoustoelectric transducer **106**. The driving earplug optoelectric transducer **102** could alternatively be a different Si, Ge, GaAs, or other photovoltaic element which has sufficient response speed and wavelength sensitivity that its output accurately reflects light input from the earmuff driver light **202**.

[**0023**] It is also possible to skip PWM and/or PFM encoding (and/or amplification) in the foregoing arrangements; for example, to omit the processor **112** and simply have the earplug driver light **108** driven in analog fashion by direct use of the sound-encoded electrical signal generated by the earplug acoustoelectric transducer **106**. However, while direct analog broadcasting is possible, it has the disadvantage of overall signal level sensitivity as opposed to PWM and PFM broadcasting with signal amplification.

[**0024**] Another possible variation involves omitting the earmuff powering light **206** and using the earmuff driver light **202** to both drive the driving earplug optoelectric transducer **104** and also power the powering earplug optoelectric transducer **110**, in which case the driving earplug optoelectric transducer **104** and the powering earplug optoelectric transducer **110** might even be combined into a single transducer. Here the sound-encoded light signal and the powering light signal transmitted by the earmuff driver light **202** are sent as a combined signal, for example, as a PWM or PFM signal wherein the PWM encoding would carry the encoded sound and the carrier frequency may be used to extract the power. In this case, the amplifier **114** is usefully included as a class-a or class-d amplification device.

[**0025**] Regarding choice of optoelectric transducers and lights, the wavelength(s) of each light source is preferably coupled as closely as possible to the efficient conversion wavelengths of the optoelectric transducer with which it will communicate, and as noted above, transducers and light sources which are not to communicate with each other preferably have different operating wavelength ranges to avoid crosstalk. Infrared light sources are preferred so that any light leakage outside the earmuff **200** will not be visible. However, it can be expensive to provide different infrared operating ranges if all of the earmuff driver light **202**/earplug optoelectric transducer **102** pair, the earplug driver light **108**/earmuff optoelectric transducer **204** pair, and the earmuff powering light **206**/earplug optoelectric transducer **110** pair are present. If significant separation in operating ranges is desired to minimize crosstalk, this will generally require that at least one of the pairs operate at wavelengths above 1500 nm, a point at which appropriate photoreceivers become (at present) more expensive. Thus, as discussed above, it is acceptable to have one or more pairs operate in the visible range as well, and/or to avoid crosstalk by use of different signal encoding schemes between different pairs (e.g., by having pair **202**/**102** communicate via an amplitude modulated signal, whereas pair **108**/**204** communicates via a PWM signal, as discussed previously).

[**0026**] Looking more specifically to the structure of the earplug (as particularly illustrated in **FIG. 1**), the earplug **100** may take a variety of forms: for example, it may be fabricated as a custom-molded plug for deep insertion into the second bend of the ear canal (as depicted in **FIG. 1**), or it may be fabricated as a generic-fit earplug made of soft rubber or expandable foam for moderate insertion into the ear canal. In either case, for greatest comfort, it is useful to provide most circuit boards or other components at or near the surface of the earplug **100** so they do not extend into the ear canal. However, to minimize space, the earplug electroacoustic transducer **104** and earplug acoustoelectric transducer **106** may be situated within the interior of the sound-damping materials of the earplug **100**, and may include sound tubes **116** (e.g., 0.125 inch outer diameter silicone tubing) as shown in **FIG. 1** to communicate sound to and from the ear canal.

[**0027**] The earmuff **200**, which is not depicted in detail in the Figures, may also take a wide variety of forms, and may be configured similarly to virtually any standard audio headset. However, a sound-damping circumaural earmuff-type headset, wherein large cups with padded rims cover the user's ears, is particularly preferred. Any circuitry, light sources, and/or photovoltaic cells may simply be situated within each ear cup, preferably nearer its base than its rim to better maintain a short and direct line of sight between the relevant components of the earplugs **100** and earmuff **200**. In this respect, the various aforementioned light sources—the earmuff driver light **202**, the earmuff drive light **206**, and/or the earplug driver light **108**—are preferably not provided as single-source light sources (i.e., as a single LED, laser diode, or other light source), and are rather provided as spaced arrays of light sources, e.g., spaced about an area on the interior of the earmuff **200** and/or the earplug **100**. This arrangement helps to assure pickup of the light signals by the earplug **100** regardless of variation in the position of the earmuff **200**, for example, the earplug **100** may still receive the light signals even if the earmuff **200** is rotated about the wearer's ear. An alternative or additional arrangement is to provide the driving earplug optoelectric transducer **102**, powering earplug optoelectric transducer **110**, and/or earmuff optoelectric transducer **204** in multiple parts spread across the areas of the earplug **100** and/or the earmuff **200**.

[**0028**] Various preferred versions of the invention have been described above to illustrate different possible features of the invention and the varying ways in which these features may be combined. Apart from combining the different features of the foregoing versions in varying ways, other modifications are also considered to be within the scope of the invention. Thus, the invention is not intended to be limited to the preferred versions of the invention described above, but rather is intended to be limited only by the claims set out below, with the invention encompassing all different versions that fall literally or equivalently within the scope of these claims.

What is claimed is:

1. An audio system comprising:

a. an earplug adapted for mounting on or within an ear, the earplug including:

(1) an earplug optoelectric transducer providing electrical output upon receipt of light input; and

(2) an earplug electroacoustic transducer coupled to the earplug optoelectric transducer, the earplug electroacoustic transducer providing acoustic output upon receipt of electrical input;

b. an earmuff with an earmuff interior sized for fitting over an ear which bears the earplug, the earmuff interior including an earmuff driver light situated therein;

wherein the earmuff driver light may be actuated to transmit light to the earplug optoelectric transducer, in turn generating an acoustic output from the earplug electroacoustic transducer.

2. The audio system of claim 1 wherein the earmuff driver light is separated from the earplug optoelectric transducer by a free space.

3. The audio system of claim 1 wherein:

a. the earplug further includes an earplug driver light thereon, and

b. the earmuff interior includes an earmuff optoelectric transducer providing electrical output upon receipt of light input from the earplug driver light.

4. The audio system of claim 3 further comprising a noise processor receiving electrical output from the earmuff optoelectric transducer and providing electrical input to the earmuff driver light.

5. The audio system of claim 3 wherein the earplug further includes an earplug acoustoelectric transducer coupled to the earplug driver light, the earplug acoustoelectric transducer providing electrical output to the earplug driver light upon receipt of acoustic input.

6. The audio system of claim 3 wherein the earplug further includes a powering earplug optoelectric transducer providing electrical output to the earplug driver light upon receipt of light input.

7. The audio system of claim 6 wherein the earplug optoelectric transducer which receives light from the earmuff driver light is integral with the powering earplug optoelectric transducer, whereby the powering earplug optoelectric transducer both

(1) generates an acoustic output from the earplug electroacoustic transducer, and

(2) provides electrical output to the earplug driver light, upon receipt of light input.

8. The audio system of claim 6 wherein the earmuff interior includes a earmuff powering light situated therein and supplying light to the powering earplug optoelectric transducer.

9. The audio system of claim 8 wherein the earmuff driver light which transmits light to the earplug optoelectric transducer is integral with the earmuff powering light, whereby the earmuff powering light both:

(1) transmits light to the earplug optoelectric transducer to generate an acoustic output from the earplug electroacoustic transducer, and

(2) supplies light to the powering earplug optoelectric transducer to generate power therein.

10. The audio system of claim 1 wherein the earplug further includes:

a. an earplug driver light, and

b. a powering earplug optoelectric transducer providing electrical output to the earplug driver light upon receipt of light input.

11. The audio system of claim 10 wherein the earmuff interior includes a earmuff powering light situated therein and supplying light to the powering earplug optoelectric transducer to power the earplug driver light.

12. The audio system of claim 10 wherein the earplug further includes an earplug acoustoelectric transducer providing electrical output to the earplug driver light upon receipt of acoustic input.

13. The audio system of claim 10 wherein the earmuff further includes an earmuff optoelectric transducer which generates electrical output upon receipt of light input from the earplug driver light.

14. The audio system of claim 13 further comprising a noise processor receiving electrical output from the earmuff optoelectric transducer and providing electrical input to the earmuff driver light.

15. An audio system comprising:

a. an earplug adapted for mounting on or within an ear, the earplug including:

(1) an earplug acoustoelectric transducer, the earplug electroacoustic transducer providing electrical output upon receipt of acoustic input;

(2) an earplug driver light coupled to the earplug electroacoustic transducer and generating light in response to acoustic input therein;

b. an earmuff with an earmuff interior sized for fitting over the earplug, the earmuff interior including an earmuff optoelectric transducer providing electrical output upon receipt of light input from the earplug driver light,

whereby acoustic input at the earplug acoustoelectric transducer results in electrical output from the earmuff optoelectric transducer.

16. The audio system of claim 15 wherein the earplug driver light is separated from the earmuff optoelectric transducer by a free space.

17. The audio system of claim 15 wherein:

a. the earmuff interior further includes an earmuff driver light;

b. the earplug further includes:

(1) an earplug optoelectric transducer providing electrical output upon receipt of light input from the earmuff driver light; and

(2) an earplug electroacoustic transducer

(a) coupled to the earplug optoelectric transducer, and

(b) providing acoustic output upon receipt of electrical input from the earplug optoelectric transducer.

18. The audio system of claim 17 further comprising a noise processor interposed between the earmuff optoelectric transducer and the earmuff driver light.

19. The audio system of claim 15 wherein:

a. the earmuff interior further includes an earmuff powering light;

b. the earplug further includes a powering earplug optoelectric transducer, the powering earplug optoelectric transducer providing electrical output to the earplug driver light upon receipt of light input from the earmuff powering light.

20. An audio system comprising:

a. an earplug adapted for mounting on or within an ear, the earplug including:

(1) an earplug optoelectric transducer providing electrical output upon receipt of light input; and

(2) an earplug driver light coupled to the earplug optoelectric transducer;

b. an earmuff with an earmuff interior sized for fitting over an ear which bears the earplug, the earmuff interior including an earmuff powering light situated therein;

wherein the earplug optoelectric transducer powers the earplug driver light upon receipt of light from the earmuff powering light.

21. The audio system of claim 20 wherein the earmuff powering light is separated from the earplug optoelectric transducer by a free space.

22. The audio system of claim 20 wherein:

a. the earmuff interior further includes an earmuff driving light situated therein;

b. the earplug further includes:

(1) a driving earplug optoelectric transducer providing electrical output upon receipt of light input; and

(2) an earplug electroacoustic transducer coupled to the driving earplug optoelectric transducer, the earplug electroacoustic transducer providing acoustic output upon receipt of electrical input from the driving earplug optoelectric transducer.

23. The audio system of claim 22 wherein the earmuff interior further includes an earmuff optoelectric transducer situated therein, the earmuff optoelectric transducer generating an electrical output upon receipt of light from the earplug driver light.

24. The audio system of claim 23 further comprising a noise processor receiving the electrical output from the earmuff optoelectric transducer, and providing an electrical input to the earmuff driving light.

25. The audio system of claim 23 wherein the earplug further includes an earplug acoustoelectric transducer, the earplug electroacoustic transducer providing electrical output to the earplug driver light upon receipt of acoustic input.

26. The audio system of claim 20 wherein the earplug further includes an earplug acoustoelectric transducer, the earplug electroacoustic transducer providing electrical output to the earplug driver light upon receipt of acoustic input.

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