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(54) **EYEWEAR SPECTACLE WITH AUDIO SPEAKER IN THE TEMPLE**

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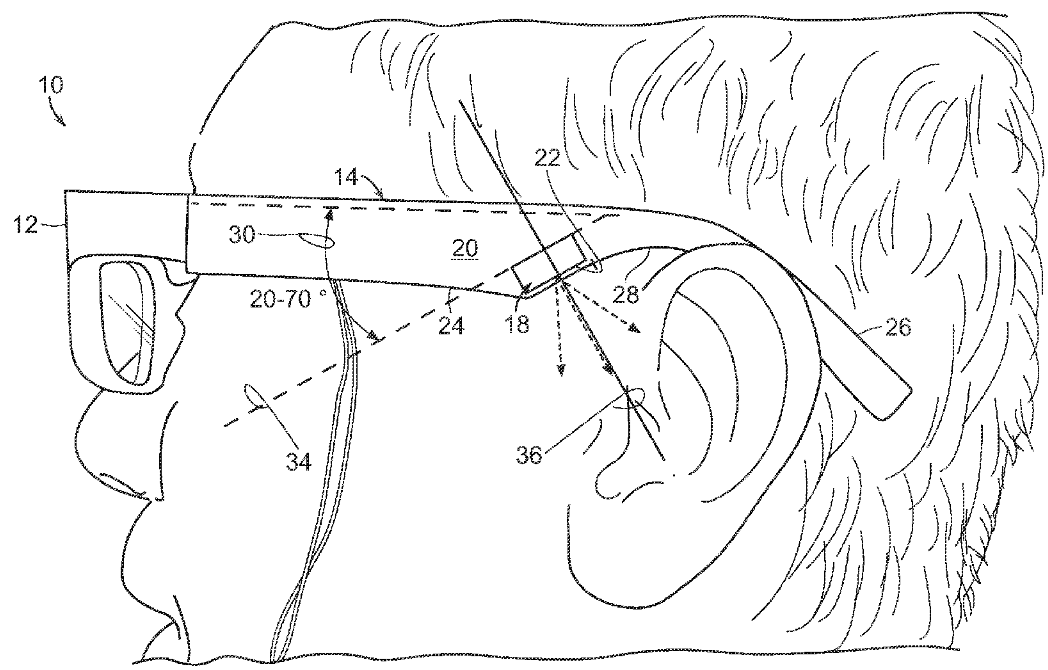
USPC **351/158**; 29/428

(57) **ABSTRACT**

Audio eyewear includes a front frame and at least one side frame member secured to the front frame for engaging a user's ear. The side frame members have speakers therein that are oriented to direct an audio port of the speaker face downwardly at an angle away from at least one side frame member, thereby directing sound downwardly and rearwardly into the users ear generally along the vertical plane. Embodiments of the invention include microphones for use in, for example, noise cancellation.



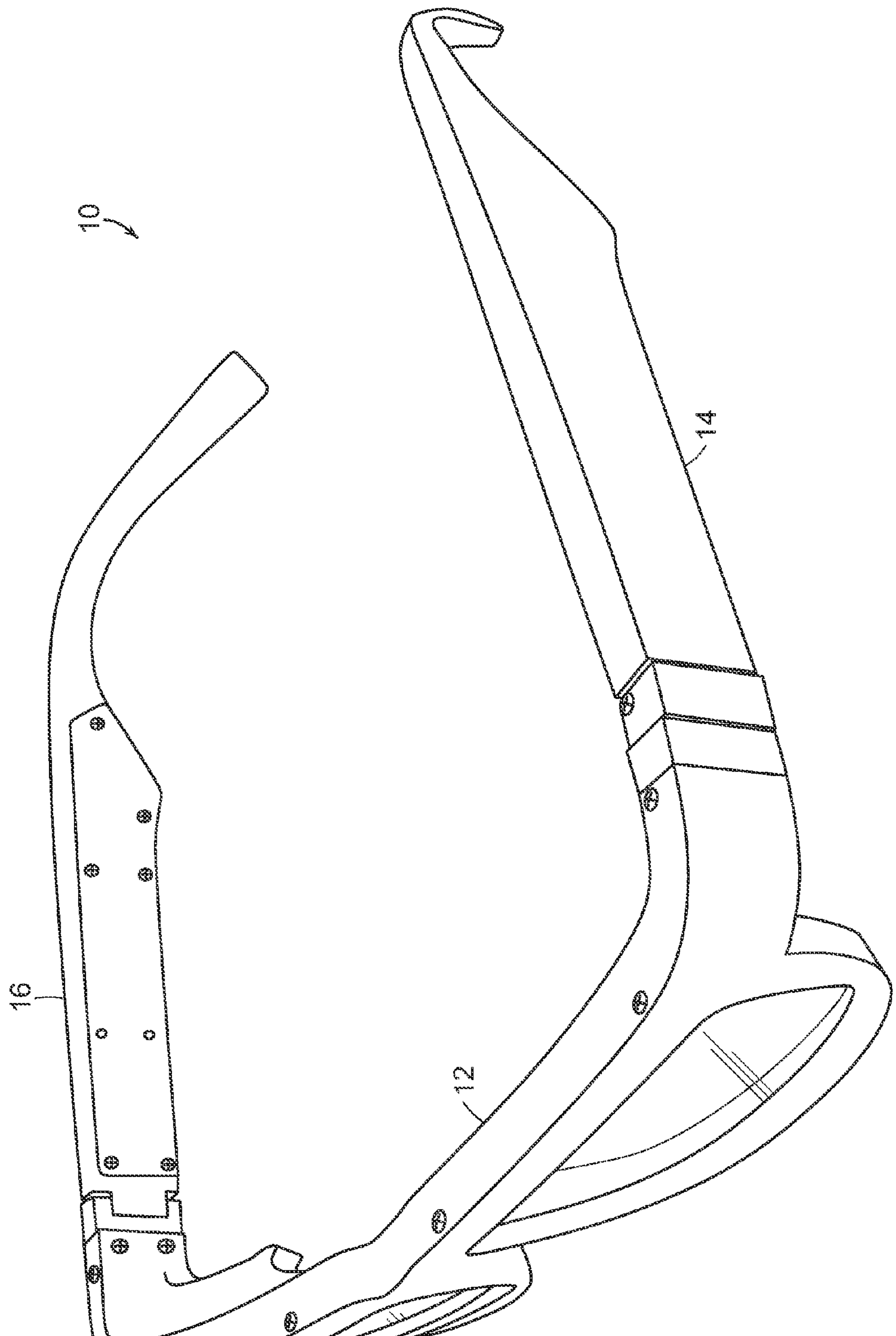


FIG. 1A

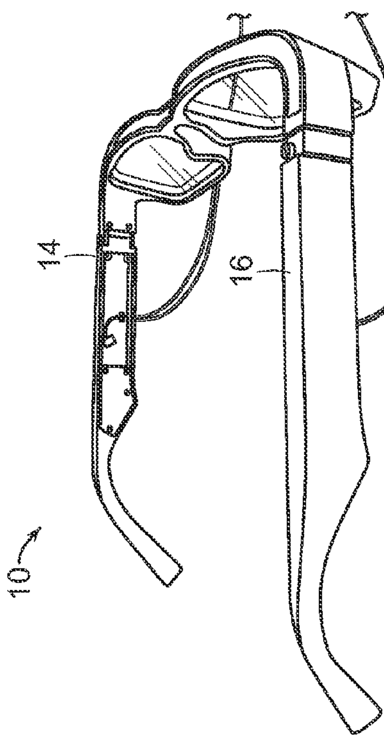


FIG. 1C

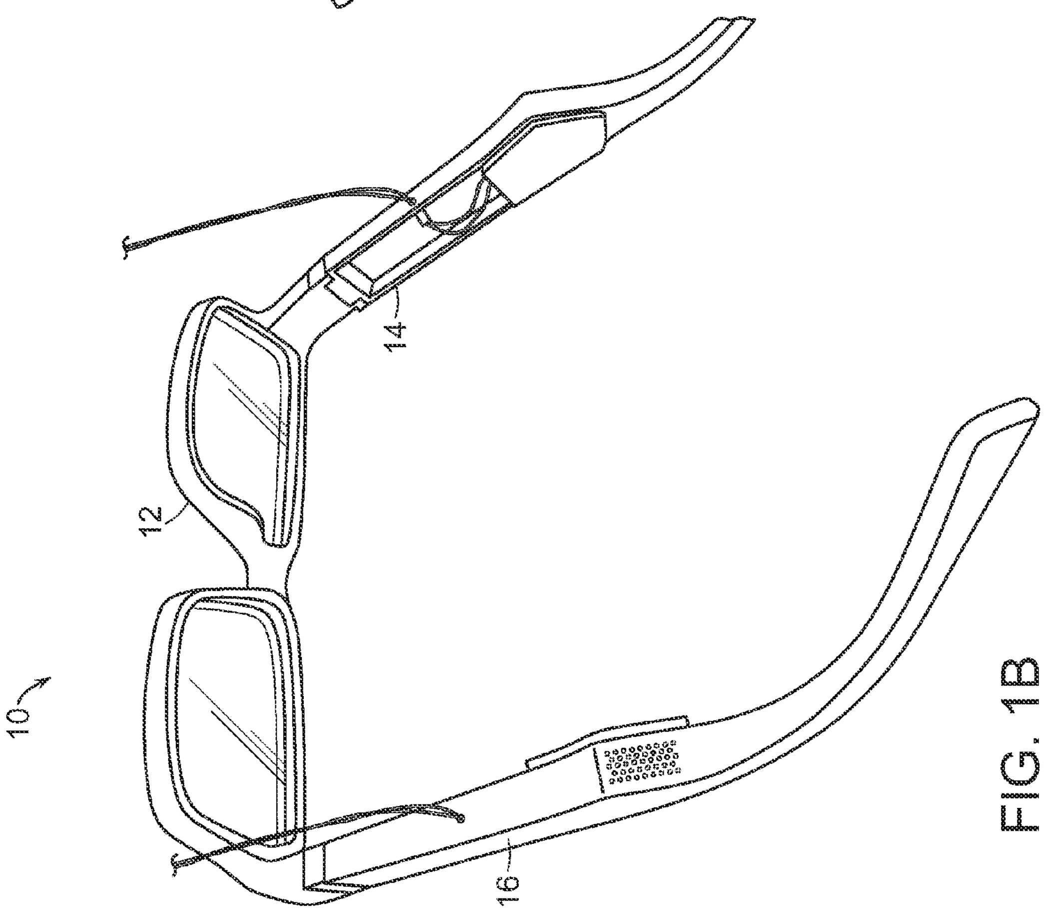


FIG. 1B

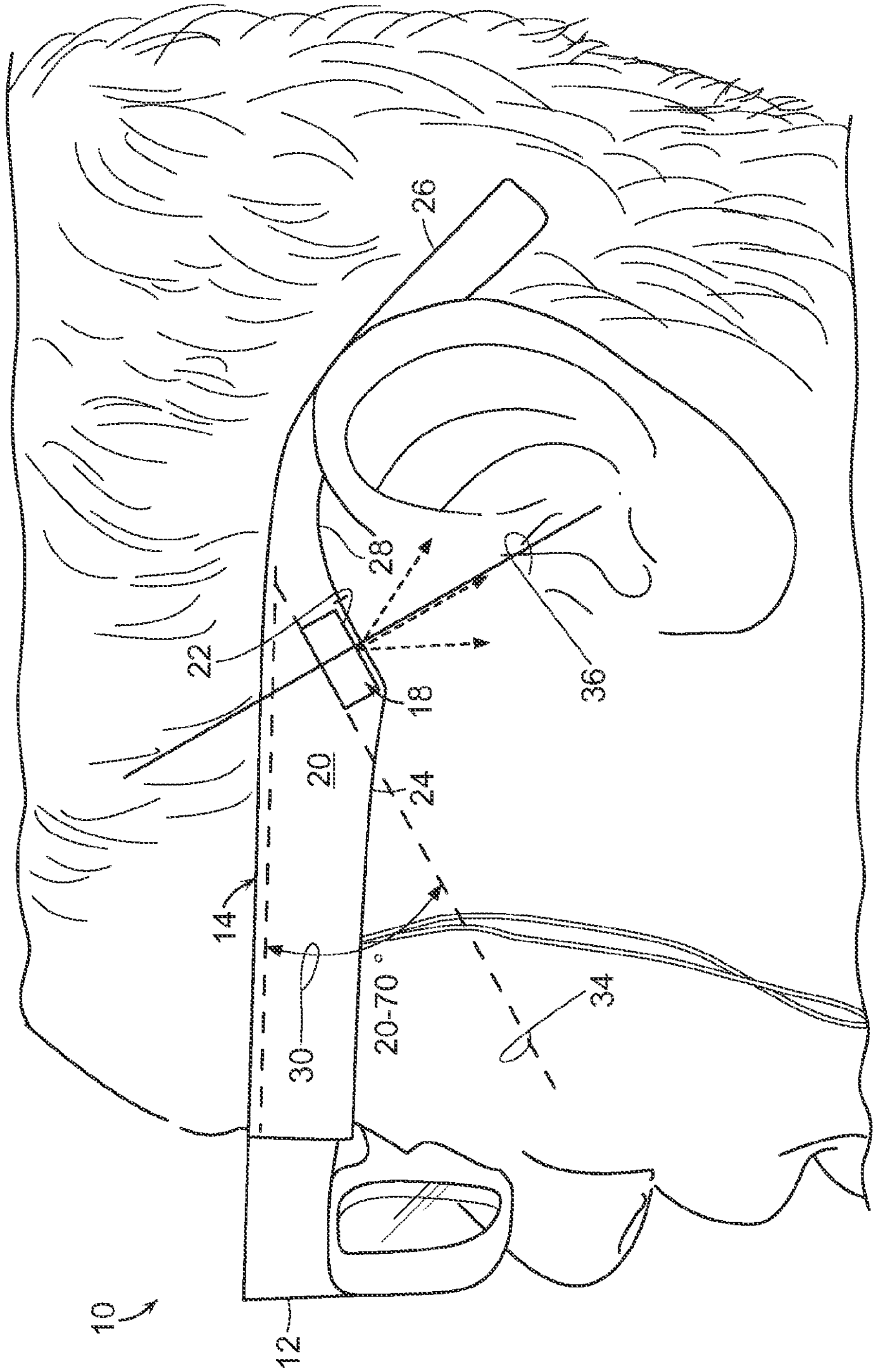


FIG. 2

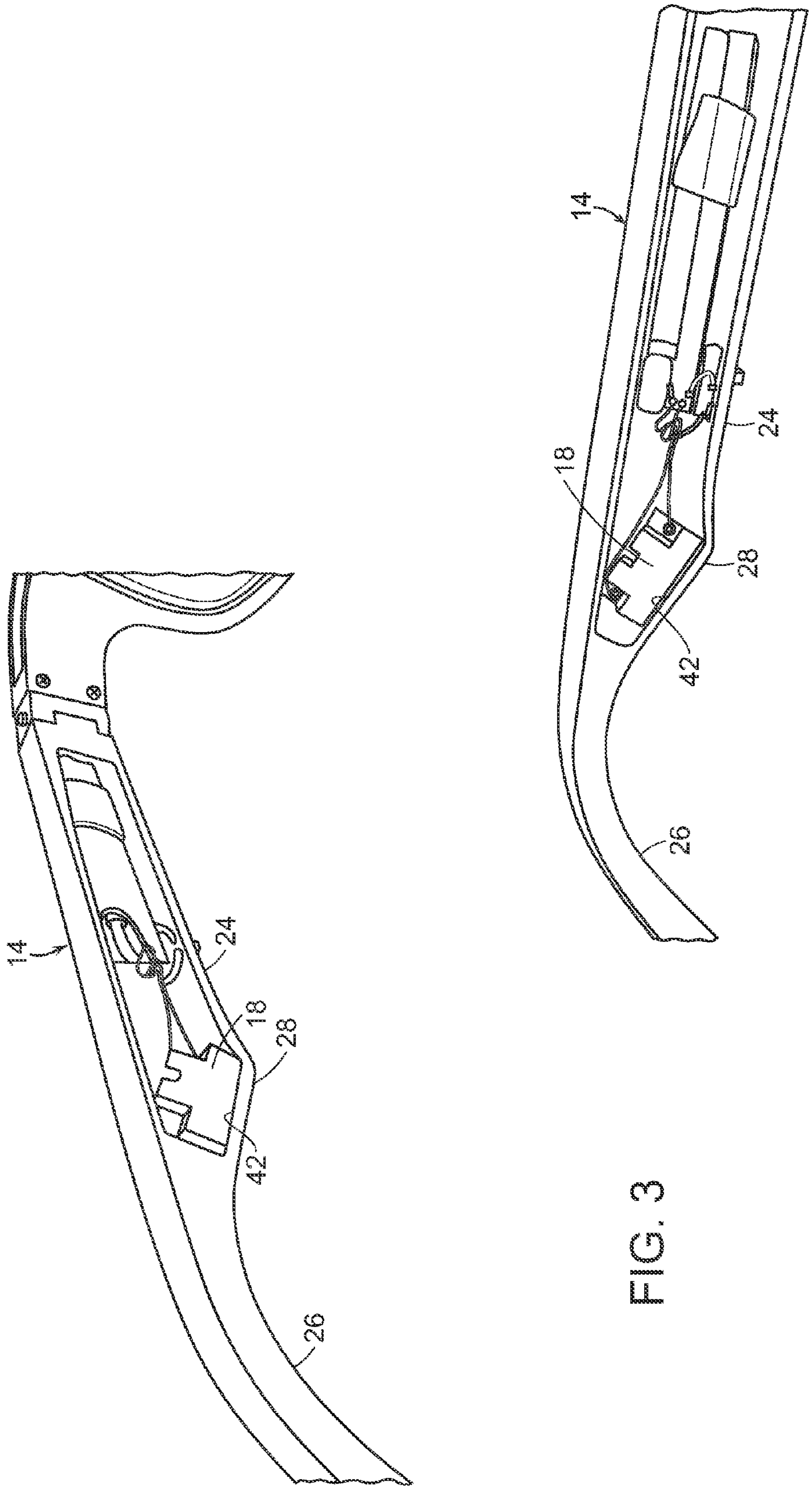


FIG. 3

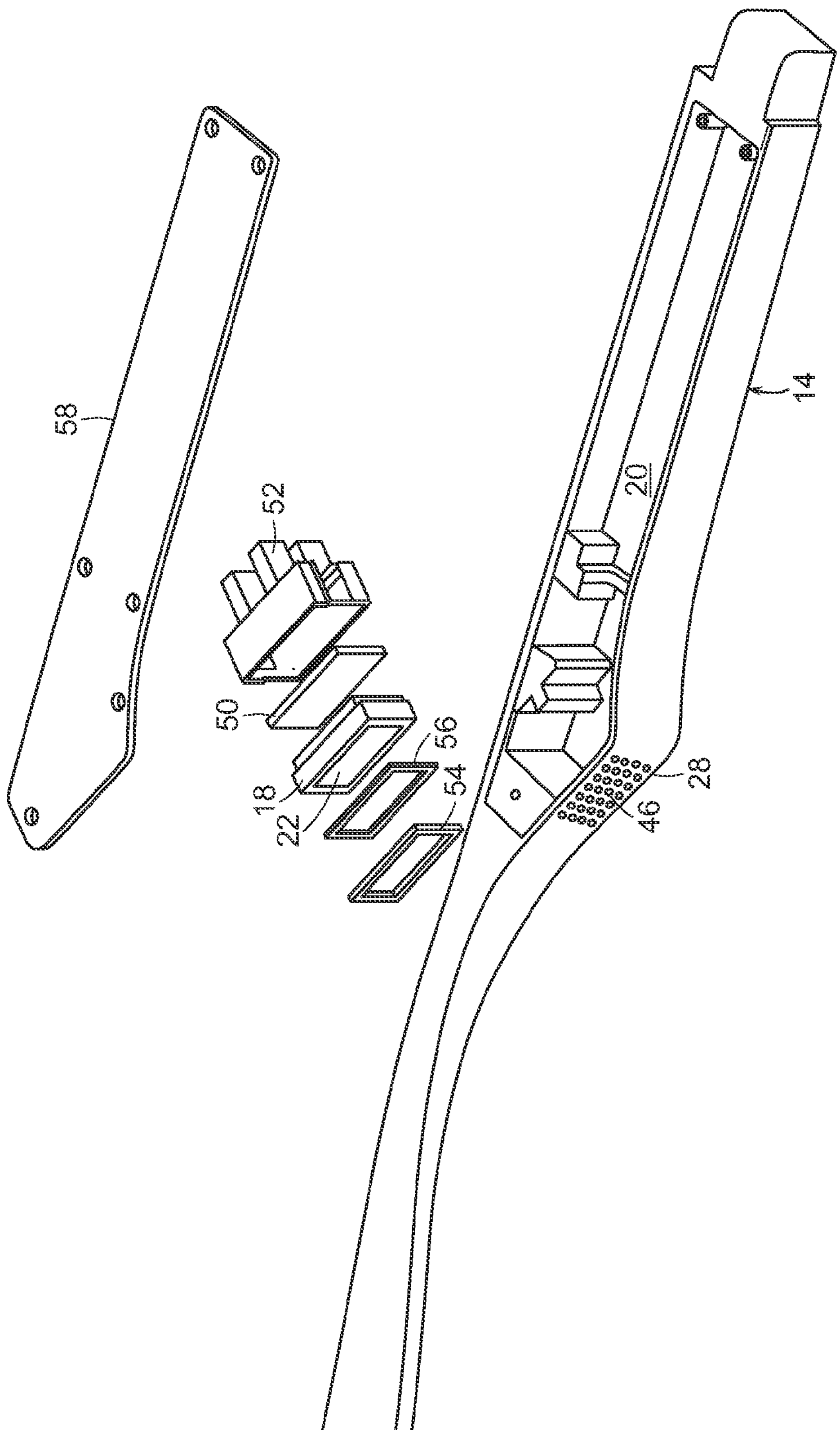


FIG. 4

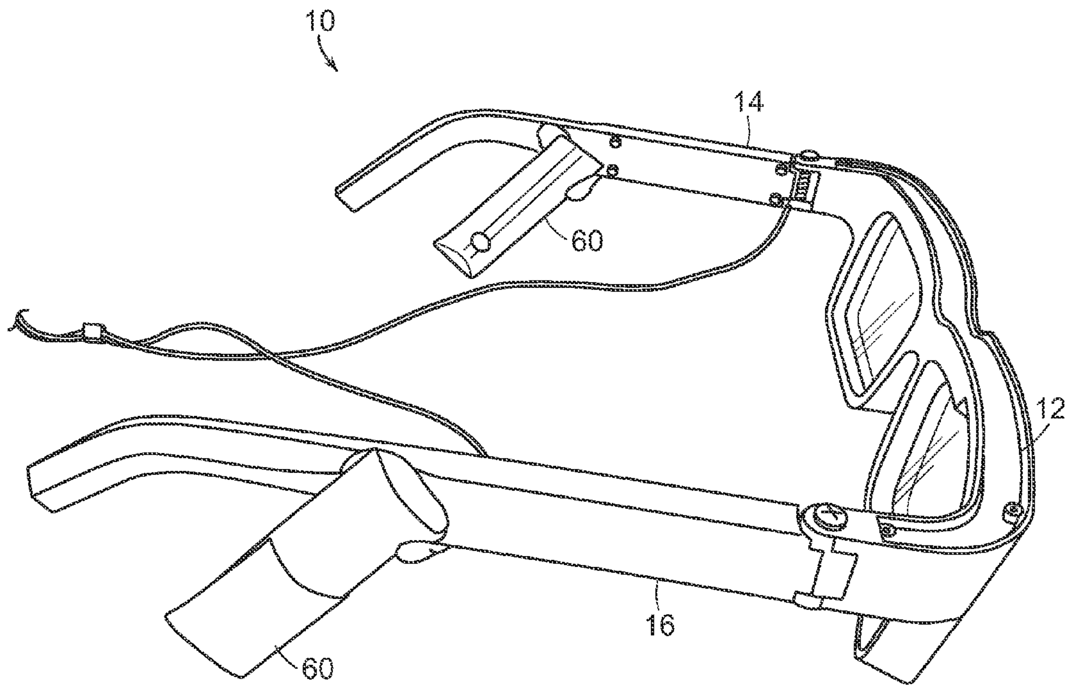


FIG. 5

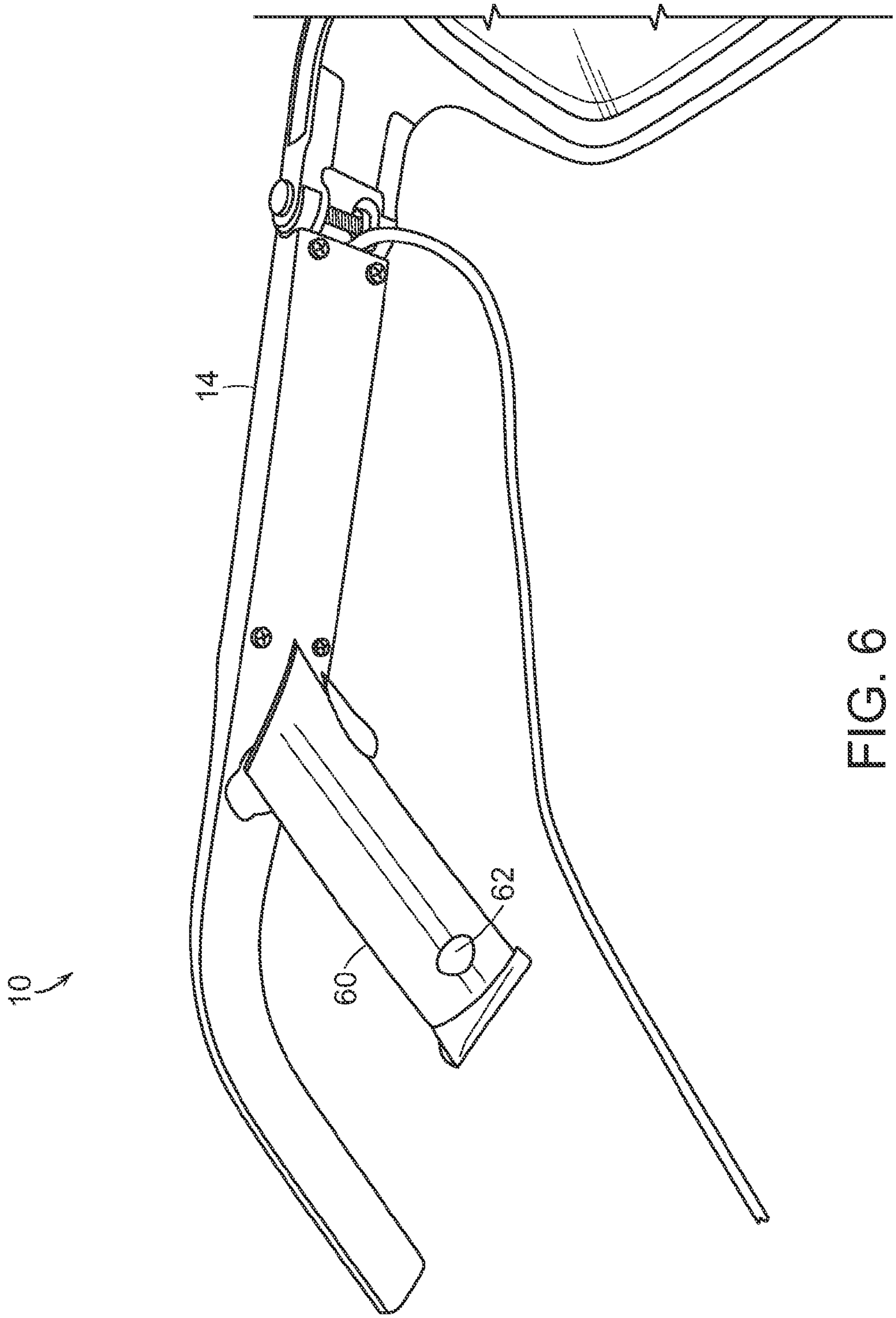


FIG. 6

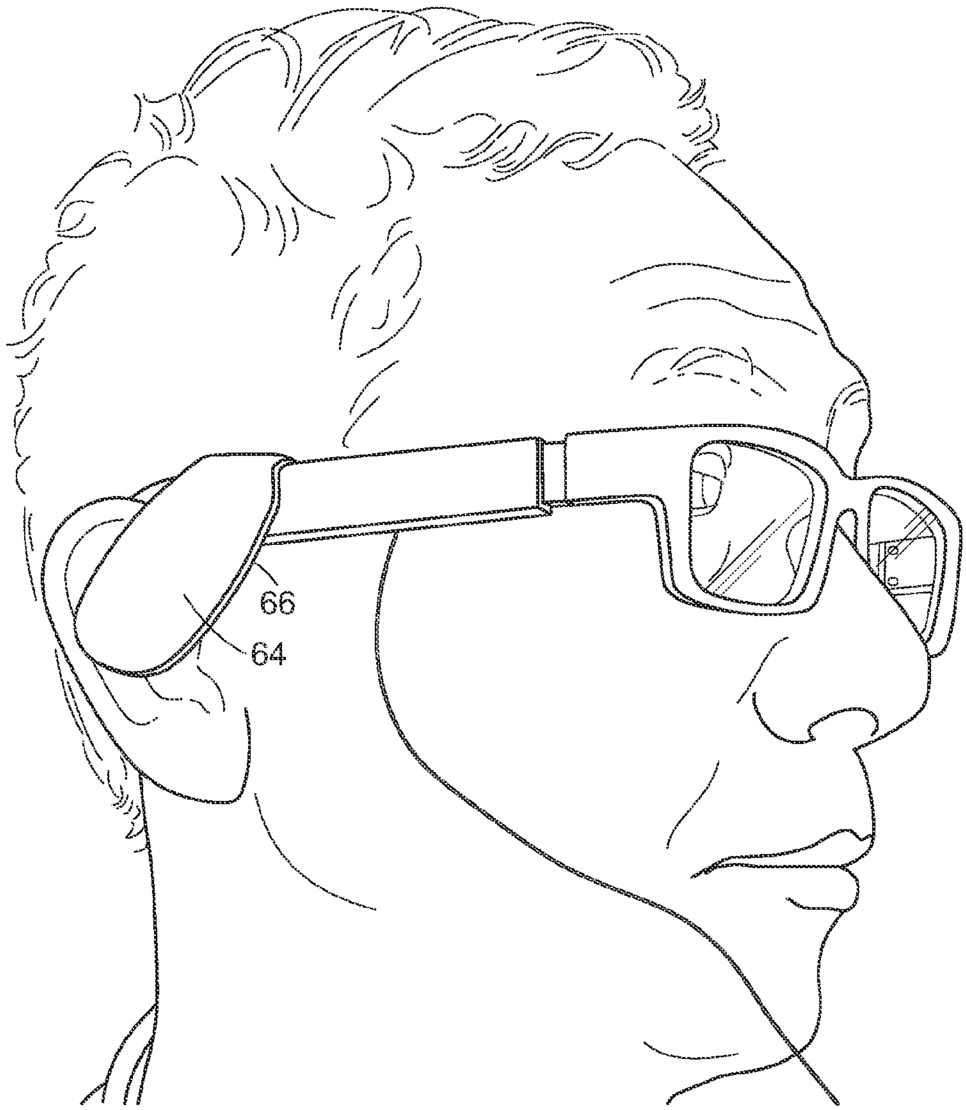


FIG. 7

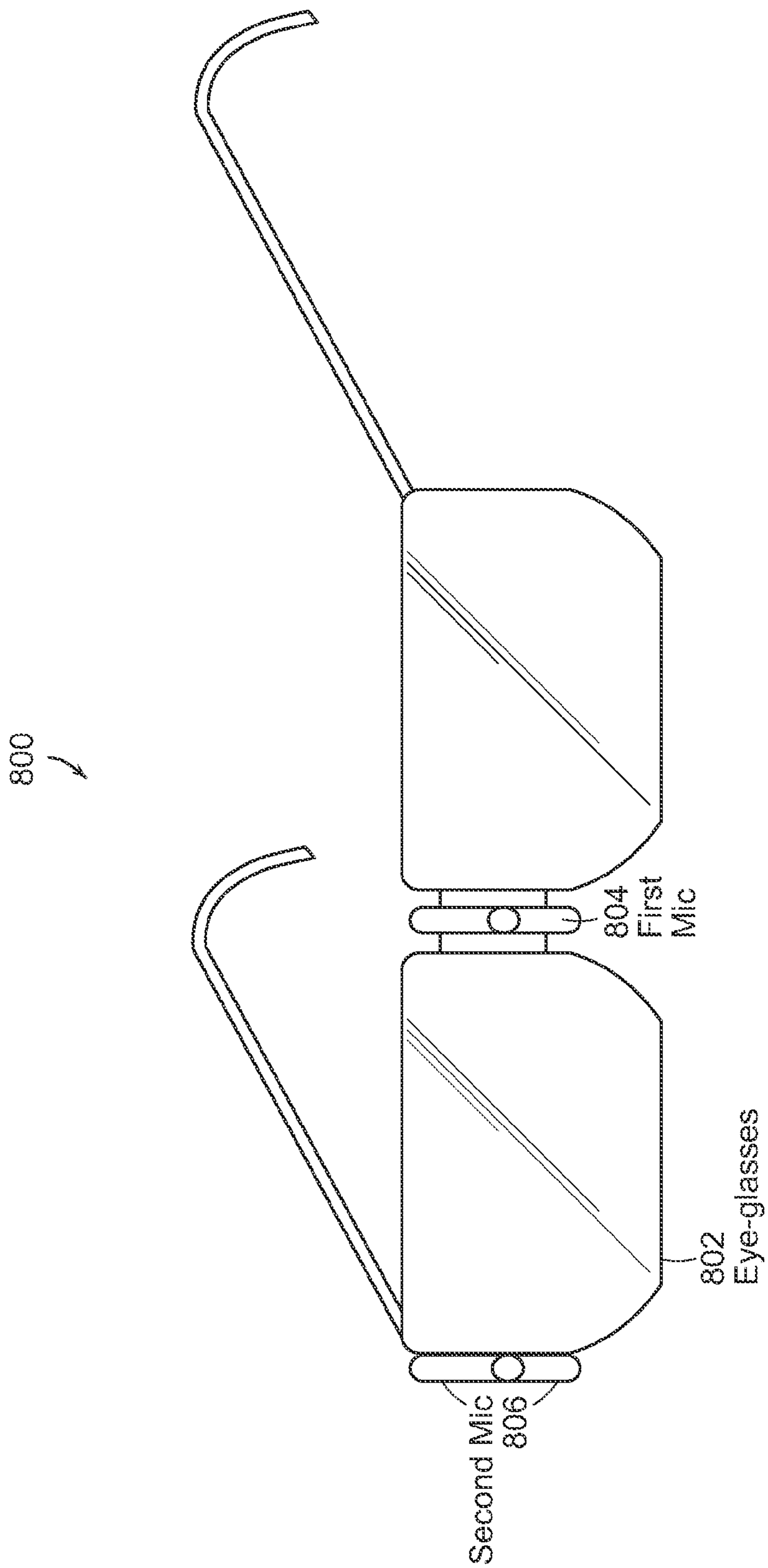


FIG. 8

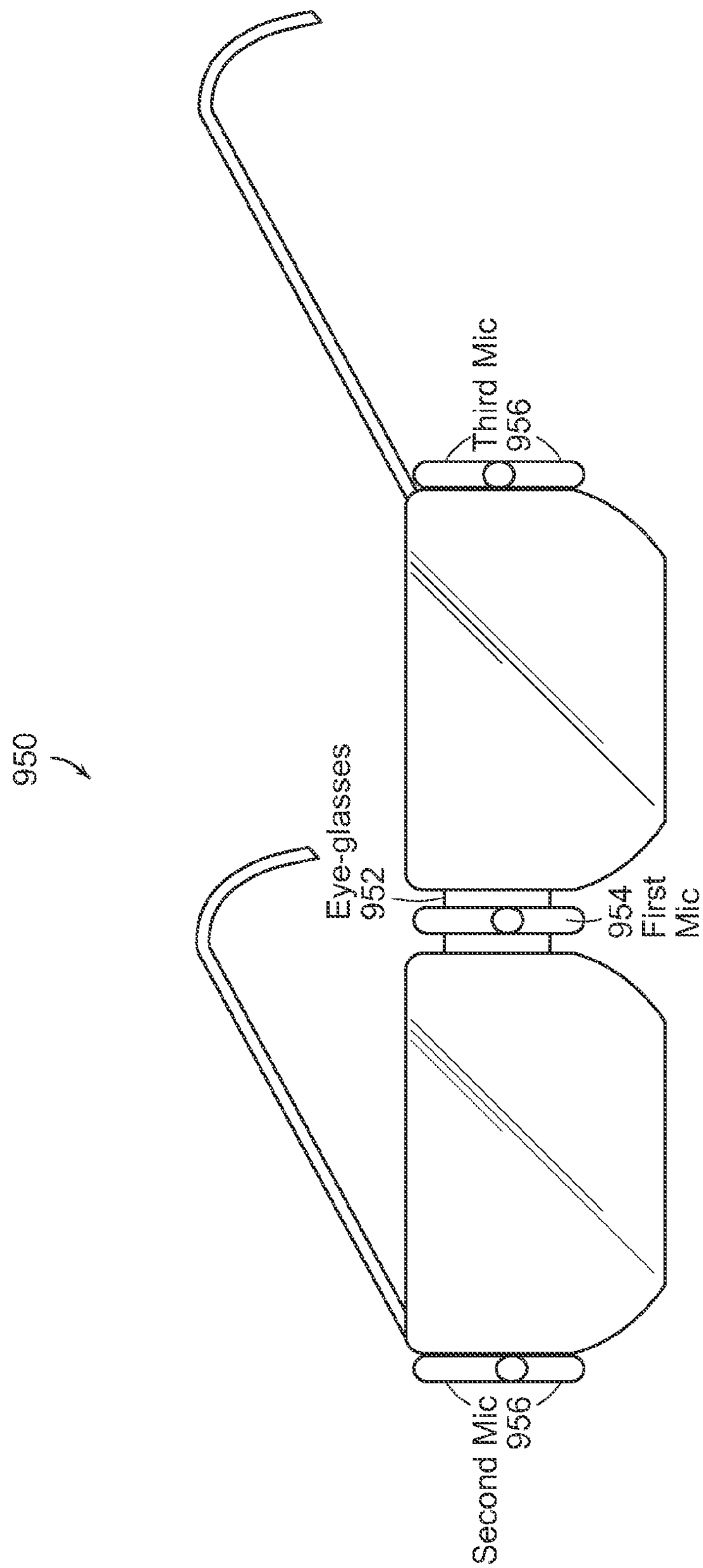

950
Third Mic
956
Eye-glasses
952
954
First
Mic
Second Mic
956

FIG. 9

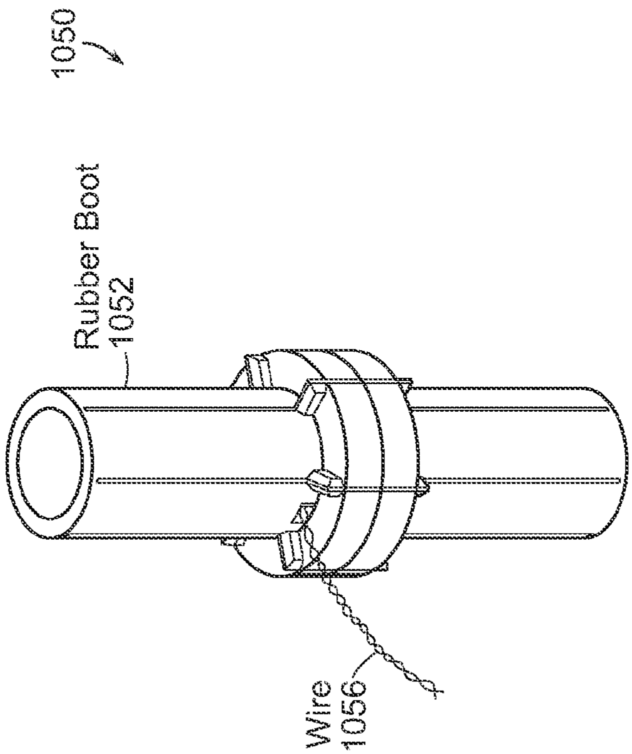


FIG. 10B

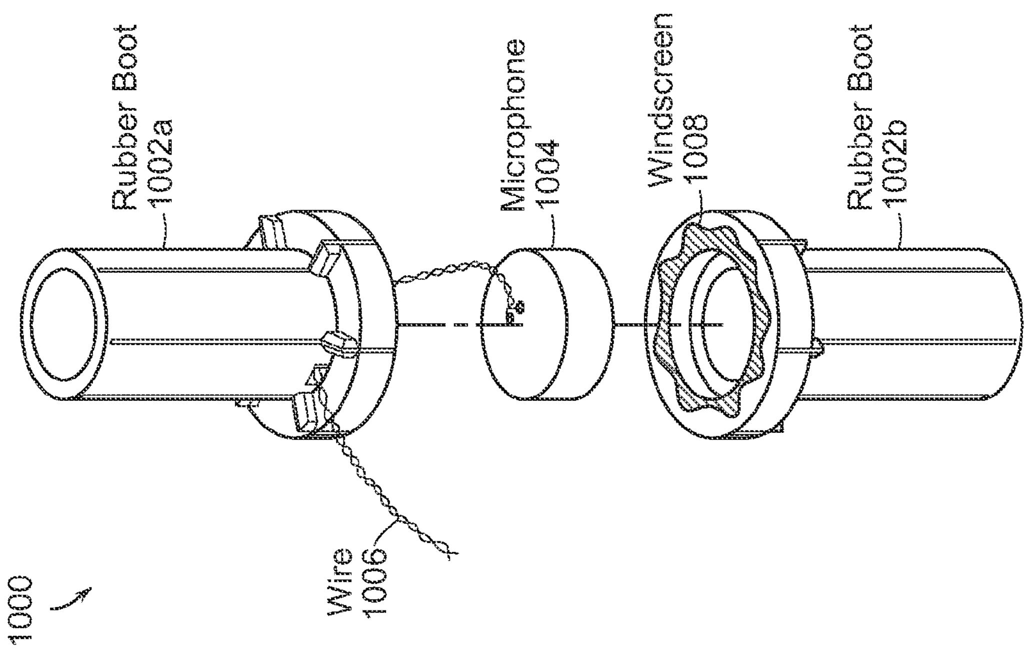


FIG. 10A

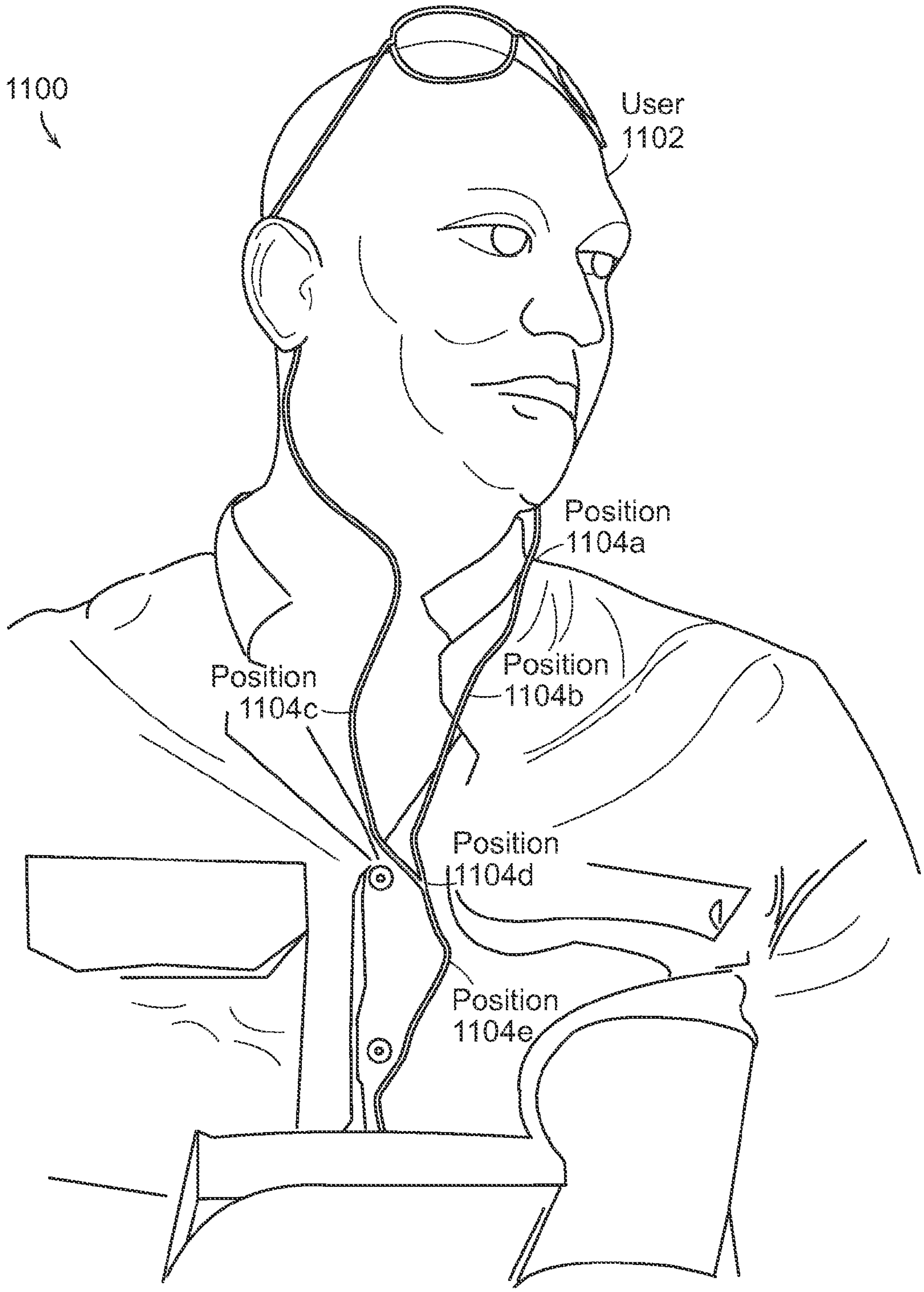

1100
User
1102
Position
1104a
Position
1104b
Position
1104c
Position
1104d
Position
1104e

FIG. 11

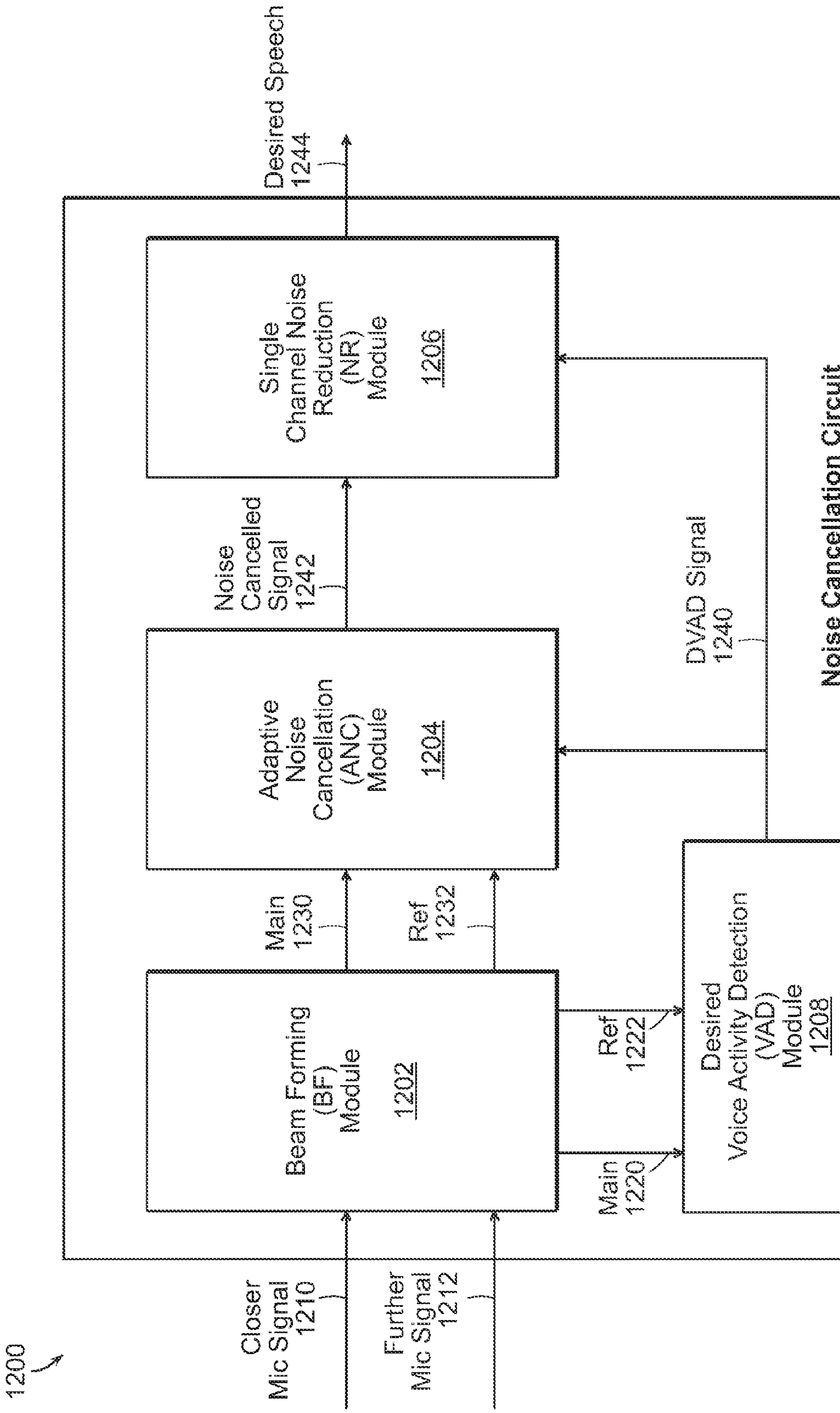

1200
Closer Mic Signal 1210
Further Mic Signal 1212
Beam Forming (BF) Module 1202
Main 1220
Ref 1222
Main 1230
Ref 1232
Desired Voice Activity Detection (VAD) Module 1208
Adaptive Noise Cancellation (ANC) Module 1204
DVAD Signal 1240
Noise Cancelled Signal 1242
Single Channel Noise Reduction (NR) Module 1206
Desired Speech 1244
Noise Cancellation Circuit 1201

FIG. 12

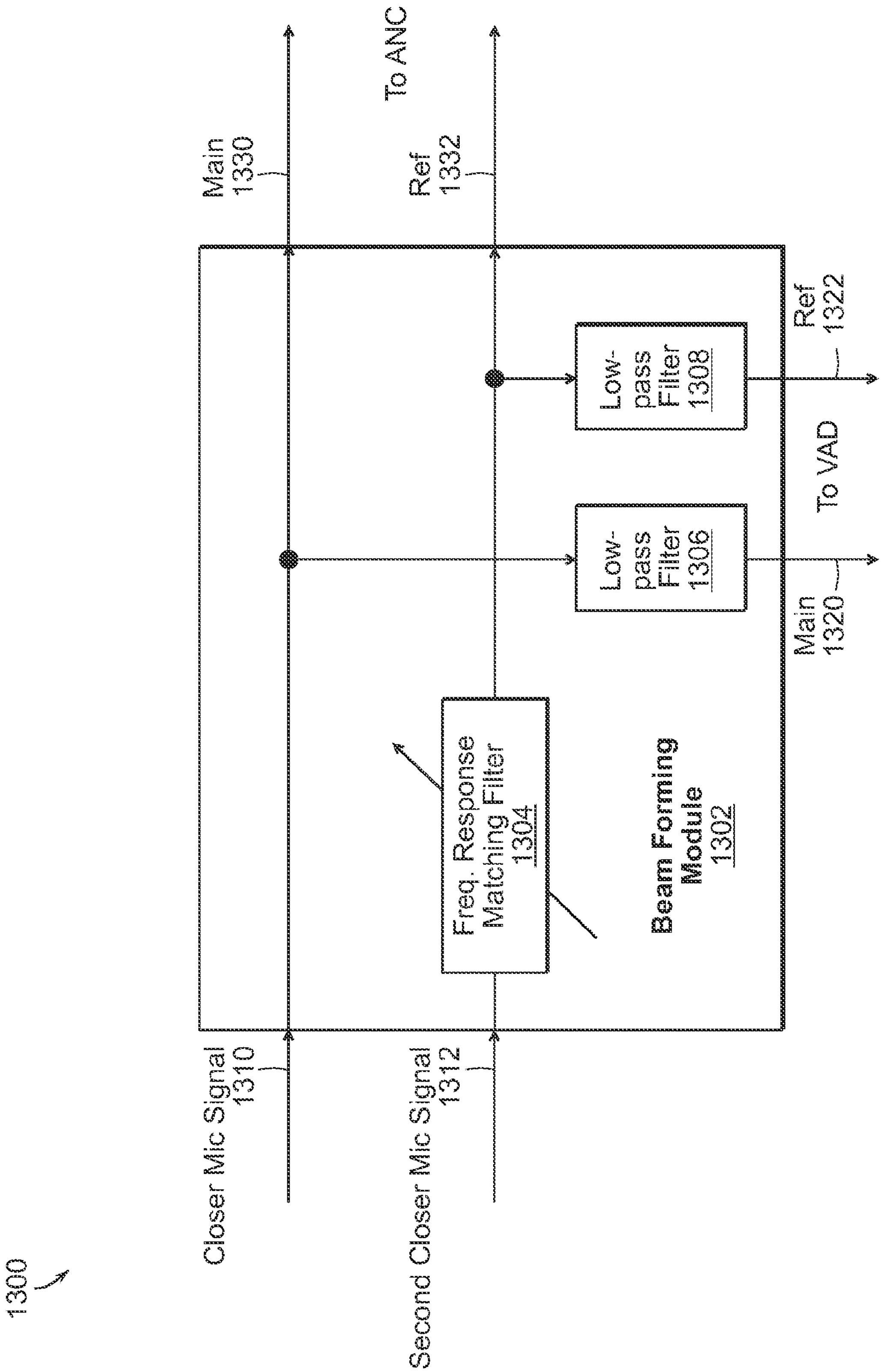

1300
Closer Mic Signal 1310
Second Closer Mic Signal 1312
Freq. Response Matching Filter 1304
Beam Forming Module 1302
Low-pass Filter 1306
Low-pass Filter 1308
Main 1320
Ref 1322
To VAD
Main 1330
Ref 1332
To ANC

FIG. 13

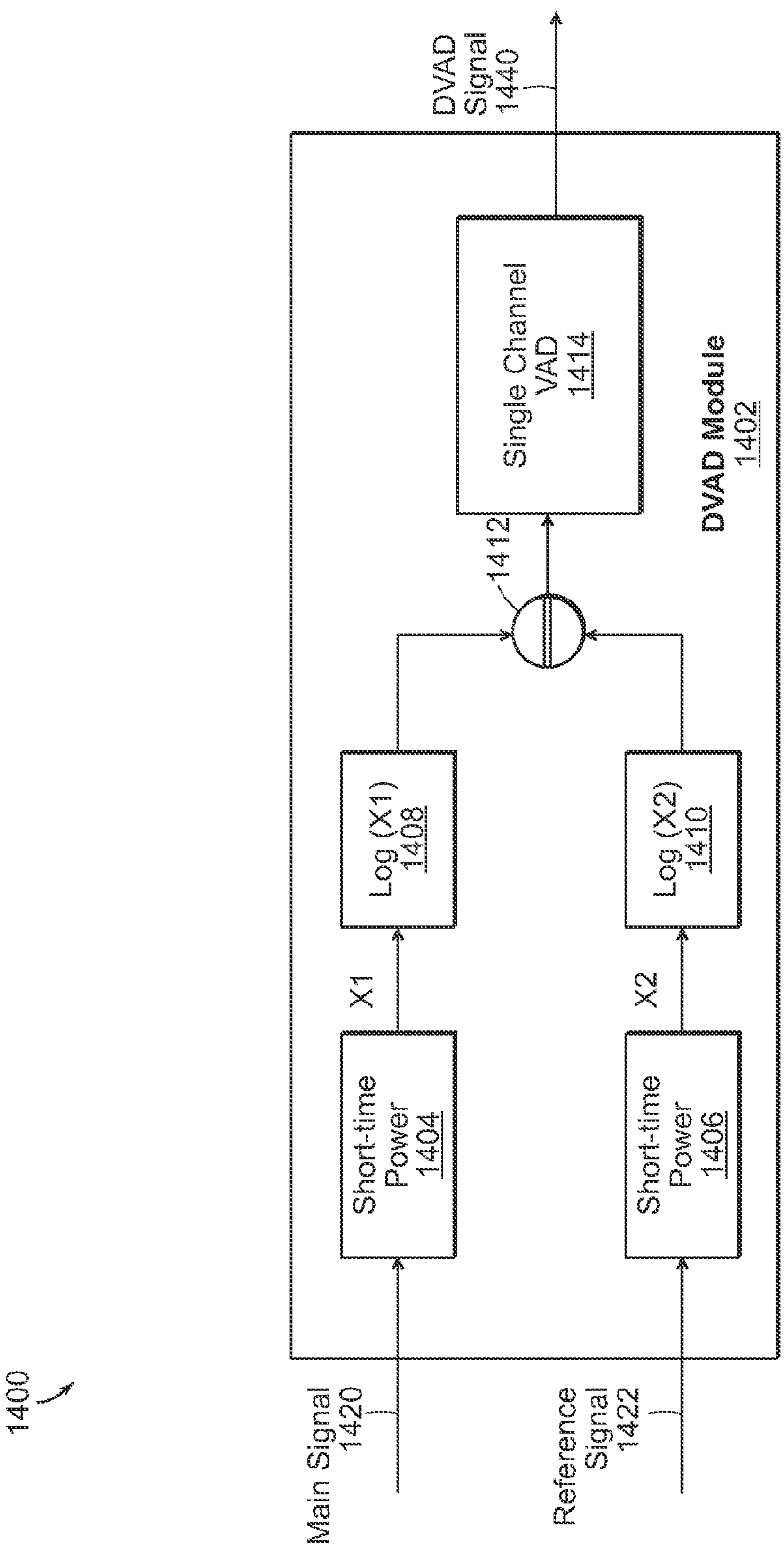
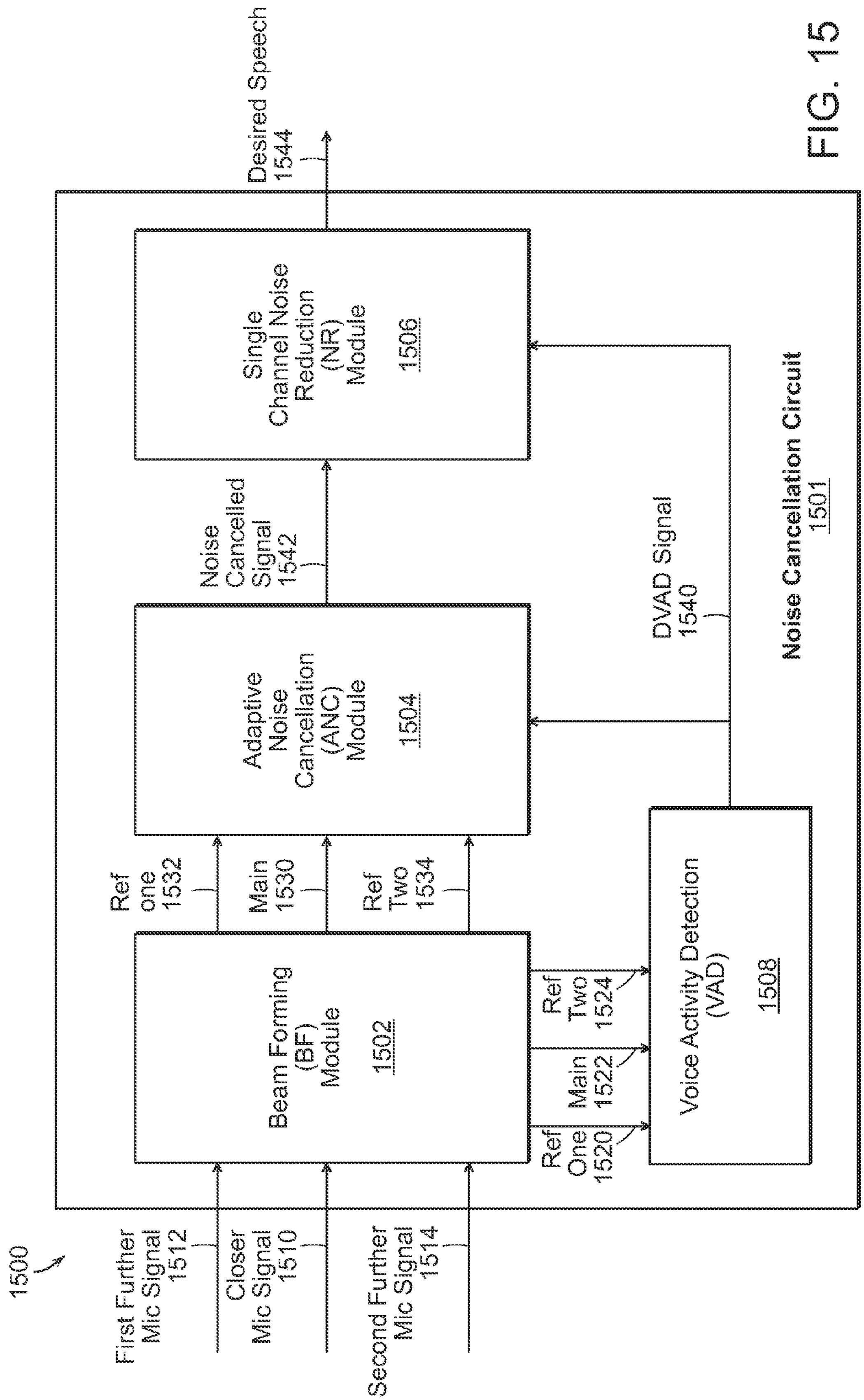

1400
Main Signal
1420
Reference Signal
1422
Short-time Power
1404
Short-time Power
1406
X1
X2
Log (X1)
1408
Log (X2)
1410
1412
Single Channel VAD
1414
DVAD Module
1402
DVAD Signal
1440

FIG. 14



1500
First Further Mic Signal 1512
Closer Mic Signal 1510
Second Further Mic Signal 1514
Beam Forming (BF) Module 1502
Ref One 1520
Main 1522
Ref Two 1524
Voice Activity Detection (VAD) 1508
Ref one 1532
Main 1530
Ref Two 1534
Adaptive Noise Cancellation (ANC) Module 1504
Noise Cancelled Signal 1542
DVAD Signal 1540
Single Channel Noise Reduction (NR) Module 1506
Desired Speech 1544
Noise Cancellation Circuit 1501

FIG. 15

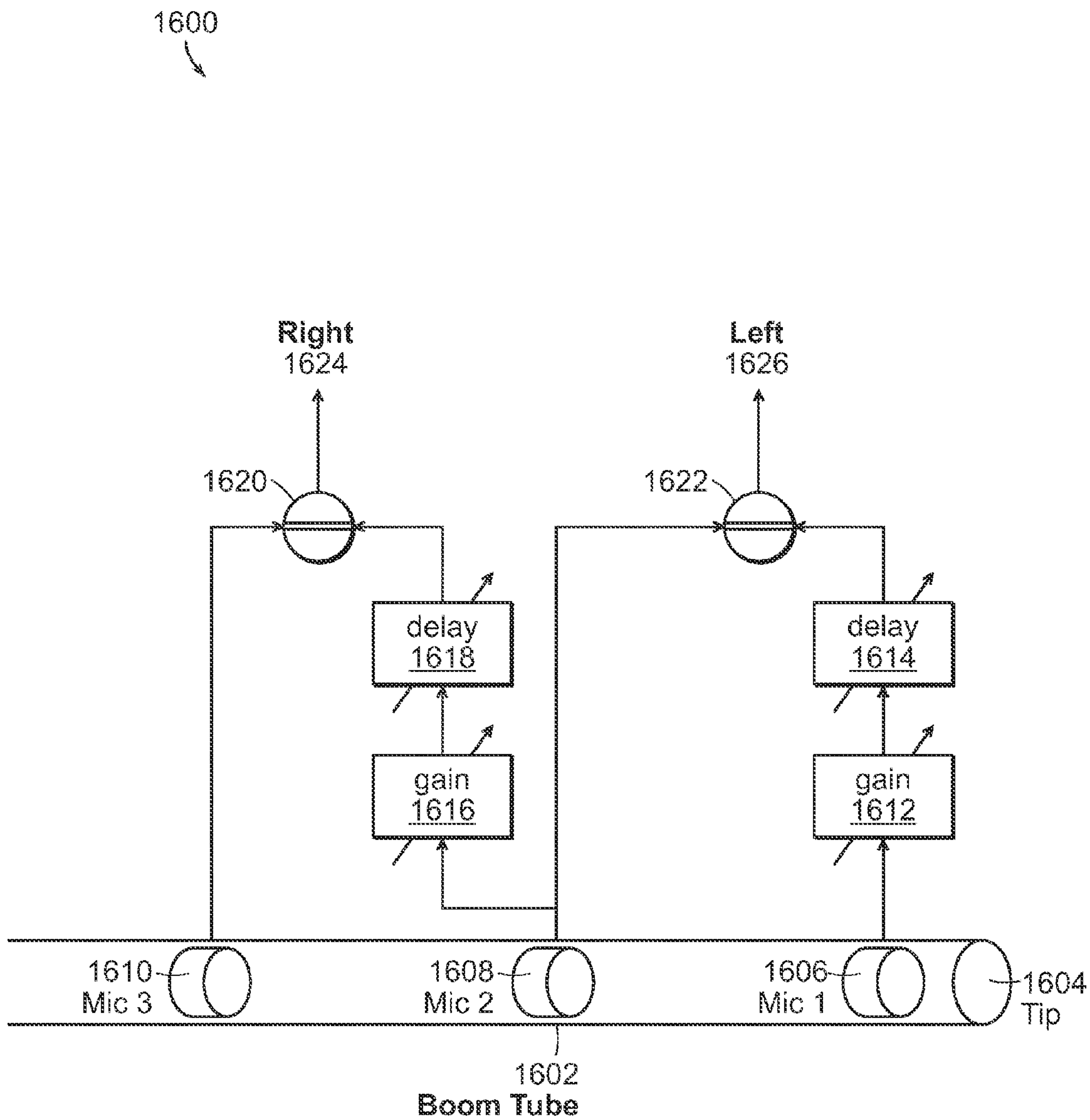

1600
Right
1624
Left
1626
1620
1622
delay
1618
delay
1614
gain
1616
gain
1612
1610
Mic 3
1608
Mic 2
1606
Mic 1
1604
Tip
1602
Boom Tube

FIG. 16

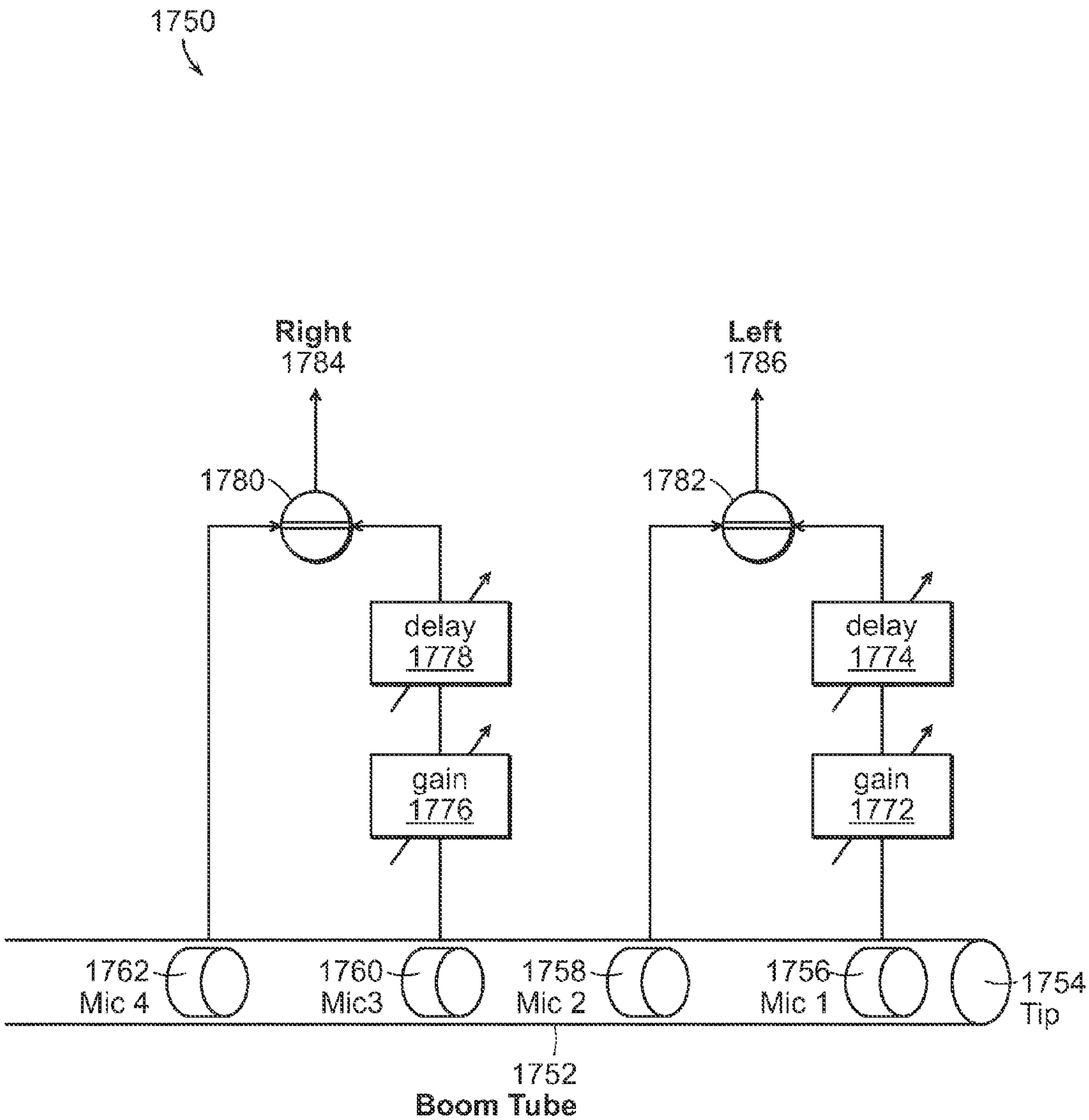

1750
Right
1784
Left
1786
1780
1782
delay
1778
delay
1774
gain
1776
gain
1772
1762
Mic 4
1760
Mic3
1758
Mic 2
1756
Mic 1
1754
Tip
1752
Boom Tube

FIG. 17

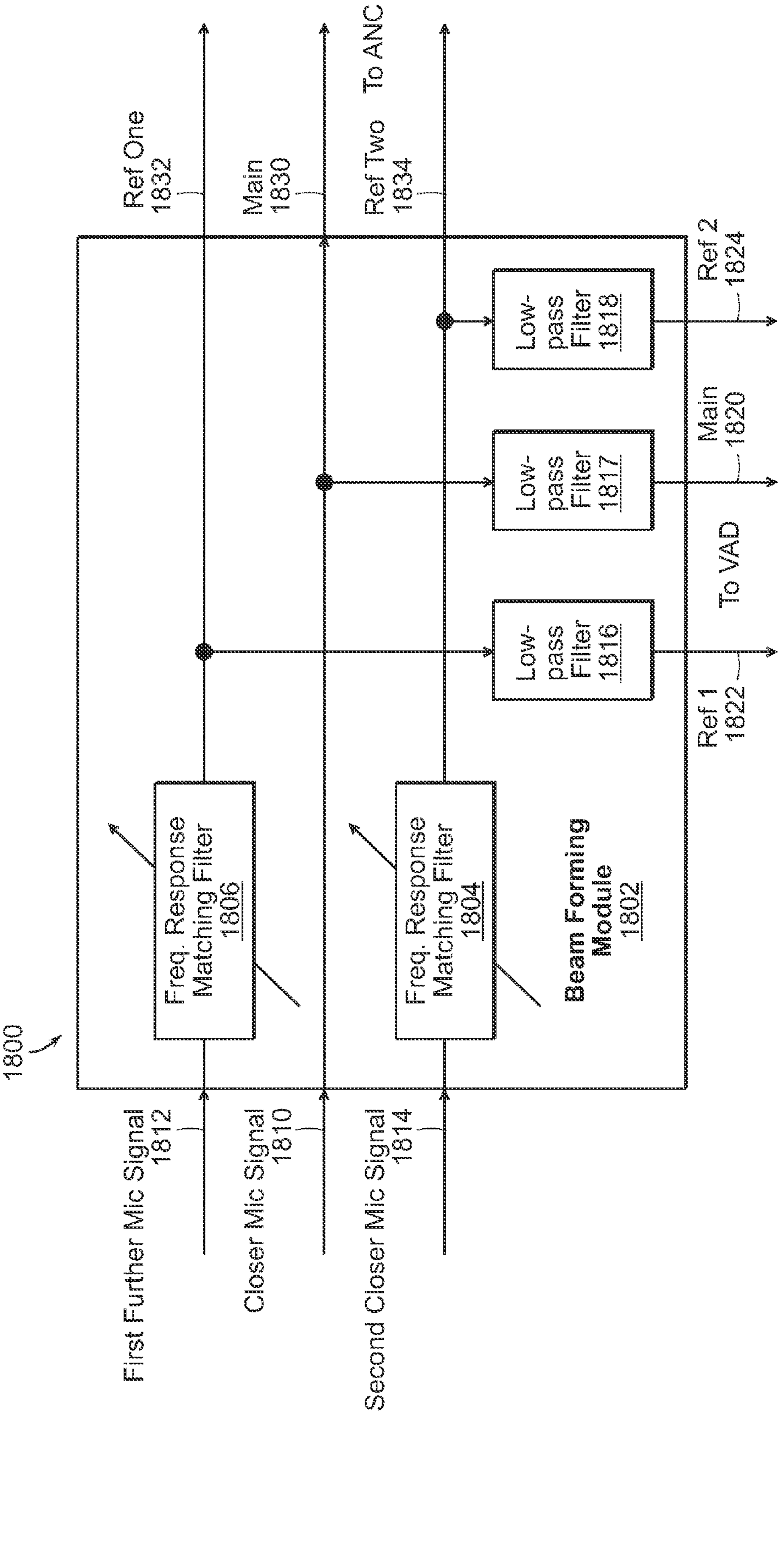

1800
First Further Mic Signal 1812
Closer Mic Signal 1810
Second Closer Mic Signal 1814
Freq. Response Matching Filter 1806
Freq. Response Matching Filter 1804
Beam Forming Module 1802
Low-pass Filter 1816
Low-pass Filter 1817
Low-pass Filter 1818
Ref 1 1822
Main 1820
Ref 2 1824
To VAD
Ref One 1832
Main 1830
Ref Two 1834
To ANC

FIG. 18

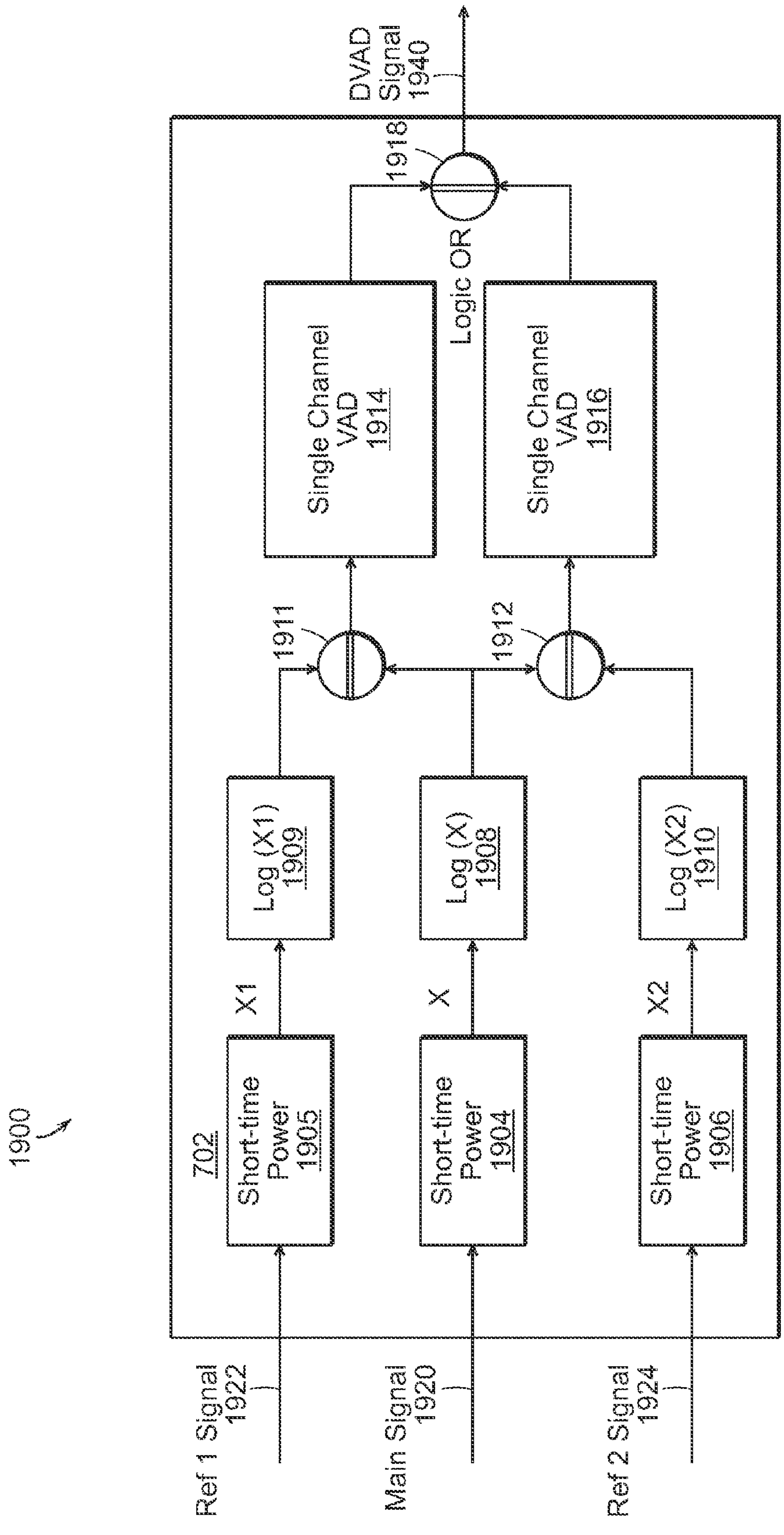

1900
Ref 1 Signal 1922
Main Signal 1920
Ref 2 Signal 1924
702
Short-time Power 1905
Short-time Power 1904
Short-time Power 1906
X1
X
X2
Log (X1) 1909
Log (X) 1908
Log (X2) 1910
1911
1912
Single Channel VAD 1914
Single Channel VAD 1916
Logic OR
1918
DVAD Signal 1940

FIG. 19

EYEWEAR SPECTACLE WITH AUDIO SPEAKER IN THE TEMPLE

RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 61/912,844, filed on Dec. 6, 2013. This application also claims the benefit of U.S. Provisional Application No. 61/780,108, filed on Mar. 13, 2013. This application also claims the benefit of U.S. Provisional Application No. 61/839,211, filed on Jun. 25, 2013. This application also claims the benefit of U.S. Provisional Application No. 61/839,227, filed on Jun. 25, 2013.

[0002] This application is being co-filed on the same day, Feb. 14, 2014, with "Eye Glasses With Microphone Array" by Dashen Fan, Attorney Docket No. 0717.2220-001. This application is being co-filed on the same day, Feb. 14, 2014, with "Sound Induction Ear Speaker For Eye Glasses" by Dashen Fan, Attorney Docket No. 0717.2221-001. This application is being co-filed on the same day, Feb. 14, 2014, with "Noise Cancelling Microphone Apparatus" by Dashen Fan, Attorney Docket No. 0717.2216-001.

[0003] The entire teachings of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0004] Traditionally, earphones have been used to present acoustic sounds to an individual when privacy is desired or it is desired not to disturb others. Examples of traditional earphone devices include over-the-head headphones having an ear cup speaker (e.g. Beats® by Dr. Dre headphones), ear bud style earphones (e.g., Apple iPod® earphones and Bluetooth® headsets), bone-conducting speakers (e.g., Google Glass). Another known way to achieve the desired privacy or peace and quiet for others is by using directional multi-speaker beam-forming. Also well-known but not conventionally used to present acoustic sounds to an individual that is not hearing-impaired are hearing aids. An example of which is the open ear mini-Behind-the-Ear (BTE) with Receiver-In-The-Aid (RITA) device. Such a hearing aid typically includes a clear "hook" that acts as an acoustic duct tube to channel audio speaker (also referred to as a receiver in telephony applications) sound to the inner ear of a user and act as the mechanical support so that the user can wear the hearing aid, the speaker being housed in the behind-the-ear portion of the hearing aid body. However, the aforementioned techniques all have drawbacks, namely, they are either bulky, cumbersome or unreliable.

[0005] Therefore, a need exists for earphones that overcome or minimize the above-referenced problem.

SUMMARY OF THE INVENTION

[0006] The present invention generally is directed to audio eyewear and methods of their use.

[0007] In one embodiment, the audio eyewear of the invention includes a front frame and at least one temple or side frame member secured to the front frame for engaging a user's ear. The at least one side frame member has a speaker therein which can be oriented such that an audio port of the speaker faces downwardly at an angle away from the front frame and the at least one side frame member, thereby directing sound downwardly rearwardly into the user's ear generally along a vertical plane.

[0008] In a particular embodiment, the eyewear device further includes an array of microphones coupled to at least one of the front frame and at least one side frame member. The array of microphones includes at least a first and second microphone. The first microphone is located at a temple region between a top corner of a lens opening defined by the front frame and having an inner edge, and the at least one side frame member. The second microphone is located at an inner edge of the lens opening. This embodiment of the eyewear device also includes first and second audio channel outputs from the first and second microphones, respectively.

[0009] In a still more particular embodiment of the invention, the eyewear device additionally includes a beam-former electronically linked to the first and second microphones, for receiving at least the first and second audio channels and outputting the main channel and one or more reference channels. A voice activity detector is electronically linked to the beam-former for receiving the main and reference channels and outputting the desired voice activity channel. An adaptive noise canceler is electronically linked to the beam-former and the voice activity detector for receiving the main, reference and desired voice activity channels and outputting an adaptive noise cancellation channel. The noise reducer is electronically linked to the voice activity detector and the adaptive noise canceller for receiving the desired voice activity and adaptive noise cancellation channels and for outputting a desired speech channel.

[0010] Still another embodiment of the invention is a method of hearing audio, including the steps of providing audio eyewear having a front frame and at least one side frame member secured to the front frame for engaging a user's ear, the at least one side frame member having a speaker therein, and orienting the speaker such that an audio port of the speaker faces downwardly relatedly at an angle away from said at least one side frame member for directing sound downwardly rearwardly in to said users' ear generally along the vertical frame.

[0011] In one embodiment of the method, an array of microphones is coupled to the eyewear, wherein the array of microphones includes at least a first and second microphone. The first microphone is arranged to couple to the eyewear above the temple region, the temple region being located approximately between the top corner of a lens opening defined by the front frame and a support frame. The second microphone is coupled to the eyewear frame about an inner edge of the lens opening. First and second channel outputs are provided from the first and second microphones, respectively.

[0012] In yet another embodiment of the method, the method further includes the steps of forming beams at a beam-former, the beam-former receiving at least the first and second audio channels and outputting a main channel and one or more reference channels. Voice activities are detected by a voice activity detector, wherein the voice activity detector receives main and reference channels and outputs a desired voice activity channel. Noise is adaptively canceled at an adaptive noise canceller, the adaptive noise canceller receiving the main, reference and desired voice activity channels and outputting an adaptive noise cancellation channel. Noise is then reduced at a noise reducer receiving the desired voice activity and adaptive noise cancellation channels, and outputting a desired speech channel.

[0013] The present invention has many advantages. For example, the eyewear spectacle of the invention is relatively compact, unobtrusive, and durable. Further, the device and method can be integrated with noise cancellation apparatus and methods that are also, optionally, components of the eyewear itself. In one embodiment, noise cancellation apparatus, including microphones, electrical circuitry, and software can be integrated with and, optionally, on board the eyewear worn by the user. In another embodiment, microphones mounted on board the eyewear can be integrated with the speakers and with circuitry, such as a computer, receiver or transmitter to thereby process signals received from an external source or the microphones, or to process and transmit signals from the microphone, and to selectively transmit those signals, whether processed or unprocessed, to the user of the eyewear through the speakers mounted in the eyewear. For example, human-machine interaction through the use of a speech recognition user interface is becoming increasingly popular. To facilitate such human-machine interaction, accurate recognition of speech is useful. It is also useful as a machine that can present information to the user through spoken words, for example by reading a text to the user. Such a machine output presentation facilitates hands-free activities of a user, which is increasingly popular. Users also do not have to hold a speaker or device in place, nor do they need to have electronics behind their ear, or earbuds blocking their ear. There are also no flimsy wires, and users do not have to tolerate the skin contact or pressure associated with the bone conduction speakers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1**A is a perspective view of one embodiment of the invention.

[0015] FIG. **1**B is a perspective view from below of the embodiment shown in FIG. **1**A.

[0016] FIG. **1**C is an elevated side-top view in perspective of the embodiment of the invention shown in FIG. **1**A.

[0017] FIG. **2** is a side view of the embodiment of FIGS. **1**A-**1**C shown being worn by a user.

[0018] FIG. **3** is a perspective view of a left side frame member of the embodiment shown in FIGS. **1**A-**1**C, wherein an interior panel has been removed to show the speaker assembly within an audio chamber defined by the left side frame member.

[0019] FIG. **4** is an exploded view of the left side frame member of the embodiment shown in FIGS. **1**A-**1**C, showing a speaker assembly, also exploded, and a compartment cover for the side frame member (missing from FIG. **3**).

[0020] FIG. **5** is an elevated side view in perspective of another embodiment of the eyewear of the invention, including sound tubes to direct sound more approximately to the users audio canal.

[0021] FIG. **6** is a close-up view of the left side frame member of the embodiment shown in FIG. **5**, showing more particularly an exit hole defined by the sound tube to direct sound toward the audio canal of the user.

[0022] FIG. **7** is still another embodiment of the audio eyewear of the invention, including a sound deflector for deflecting sound from speakers within the side frame members toward the audio canal of the wearer.

[0023] FIG. **8** is an illustration of an embodiment of an eyewear and sound induction ear speaker device of the invention that includes two remote microphones that are electronically linked with the eyewear frame of the eyewear sound induction ear speaker device.

[0024] FIG. **9** is an illustration of another embodiment of eyewear of the invention that includes three remote microphones.

[0025] FIG. **10**A is an exploded view of a rubber boot and microphone, the rubber boot being suitable for use with the microphone according to one embodiment of the invention.

[0026] FIG. **10**B is a perspective view of the assembled rubber boot shown in FIG. **10**A.

[0027] FIG. **11** is a representation of another embodiment of the invention showing alternate and optional placement positions of the microphones.

[0028] FIG. **12** is a block diagram illustrating an example embodiment of the noise cancellation circuit employed in one embodiment of the eyewear sound induction user speaker device of the invention.

[0029] FIG. **13** is a block diagram of a beam-forming module suitable for use in the embodiment of the invention illustrated in FIG. **12**.

[0030] FIG. **14** is a block diagram illustrating an example embodiment of a desired voice activity detection module employed in another embodiment of the eyewear sound induction ear speaker device of the invention.

[0031] FIG. **15** is a block diagram illustrating an example embodiment of a noise cancellation circuit employed in an embodiment of the eyewear sound induction ear speaker device of the invention.

[0032] FIG. **16** is an example embodiment of a boom tube housing three microphones in an arrangement of one embodiment of the eyewear sound induction ear speaker device of the invention.

[0033] FIG. **17** is an example embodiment of a boom tube housing four microphones in an arrangement of another embodiment of the eyewear sound induction ear speaker device of the invention.

[0034] FIG. **18** is a block diagram illustrating an example embodiment of a beam-forming module accepting three signals and another embodiment of the eyewear sound induction ear speaker device of the invention.

[0035] FIG. **19** is a block diagram illustrating an example embodiment of a desired voice activation detection module of yet another embodiment of the eyewear sound induction ear speaker device of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0036] The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanied drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis being placed upon illustrating embodiments of the present invention.

[0037] The invention generally is directed to audio eyewear and methods of its use.

[0038] In one embodiment of the invention, shown in FIGS. **1**A-**1**C, audio eyewear **10** includes front frame **12**. Side frame members **14**, **16** are secured to front frame member **12**. Side frame members **14**, **16** include speakers (not shown) therein. The speakers are configured so that audio ports of the speakers face downward at an angle away from side frame members **14**, **16**, thereby directing sound downwardly rearwardly into the users' ear generally along a vertical plane. FIGS. **1**B and **1**C show alternate views of audio eyewear **10** of FIG. **1**A.

[0039] In particular embodiments, such as is shown in FIG. **2**, side frame member **14**, includes thick forward portion **24**

containing speaker **18**, and thin rearward portion **26** extending rearwardly from thick forward portion **24** for engaging the user's ear. Speaker **18** can be positioned within cavity **20** formed within the at least one side frame member **14**. As can be seen in FIG. **3** speaker **18** can be positioned at a downward facing lower transition surface **28** that narrows the thick forward portion **24** into the thin rearward portion **26** along a rearwardly extending upward angle **30**, and angles audio port **22** of speaker **18** downwardly rearwardly. Referring back to FIG. **2**, speaker **18** is in speaker plane **34** that is normal to a sound direction axis **36** of audio port **22** that is angled downwardly at least about 20 degrees or greater (preferably about 20 to 70 degrees) relative to the horizontal or longitudinal plane of the at least one side frame member **14**, and represented by angle **30**. Referring back to FIG. **2**, speaker **18** is mounted against inner **42** side of lower transition surface **28** with sealing arrangement **48**. Lower transition surface **28** defines audio openings **46** for allowing sound from speaker **18** to pass through, as shown in FIG. **4**, which is an exploded view of left side frame **14**. As shown therein, sealing arrangement **48** seals speaker **18** and printed circuit board **50** between mask **52** and audio openings **46** with gasket **54** and sticky gasket **56**. Mask **52** is fabricated from a suitable material, such as is known in the art, including, for example, rubber or silicone. Gasket **54** and sticky gasket **56** are also fabricated from a suitable material, such as is known in the art. Compartment cover **58** overlays sealing arrangement **48** and is secured to the remainder of left side frame **14** by screws.

[0040] In some embodiments left **14** and right **16** frame members can be secured to opposite sides of front frame **12**. Each side frame member **14**, **16** has a respective speaker therein for providing sound to both ears of the user. At least one of the right **16** and left **14** side frame members and front frame **12** can contain electronics, microphones (not shown) and a battery (not shown). Electrical signals from the speakers and the microphones can be connected to a cell phone (not shown). At least one of the electronics and software in at least one of eyewear **10** and the cell phone can automatically adjust volume of the speakers according to ambient noise measured by the microphones.

[0041] In another embodiment, shown in FIGS. **5** and **6**, a sound tube **60** is attached to the at least one of side frame members **14**, **16** for directing sound from a speaker (not shown) in side frame member **14**, **16** into the users' ear. Sound tube **60** is mounted to the at least one side frame member **62** and defines inlet **64** opening for receiving sound from the speaker, and an outlet opening facing the user's ear for directing the sound from the speaker to the user's ear or into the ear canal.

[0042] In another embodiment, shown in FIG. **7**, sound deflecting surface **66** extends from an outer surface of the at least one side frame member **64** and over a portion of the user's ear for channeling sound from a speaker (not shown) into the user's ear while also allowing ambient sound to be heard. The sound channel members, whether a sound tube or a sound deflecting surface are, in one embodiment, removably attached by magnetic or mechanical attachment fittings, and can be attached to both right and left side frame members for directing sound to both ears.

[0043] The present invention can also provide a method of hearing audio signals including, with reference to FIGS. **1-4**, providing audio eyewear **10** having a front frame **12** and at least one side frame member **14**, **16** secured to front frame **12** for engaging a user's ear. Speaker **18**, for example, is oriented such that audio port **22** of speaker **18**, faces downwardly rearwardly at an angle **30** away from the at least one side frame member **14**, for directing sound downwardly rearwardly into the user's ear generally along a vertical plane.

[0044] FIG. **8** is a diagram **800** illustrating another example embodiment of eye-glasses **802** of the invention having two embedded microphones, in addition to the speakers and side frame members discussed above. Eye-glasses **802** have two microphones **804** and **806**, a first microphone **804** being arranged in the middle of eye-glasses **802** frame and second microphone **806** being arranged on the side of eye-glasses **802** frame. Microphones **804** and **806** can be pressure-gradient microphone elements, either bi- or uni-directional. Each microphone **804** and **806** is an assembly that includes a microphone (not shown) within a rubber boot as further described infra with reference to FIGS. **10**A and **10**B. The rubber boot provides an acoustic port on the front and the back side of the microphone with acoustic ducts. The two microphones **804** and **806** and their respective boots can be identical. Microphone elements **804** and **806** can be sealed air-tight (e.g., hermetically sealed) inside the rubber boots. The acoustic ducts are filled with wind-screen material. The ports are sealed with woven fabric layers. The lower and upper acoustic ports are sealed with a water-proof membrane. The microphones can be built into the structure of the eye glasses frame. Each microphone has top and bottom holes, being acoustic ports. In an embodiment, the two microphones **804** and **806**, which can be pressure-gradient microphone elements, can each be replaced by two omni-directional microphones.

[0045] FIG. **9** is a diagram **950** illustrating an example embodiment of eye-glasses **952** having three embedded microphones. Each pressure-gradient microphone element can be replaced with two omni-directional microphones at the location of each acoustic port, resulting in four total microphones. The signal from these two omni-directional microphone can be processed by electronic or digital beam-forming circuitry described above to produce a pressure gradient beam pattern. This pressure gradient beam pattern replaces the equivalent pressure-gradient microphone.

[0046] In an embodiment of the present invention, if a pressure-gradient microphone is employed, each microphone is within a rubber boot that extends an acoustic port on the front and the back side of the microphone with acoustic ducts. At the end of rubber boot, the new acoustic port is aligned with the opening in the tube, where empty space is filled with wind-screen material. If two omni-directional microphones are employed in place of one pressure-gradient microphone, then the acoustic port of each microphone is aligned with the opening.

[0047] In an embodiment, a long boom dual-microphone headset can look like a conventional close-talk boom microphone, but is a big boom with two-microphones in parallel. An end microphone of the boom is placed in front of user's mouth. The close-talk long boom dual-microphone design targets heavy noise usage in military, aviation, industrial and has unparalleled noise cancellation performance. For example, one main microphone can be positioned directly in front of mouth. A second microphone can be positioned at the side of the mouth. The two microphones can be identical with identical casing. The two microphones can be placed in parallel, perpendicular to the boom. Each microphone has front and back openings. DSP circuitry can be in the housing between the two microphones.

[0048] Microphone is housed in a rubber or silicon holder (e.g., the rubber boot) with an air duct extending to the acoustic ports as needed. The housing keeps the microphone in an air-tight container and provides shock absorption. The microphone front and back ports are covered with a wind-screen layer made of woven fabric layers to reduce wind noise or wind-screen foam material. The outlet holes on the microphone plastic housing can be covered with water-resistant thin film material or special water-resistant coating.

[0049] In another embodiment, a conference gooseneck microphone can provide noise cancellation. In large conference hall, echoes can be a problem for sound recording. Echoes recorded by a microphone can cause howling. Severe echo prevents the user from tuning up speaker volume and causes limited audibility. Conference hall and conference room can be decorated with expensive sound absorbing materials on their walls to reduce echo to achieve higher speaker volume and provide an even distribution of sound field across the entire audience. Electronic echo cancellation equipment is used to reduce echo and increase speaker volume, but such equipment is expensive, can be difficult to setup and often requires an acoustic expert.

[0050] In an embodiment, a dual-microphone noise cancellation conference microphone can provide an inexpensive, easy to implement solution to the problem of echo in a conference hall or conference room. The dual-microphone system described above can be placed in a desktop gooseneck microphone. Each microphone in the tube is a pressure-gradient bi-directional, uni-directional, or super-directional microphone.

[0051] In a head mounted computer, a user can desire a noise-canceling close-talk microphone without a boom microphone in front of his or her mouth. The microphone in front of the user's mouth can be viewed as annoying. In addition, moisture from the user's mouth can condense on the surface of the Electret Condenser Microphone (ECM) membrane, which after long usage can deteriorate microphone sensitivity.

[0052] In an embodiment, a short tube boom headset can solve these problems by shortening the boom, moving the ECM away from the user's mouth and using a rubber boot to extend the acoustic port of the noise-canceling microphone. This can extend the effective close-talk range of the ECM. This maintains the noise-canceling ECM property for far away noises. In addition, the boom tube can be lined with wind-screen form material. This solution further allows the headset computer to be suitable for enterprise call center, industrial, and general mobile usage. In an embodiment with identical dual-microphones within the tube boom, the respective rubber boots of each microphone can also be identical.

[0053] In an embodiment, the short tube boom headset can be a wired or wireless headset. The headset includes the short microphone (e.g., and ECM) tube boom. The tube boom can extend from the housing of the headset along the user's cheek, where the tube boom is either straight or curved. The tube boom can extend the length of the cheek to the side of the user's mouth, for instance. The tube boom can include a single noise-cancelling microphone on its inside.

[0054] The boom tube can further include a dual microphone inside of the tube. A dual microphone can be more effective in cancelling out non-stationary noise, human noise, music, and high frequency noises. A dual microphone can be more suitable for mobile communication, speech recognition, or a Bluetooth headset. The two microphones can be identical, however a person of ordinary skill in the art can also design a tube boom having microphones of different models.

[0055] In an embodiment having dual-microphones, the two microphones enclosed in their respective rubber boats are placed in series along the inside of the tube.

[0056] The tube can have a cylindrical shape, although other shapes are possible (e.g., a rectangular prism, etc.). The short tube boom can have two openings, one at the tip, and a second at the back. The tube surface can be covered with a pattern of one or more holes or slits to allow sound to reach the microphone inside the tube boom. In another embodiment, the short tube boom can have three openings, one at the tip, another in the middle, and another in the back. The openings can be equally spaced, however, other a person of ordinary skill in the art can design other spacings.

[0057] The microphone in the tube boom is a bi-directional noise-cancelling microphone having pressure-gradient microphone elements. The microphone can be enclosed in a rubber boot extending acoustic port on the front and the back side of the microphone with acoustic ducts. Inside of the boot, the microphone element is sealed in the air-tight rubber boot.

[0058] Within the tube, the microphone with the rubber boot is placed along the inside of the tube. An acoustic port at the tube tip aligns with the boom opening, and an acoustic port at the tube back aligns with boom opening. The rubber boot can be offset from the tube ends to allow for spacing between the tube ends and the rubber boot. The spacing further allows breathing room and for room to place a wind-screen of appropriate thickness. The rubber boot and inner wall of the tube remain air-tight, however. A wind-screen foam material (e.g., wind guard sleeves over the rubber boot) fills the air-duct and the open space between acoustic port and tube interior/opening.

[0059] Referring to FIG. **9**, the eye-glasses **952** of FIG. **9** are similar to the eye-glasses **802** of FIG. **8**, but instead employs three microphones instead of two. The eye-glasses **952** of FIG. **9** have a first microphone **954** arranged in the middle of the eye-glasses **952**, a second microphone **956** arranged on the left side of the eye-glasses **952**, and a third microphone **958** arranged on the right side of the eye-glasses **952**. The three microphones can be employed in the three-microphone embodiment described above.

[0060] FIG. **10**A is a diagram **1000** illustrating an example embodiment of a rubber boot **1002***a-b* shown in an expanded view. The rubber boot **1002***a-b* is separated into a first half of the rubber boot **1002***a* and a second half of the rubber boot **1002***b*. Each rubber boot **1002***a-b* is lined by a wind-screen **1008** material, however FIG. **10**A shows the wind-screen in the second half of the rubber boot **1002***b*. In a pressure-gradient microphone, the air-duct and the open space between acoustic port and boom interior is filled with wind-screen foam material, such as wind guard sleeves over the rubber boots.

[0061] A microphone **1004** is arranged to be played between the two halves of the rubber boot **1002***a-b*. The microphone **1004** and rubber boot **1002***a-b* are sized such that the microphone **1004** fits in a cavity within the halves of the rubber boot **1002***a-b*. The microphone is coupled with a wire **1006**, that extends out of the rubber boot **1002***a-b* and can be connected to, for instance, the noise cancellation circuit described above.

[0062] FIG. **10**B is a diagram **1050** illustrating an example of a rubber boot **1052**. The rubber boot **1052** of FIG. **10**B is shown to have both halves joined together, where a microphone (not shown) is inside. A wire **1056** coupled to the microphone exist the rubber boot **1052** such that it can be connected to, for instance, the noise cancellation circuit described below, with reference to FIGS. **12** through **15**.

[0063] FIG. **11** is an illustration of an embodiment of the invention **1100** showing various optional positions of placements of the microphones **1104***a-e*. As described above, the microphones are pressure-gradient. In an embodiment, microphones can be placed in any of the locations shown in FIG. **11**, or any combination of the locations shown in FIG. **10**. In a two-microphone system, the microphone closest to the user's mouth is referred to as MIC1, the microphone further from the user's mouth is referred to as MIC2. In an embodiment, both MIC1 & MIC2 can be inline at position 1 **1004***a*. In other embodiments, the microphones can be positioned as follows:

[0064] MIC1 at position 1 **1104***a* and MIC2 at position 2 **1104***b;*

[0065] MIC1 at position 1 **1104***a* and MIC2 at position 3 **1104***c;*

[0066] MIC1 at position 1 **1104***a* and MIC2 at position 4 **1104***d;*

[0067] MIC1 at position 4 **1104***d* and MIC2 at position 5 **1104***e;*

[0068] Both MIC1 and MIC2 at position 4 **1104***d*.

[0069] If position 4 **1104***d* has a microphone, it is employed within a pendant.

[0070] The microphones can also be employed at other combinations of positions **1104***a-e*, or at positions not shown in FIG. **11**.

[0071] FIG. **12** is a block diagram **1200** illustrating an example embodiment of a noise cancellation circuit employed in the present invention. Signals **1210** and **1212** from two microphones are digitized and fed into the noise cancelling circuit **1201**. The noise cancelling circuit **1201** can be a digital signal processing (DSP) unit (e.g., software executing on a processor, hardware block, or multiple hardware blocks). In an embodiment, the noise cancellation circuit **1201** can be a digital signal processing (DSP) chip, a system-on-a-chip (SOC), a Bluetooth chip, a voice CODEC with DSP chip, etc. Noise cancellation circuit **1201** can be located in a Bluetooth headset near the user's ear, in an inline control case with battery, or inside the connector, etc. Noise cancellation circuit **1201** can be powered by a battery or by a power source of the device that the headset is connected to, such as the device's batter, or power from a USB, micro-USB, or Lightening connector.

[0072] Noise cancellation circuit **1201** includes four functional blocks, all of which are electronically linked, either wirelessly or by hard-wire: beam-forming (BF) module **1202**, Desired Voice Activity Detection (VAD) Module **1208**, adaptive noise cancellation (ANC) module **1204** and single signal noise reduction (NR) module **1206**. Two signals **1210** and **1212** are fed into the BF module **1202**, which generates main signal **1230** and reference signal **1232** to the ANC module **1204**. A closer microphone signal **1210** is collected from a microphone closer to the user's mouth and a further microphone signal is collected from a microphone further from the user's mouth, relatively. BF module **1202** also generates a main signal **1220** and reference signal **1222** for desired VAD module **1208**. The main signal **1220** and reference signal **1222** can, in certain embodiments, be different from the main signal **1230** and reference signal **1232** generated for the for ANC module **1204**.

[0073] The ANC module **1204** processes the main signal **1230** and the reference signal **1232** to cancel out noises from the two signals and output noise cancelled signal **1242** to single channel NR module **1206**. Single signal NR module **1206** post-processes the noise cancelled signal **1242** from the ANC module **1204** to remove any further residue noise. Meanwhile, the VAD module **108** derives, from the main signal **1220** and reference signal **1222**, a desired voice activity detection (DVAD) signal **1140** that indicates the presence or absence of speech in the main signal **1220** and reference signal **1222**. The DVADs signal **1240** can then be used to control the ANC modules **1204** and the NR module **1206** from the result of BF modules **1202**. The DVAD signal **1240** indicates to the ANC module **1204** and Single Channel NR module **106** which sections of the signal have voice data to analyze, which can increase the efficiency of processing of the ANC module **1204** and single channel NR modules **1206** by ignoring sections of the signal without voice data. Desired speech signal **1244** is generated by single channel NR module **1206**.

[0074] In an embodiment, the BF modules **1202**, ANC module **1204**, single NR reduction module **1206**, and desired VAD module **1208** employs linear processing (e.g., linear filters). A linear system (which employs linear processing) satisfies the properties of superposition and scaling or homogeneity. The property of superposition means that the output of the system is directly proportional to the input. For example, a function F(x) is a linear system if:

$$F(x_1+x_2+\dots)=F(x_1)+F(x_2)+\dots$$

[0075] A satisfies the property of scaling or homogeneity of degree one if the output scales proportional to the input. For example, a function F(x) satisfies the properties of scaling or homogeneity if, for a scalar α:

$$F(\alpha x)=\alpha F(x)$$

[0076] In contract, a non-linear function does not satisfy both of these conditions.

[0077] Prior noise cancellation systems employ non-linear processing. By using linear processing, increasing the input changes the output proportionally. However, in non-linear processing, increasing the input changes the output non-proportionally. Using linear processing provides an advantage for speech recognition by improving feature extraction. Speaker recognition algorithm is developed based on noiseless voice recorded in quiet environment with no distortion. A linear noise cancellation algorithm does not introduce nonlinear distortion to noise cancelled speech. Speech recognition can deal with linear distortion on speech, but not nonlinear distortion of speech. Linear noise cancellation algorithm is "transparent" to the speech recognition engine. Training speech recognition on the variations of nonlinear distorted noise is impossible. Non-linear distortion can disrupt the feature extraction necessary for speech recognition.

[0078] An example of a linear system is a Weiner Filter, which is a linear single channel noise removal filter. The Wiener filter is a filter used to produce an estimate of a desired or target random process by linear time-invariant filtering an observed noisy process, assuming known stationary signal, noise spectra, and additive noise. The Wiener filter minimizes the mean square error between the estimated random process and the desired process.

[0079] FIG. **13** is a block diagram **1300** illustrating an example embodiment of a beam-forming module **1302** that can be employed in noise cancelling circuit **1201** of FIG. **12**.

The BF module **1302** receives closer microphone signal **1310** and further microphone signal **1312**.

[0080] A further microphone signal **1312** is inputted to a frequency response matching filter **1304**. The frequency response matching filter **1304** adjusts gain, phase, and shapes the frequency response of the further microphone signal **1312**. For example, the frequency response matching filter **1304** can adjust the signal for the distance between the two microphones, such that an outputted reference signal **1332** representative of the further microphone signal **1312** can be processed with the main signal **1330**, representative of the closer microphone signal **1310**. The main signal **1330** and reference signal **1332** are sent to the ANC module.

[0081] Closer microphone signal **1310** is outputted to the ANC module as a main signal **1330**. Closer microphone signal **1310** is also inputted to a low-pass filter **1306**. Reference signal **1332** is input to low-pass filter **1308** to create reference signal **1322** sent to the Desired VAD module. Low-pass filters **1306** and **1308** adjust the signal for a "close talk case" by, for example, having a gradual low off from 2 kHz to 4 kHz, in one embodiment. Other frequencies can be used for different designs and distances of the microphones to the user's mouth, however.

[0082] FIG. **14** is a block diagram illustrating an example embodiment of a Desired Voice Activity Detection Module **1402**. The DVAD module **1402** receives a main signal **1420** and a reference signal **1422** from the beam-forming module. The main signal **1420** and reference signal **1422** are processed by respective short-time power modules **1404** and **1406**. The short-time power modules **1404** and **1406** can include a root mean square (RMS) detector, a power (PWR) detector, or an energy detector. The short-time power modules **1404** and **1406** output signals to respective amplifiers **1408** and **1410**. The amplifiers can be logarithmic converters (or log/logarithmic amplifiers). The logarithmic converters **1408** and **1410** output to a combiner **1412**. The combiner **1412** is configured to combine signals, such as the main signal and one of the at least one reference signals, to produce a voice activity difference signal by subtracting the detection(s) of the reference signal from the main signal (or vice-versa). The voice activity difference signal is inputted into a single channel VAD module **1414**. The single channel VAD module can be a conventional VAD module. The single channel VAD **1414** outputs the desired voice activity signal.

[0083] FIG. **15** is a block diagram **1500** illustrating an example embodiment of a noise cancellation circuit **1501** employed to receive a closer microphone signal **1510** and a first and second further microphone signal **1512** and **1514**, respectively. The noise cancellation circuit **1501** is similar to the noise cancellation circuit **1201**, described in relation to FIG. **12**, however, the noise cancellation circuit **1501** is employed to receives three signals instead of two. A beam-forming (BF) module **1502** is arranged to receive the signals **1510**, **1512** and **1514** and output a main signal **1530**, a first reference signal **1532** and second reference signal **1534** to an adaptive noise cancellation module **1504**. The beam-forming module is further configured to output a main signal **1522**, first reference signal **1520** and second reference signal **1524** to a voice activity detection (VAD) module **1508**.

[0084] The ANC module **1504** produces a noise cancelled signal **1542** to a Single Channel Noise Reduction (NR) module **406**, similar to the ANC module **1204** of FIG. **12**. The single NR module **1506** then outputs desired speech **1544**. The VAD module **1508** outputs the DVAD signal to the ANC module **1504** and the single channel NR module **1506**.

[0085] FIG. **16** is an example embodiment of beam-forming from a boom tube **1602** housing three microphones **1606**, **1608**, and **1610**. A first microphone **1606** is arranged closest to a tip **1604** of the boom tube **1602**, a second microphone **1608** is arranged in the boom tube **1602** further away from the tip **1604**, and a third microphone **1610** is arranged in the boom tube **1602** even further away from the tip **1604**. The first microphone **1606** and second microphone **1608** are arranged to provide data to output a left signal **1626**. The first microphone is arranged to output its signal to a gain module **1612** and a delay module **1614**, which is outputted to a combiner **1622**. The second microphone is connected directly to the combiner **1622**. The combiner **1622** subtracts the two provided signals to cancel noise, which creates the left signal **1626**.

[0086] Likewise, the second microphone **1608** is connected to a gain module **1616** and a delay module **1618**, which is outputted to a combiner **1620**. The third microphone **1610** is connected directly to the combiner **1620**. The combiner **1620** subtracts the two provided signals to cancel noise, which creates the right signal **1620**.

[0087] FIG. **17** is an example embodiment of beam-forming from a boom tube **1752** housing four microphones **1756**, **1758**, **1760** and **1762**. A first microphone **1756** is arranged closest to a tip **1754** of the boom tube **1752**, a second microphone **1758** is arranged in the boom tube **1752** further away from the tip **1754**, a third microphone **1760** is arranged in the boom tube **1752** even further away from the tip **1754**, and a fourth microphone **1762** is arranged in the boom tube **1752** away from the tip **1754**. The first microphone **1756** and second microphone **1758** are arranged to provide data to output a left signal **1786**. The first microphone is arranged to output its signal to a gain module **1772** and a delay module **1774**, which is outputted to a combiner **1782**. The second microphone is connected directly to the combiner **1758**. The combiner **1782** subtracts the two provided signals to cancel noise, which creates the left signal **1786**.

[0088] Likewise, the third microphone **1760** is connected to a gain module **1776** and a delay module **1778**, which is outputted to a combiner **1780**. The fourth microphone **1762** is connected directly to the combiner **1780**. The combiner **1780** subtracts the two provided signals to cancel noise, which creates the right signal **1784**.

[0089] FIG. **18** is a block diagram **1800** illustrating an example embodiment of a beam-forming module **1802** accepting three signals **1810**, **1812** and **1814**. A closer microphone signal **1810** is output as a main signal **1830** to the ANC module and also inputted to a low-pass filter **1817**, to be outputted as a main signal **1820** to the VAD module. A first further microphone signal **1812** and second closer microphone signal **1814** are inputted to respective frequency response matching filters **1806** and **1804**, the outputs of which are outputted to be a first reference signal **1832** and second reference signal **1834** to the ANC module. The outputs of the frequency response matching filters **1806** and **1804** are also outputted to low-pass filters **1816** and **1818**, respectively, which output a first reference signal **1822** and second reference signal **1824**, respectively.

[0090] FIG. **19** is a block diagram **1900** illustrating an example embodiment of a desired voice activity detection (VAD) module **1902** accepting three signals **1920**, **1922** and **1924**. The VAD module **1902** receives a main signal **1920**, a first reference signal **1922** and a second reference signal **1924** at short-time power modules **1904**, **1905** and **1906**, respectively. The short-time power modules **1904**, **1905**, and **1906** are similar to the short-time power modules described in relation to FIG. **14**. The short-time power modules **1904**, **1905**, and **1906** output to respective amplifiers **1908**, **1909** and **1910**, which can each be a logarithmic converter. Amplifiers **1908** and **1909** output to a combiner module **1911**, which subtracts the two signals and outputs the difference to a single channel VAD module **1914**. Amplifiers **1910** and **1908** output to a combiner module **1912**, which subtracts the two signals and outputs the difference to a single channel VAD module **1916**. The single channel VAD modules **1914** and **1916** output to a logical OR-gate **1918**, which outputs a DVAD signal **1940**.

[0091] The relevant teaching of all patents, published applications and references cited herein are incorporated by reference in their entirety.

[0092] While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

What is claimed is:

1. Audio eyewear, comprising:

a) a front frame; and

b) at least one side frame member secured to the front frame for engaging a user's ear, the at least one side frame member having a speaker therein, the speaker being oriented such that an audio port of the speaker faces downwardly at an angle away from said at least one side frame member, thereby directing sound downwardly rearwardly into said user's ear generally along a vertical plane.

2. The eyewear of claim **1** in which said at least one side frame member includes a relatively thick forward portion containing the speaker, and a relatively thin rearward portion extending rearwardly from the thick forward portion for engaging said user's ear, the speaker being positioned at a downward facing lower transition surface that narrows from the thick forward portion into the thin rearward portion along a rearwardly extending upward angle, and angles the audio port of speaker downwardly rearwardly.

3. The eyewear of claim **2** in which the speaker is positioned within a cavity defined by said at least one side frame member.

4. The eyewear of claim **2** in which the speaker defines a speaker plane that is angled downwardly at least about 20 degrees relative to a longitudinal plane of said at least one side frame member.

5. The eyewear of claim **3** in which the speaker is mounted against an inner side of the lower transition surface with a sealing arrangement, the lower transition surface defining audio openings to thereby cause sound from the speaker to pass there through.

6. The eyewear of claim **1** in which said at least one side frame member includes right and left side frame members secured to opposite sides of the front frame, each side frame member having a respective speaker therein.

7. The eyewear of claim **6** in which at least one of the right and left side frame members and front frame contains at least one of electronics, at least one microphone, and at least one battery.

8. The eyewear of claim **7** in which electrical signals from the speakers and the at least one microphone are functionally linked to a cell phone, and at least one of the electronics and software in at least one of the eyewear and cell phone are capable of automatically adjusting volume of the speakers according to ambient noise measured by the microphones.

9. The eyewear of claim **8**, wherein at least one of the left and right side frame members and front frame includes an array of the microphones, including at least a first microphone and a second microphone, the first microphone coupled to at least one of the left and right side frame members and the front frame about a temple region of the user, the temple region being located approximately between a top corner of a lens opening defined by the front frame, and providing a first audio channel output, and the second microphone coupled to at least one of the left and right side frame members and front frame about an inner edge of the lens opening and providing a second audio channel output.

10. The eyewear of claim **9**, further including a digital signal processor located at least one of the left and right side frame members and the front frame member, the digital signal processor including:

a) a beam-former electronically linked to at least the first and second audio channel outputs and output a main channel and one or more reference channels;

b) a voice activity detector electronically linked to the main and reference channels and output a desired voice activity channel;

c) an adaptive noise canceller electronically linked to the main, reference, and desired voice activity channels and output an adaptive noise cancellation channel; and

d) a noise reducer electronically linked to the voice activity detector of adaptive noise canceller to thereby receive the desired voice activity and adaptive noise cancellation channels and output a desired speech channel.

11. The eyewear device of claim **10**, wherein the array of microphones are digital microphones and the beam-former is a digital beam-former.

12. The eyewear device of claim **9**, wherein the array of microphones further includes:

a) a third microphone coupled to the eyeglasses frame about an outer lower corner of the lens opening below the first microphone and providing a third audio channel output; and

b) a fourth microphone coupled to the glasses frame about a bridge support region above the second microphone and providing a fourth audio channel output.

13. The eyewear device of claim **12**, wherein the array of microphones are omni-directional microphones.

14. The eyewear device of claim **13**, wherein the omni-directional microphones are any combination of the following: electret condenser microphones, analog microelectromechanical systems (MEMS) microphones, or digital MEMS microphones.

15. The eyewear device of claim **12**, wherein the array of microphones is coupled to the eyeglasses frame using at least one flexible printed circuit board (PCB) strip.

16. The eyewear device of claim **15**, wherein the array of microphones is coupled to the eyeglasses frame using an upper flexible PCB strip including the first and fourth microphones and a lower flexible PCB strip including the second and third microphones.

17. The eyewear device of claim 16, wherein:
a) the eyeglasses frame further includes an array of vents corresponding to the array of microphones;
b) the array of microphones are bottom port microelectromechanical systems (MEMS) microphones;
c) the first and fourth MEMS microphones are coupled to the upper flexible PCB strip;
d) the second and third MEMS microphones are coupled to the lower flexible PCB strip; and
e) the array of MEMS microphones being arranged such that the bottom ports receive acoustic signals through the corresponding vents.

18. The eyewear device of claim 17, further including a membrane sandwiched between the eyeglasses frame and the microphone.

19. The eyewear device of claim 18, wherein the membrane is a wind-screen membrane and a water-proofing membrane.

20. The eyewear device of claim 1, further including an array of microphones coupled to at least one of the front frame and the at least one side frame member, the array of microphones including at least a first and second microphone, the first microphone coupled to the eyewear at a temple region, the temple region being located approximately between a top corner of a lens opening defined by the front frame and having an inner edge, and the at least one side frame member, and the second microphone at an inner edge of the lens opening, and providing a first and second audio channel output from the first and second microphones, respectively.

21. The eyewear device of claim 20, further including a digital signal processor having:
a) a beam-former electronically linked to the first and second microphones, for receiving at least the first and second audio channels and outputting a main channel and one or more reference channels;
b) a voice activity detector electronically linked to the beam-former, for receiving the main and reference channels and outputting a desired voice activity channel;
c) an adaptive noise canceller electronically linked to the beam-former and the voice activity detector for receiving the main, reference, and desired voice activity channels and outputting an adaptive noise cancellation channel; and
d) a noise reducer electronically linked to the voice activity detector and the adaptive noise canceller for receiving the desired voice activity and adaptive noise cancellation channels and outputting a desired speech channel.

22. The eyewear device of claim 21, wherein at least one of the beam-former, the voice activity detector, the adaptive noise canceller and the noise reducer are integrated into at least one of the front frame and the at least one side frame member.

23. The eyewear device of claim 1, further including a sound channel member attached to said at least one side frame member for directing sound from the speaker into said user's ear.

24. The eyewear of claim 23 in which the sound channel member includes a sound deflecting surface that extends from an outer surface of said at least one side frame member and over a portion of said user's ear for channeling sound from the speaker into said user's ear while also allowing ambient sound to be heard.

25. The eyewear of claim 23 in which the sound channel member includes a sound tube mounted to the at least one side frame member, and having an inlet opening for receiving sound from the speaker and an outlet opening facing said user's ear for directing the sound from the speaker to said user's ear.

26. A method of hearing audio, comprising the steps of:
a) providing audio eyewear frame having a front frame and at least one side frame member secured to the front frame for engaging a user's ear, the at least one side frame member having a speaker therein; and
b) orienting the speaker such that an audio port of the speaker faces downwardly rearwardly at an angle away from said at least one side frame member for directing sound downwardly rearwardly into said user's ear generally along a vertical plane.

27. The method of claim 26, further including the steps of:
a) providing said at least one side frame member with a thick forward portion containing the speaker, and a thin rearward portion extending rearwardly from the thick forward portion for engaging said user's ear; and
b) positioning the speaker at a downward facing lower transition surface that narrows from the thick forward portion to the thin rearward portion along a rearwardly extending upward angle, and angling the audio port of the speaker downwardly rearwardly.

28. The method of claim 27, further including positioning the speaker within a cavity formed within said at least one side frame member.

29. The method of claim 28, further including mounting the speaker against an inner side of the lower transition surface with a sealing arrangement, the lower transition surface having audio openings for allowing sound from the speaker to pass through.

30. The method of claim 27, further including angling a speaker plane of the speaker downwardly at least about 20 degrees relative to a longitudinal plane of said at least one side frame member.

31. The method of claim 26, further including providing right and left side frame members secured to opposite sides of the front frame, each side frame member having a respective speaker therein.

32. The method of claim 31, further including containing within at least one of the right and left side frame members and front frame, and at least one of electronics, at least one microphone and at least one battery.

33. The method of claim 32, further including linking electrical signals from at least one of the speakers and the at least one microphone to a cell phone, and with at least one of the electronics and software in at least one of the eyewear and cell phone, automatically adjusting volume of the speakers according to ambient noise measured by the microphones.

34. The method of claim 26, further comprising the steps of:
a) coupling an array of microphones to the eyewear, the array of microphones including at least a first and second microphone;
b) arranging the first microphone to couple to the eyewear about a temple region, the temple region being located approximately between a top corner of a lens opening and a support arm;
c) arranging the second microphone to couple to the eyewear frame about an inner edge of the lens opening; and
d) providing a first and second audio channel output from the first and second microphones, respectively.

35. The method of claim **34**, further including the steps of:
a) forming beams at a beam-former, the beam-former receiving at least the first and second audio channels and outputting a main channel and one or more reference channels;
b) detecting voice activity at a voice activity detector, the voice activity detector receiving the main and reference channels and outputting a desired voice activity channel;
c) adaptively cancelling noise at an adaptive noise canceller, the adaptive noise canceller receiving the main, reference, and desired voice activity channels and outputting an adaptive noise cancellation channel; and
d) reducing noise at a noise reducer receiving the desired voice activity and adaptive noise cancellation channels and outputting a desired speech channel.

36. The method of claim **35**, wherein the first and second audio channels are produced digitally and the beams are formed digitally.

37. The method of claim **34**, further including the steps of:
a) arranging a third microphone to couple to the eyewear about an outer lower corner of the lens opening below the first microphone;
b) arranging a fourth microphone to couple to the eyewear about a bridge support region above the second microphone; and
c) providing a third and fourth audio channel output from the third and fourth microphones, respectively.

38. The method of claim **37**, wherein an array of omni-directional microphones are coupled to the eyeglasses frame.

39. The method of claim **38**, wherein the coupled array of omni-directional microphones are any combination of the following: electret condenser microphones, analog microelectromechanical systems (MEMS) microphones, or digital MEMS microphones.

40. The method of claim **37**, wherein coupling the array of microphones to the eyewear uses at least one flexible printed circuit board (PCB) strip.

41. The method of claim **40**, wherein coupling the array of microphones to the eyeglasses frame uses an upper flexible PCB strip including the first and fourth microphones and a lower flexible PCB strip including the second and third microphones.

42. The method of claim **41**, wherein coupling the array of microphones to the eyeglasses frame further includes the steps of:
a) coupling each microphone of the array of microphones to a corresponding vent of an array of vents, the array of microphones being bottom port or top port microelectromechanical system (MEMS) microphones and the vents being located in the eyeglasses frame, wherein the first and fourth MEMS microphones are coupled to the upper flexible PCB strip and the second and third MEMS microphones are coupled to the lower flexible PCB strip; and
b) arranging the array of MEMS microphones such that the ports received acoustic signals through the corresponding vents.

43. The method of claim **42**, further including coupling a membrane between the eyeglasses frame and the microphones.

44. The method of claim **43**, further including wind-screening and water-proofing the array of microphones using the membrane, the membrane being made of a wind-screen and water-proofing material.

45. The method of claim **26**, further including directing sound from the speaker into said user's ear with a sound channel member attached to said at least one side frame member.

46. The method of claim **45**, further including channeling sound from the speaker into said user's ear while also allowing ambient sound to be heard with the sound channel member, the sound channel member including a sound deflecting surface that extends from an outer surface of said at least one side frame member and over a portion of said user's ear.

47. The method of claim **45**, further including directing the sound from the speaker to said user's ear with the sound channel member, the sound channel member including a sound tube mounted to the at least one side frame member, and having an inlet opening for receiving sound from the speaker and an outlet opening facing said user's ear through which the sound exits.

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