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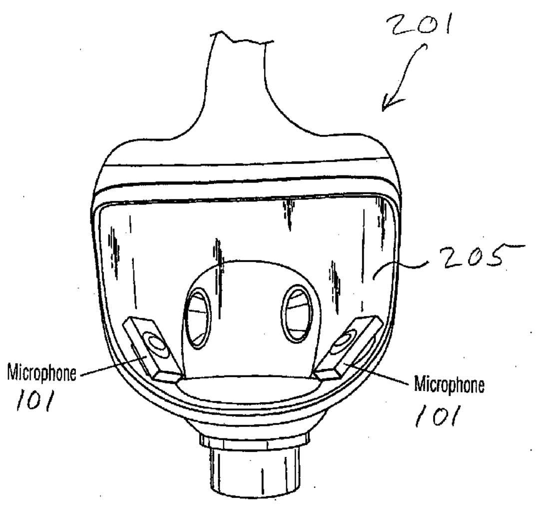
(54) Title: FACEMASK COMMUNICATION SYSTEM



(57) Abstract: A facemask communication system includes a plurality of microphones within the inside compartment of the facemask for detecting sounds voiced by the wearer. The microphones have cardioid sound reception patterns even when the region at the rear of the microphones are blocked by channeling sound to the rear surfaces of the diaphragms through a sound guide. The signals from the microphones are wirelessly transmitted through the transparent window of the facemask using electromagnetic radiation. After transmission through the transparent window, signal processing is performed on the signals. A digital signal processor processes the audio signal generated by the microphones in the time and frequency domain. The signal processor can include at least one adaptive filter to enhance a wanted signal in the audio signal and at least one adaptive filter to reduce an unwanted signal in the audio signal. Breathing noise in the signals is reduced using a plurality of microphones to provide signals to the signal processor. The system provides voice recognition for automatically responding to commands.

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Facemask Communication System

Field of the Invention

The present invention relates to communicating from within an enclosed space having poor acoustical qualities to an external region.

Background of the Invention

Facemasks are often used by firefighters, lab workers, members of the military and others to provide oxygen or keep out contaminants when working in potentially harmful environments. Such a mask needs to form an airtight seal with the face of the wearer. This can make it difficult for the wearer to communicate intelligibly through the facemask.

One solution might be to include a microphone within the inside compartment of the facemask for transmitting sound out of the facemask. However, this presents difficulties. If wires are used to transmit the sound from the microphone to outside of the facemask then the wires might break the seal between the facemask and the face of the wearer. Even if the seal is maintained, extra wires can be uncomfortable or get in the way.

Another possible solution would be to provide a complete walkie-talkie within the inside compartment of the facemask for transmitting the sound from the microphone to others who have receiving walkie-talkies. However, such walkie-talkies would be large and uncomfortable within the small space inside the facemask.

The poor acoustic properties within the inside compartment a facemask also presents problems for using a microphone inside the compartment. There is muffling as well as many reflected sound waves within the compartment. There is also breathing noise within the facemask, causing additional difficulty in picking-up and processing the signal. One way to reduce this noise would be to perform signal processing on the output signal from the microphone. However, it is difficult to fit signal processing hardware within the inside compartment of a facemask.

Another way to improve the sound quality would be through the use of a cardioid microphone. Cardioid microphones can be contrasted with omnidirectional microphones. An omnidirectional microphone generally includes a diaphragm with electronics that measure the diaphragm motion and change it into a signal. A housing allows sound to enter from the front of the diaphragm, but blocks sound from entering from the rear of the diaphragm. Thus, sounds from the front of the microphone, sides of the microphone, and from behind the microphone all enter from the front of the diaphragm and there is no directionality to the microphone. The polar pattern of the amount of sound picked up by an omnidirectional microphone is substantially a circular pattern.

Cardioid microphones, on the other hand, pick up sound from the source they are aimed at. They discriminate against sounds from the sides and rear. Ports both in front and at the rear of the microphone are provided to allow sound to enter from both the front and rear of the diaphragm. These ports are carefully sized and acoustic damping such as felt or foam is added to create an acoustic phase-shift network. In principle, this is similar to an RLC circuit, which delays the signal passing through it. Similarly, in cardioid microphones, the rear ports delay the sound reaching the back of the diaphragm.

Sound approaching the cardioid microphone from the rear is canceled out. Suppose a sound wave approaches the mic from the rear. It travels to the diaphragm by two paths: outside the mic and inside the mic through the ports. Some of the sound wave travels to the front of the diaphragm, outside the mic. The travel time, for sound to travel from the rear port location around the outside of the mic to the front port, can be called T. Some sound also enters the rear ports and is delayed. If the delay to arrive at the rear of the diaphragm from inside the mic is set the same as the delay to arrive at the back of the diaphragm from outside the mic, sounds arrive at the front and rear of the diaphragm at the same time, in phase. Sounds push on opposite sides of the diaphragm, also in phase. The diaphragm cannot move, so sounds from the rear make a very weak signal. Rear sounds thus cancel out.

On the other hand, sounds coming from the front do not cancel out. Frontal sound waves travel to the rear ports during time T. Inside the mic, the phase-shift network further delays the sound by time T. The total delay is 2T.

Since there is a big delay or phase shift between the signals at the diaphragm's front and rear, a frontal sound makes a strong signal.

The polar pattern of the amount of sound picked up by the cardioid microphone is substantially a cardioid pattern, picking up more sound from the direction it is pointed at, less sound from the sides, and even less sound from the rear.

However, traditional cardioid microphones are not ideal for mounting within the inside compartment of a facemask. In order to fit within the small facemask compartment, the microphone should be mounted on a wall of the facemask. This blocks sound from entering the rear of the diaphragm. Traditional cardioid microphones lose their cardioid properties if sound is blocked from entering through the rear.

It would be desirable to provide a communications system which would allow clear communications from within the inside compartment of a facemask. It would also be desirable to provide a cardioid microphone that could function within the inside compartment of a facemask. It would further be desirable to provide signal processing to reduce the noise in the signal provided by the microphone.

Summary of the Invention

The present invention provides a reduced noise and hands-free communication system for full-face protection mask. A plurality microphones are positioned within the mask.

In specific terms, the invention is a facemask communication system including a plurality of microphones within the inside compartment of the facemask for detecting sounds voiced by the wearer. The microphones have a cardioid sound reception pattern, even when the region at the rear of the microphones are blocked, by channeling sound to the rear surfaces of the diaphragms through a sound guide. The signals from the microphones are wirelessly transmitted through the transparent window of the facemask using electromagnetic radiation. After transmission through the transparent window, signal processing is performed on the signals. A digital signal processor processes the audio signal generated by the microphones in the time and frequency domain. The signal processor can include at least one adaptive filter to enhance a wanted signal in the audio signal and at least one adaptive filter to reduce an unwanted signal in the audio signal. The system provides voice recognition for automatically responding to commands.

Also, more generally, the invention is for facemask communication system comprising a facemask having an inside compartment covering at least the mouth of a wearer; and at least one microphone within the facemask for detecting the voiced sounds of the wearer and converting the sounds to signals.

Also, the invention can apply to a general communication system, other than just a facemask communication system, for communicating across a solid barrier. The communication system comprises a microphone on one side of the solid barrier for detecting sound and converting the sound into an electrical signal; a transmitter for transmitting the electrical signal wirelessly across the solid barrier; a receiver for receiving the transmitted electrical signal; and a processor for processing sound information in the received electrical signal. The solid barrier is a transparent window. Also, the signal can be transmitted by infrared radiation from a diode transmitter and received by a diode receiver. Alternatively, the signal can be transmitted by RF radiation.

Brief Description of the Figures

Further preferred features of the invention will now be described for the sake of example only with reference to the following figures, in which:

FIGURE 1 shows a microphone of the present invention having a cardioid sound reception pattern.

FIGURES 2a and 2b show an inside and outside view, respectively, of a full-face protection facemask of the present invention.

FIGURE 3 shows an embodiment of the invention in which light is used to transmit the audio signal across a window.

FIGURE 4 shows an embodiment of the invention in which RF radiation is used to transmit the audio signal across a window.

FIGURE 5 illustrates the polar pattern for the sound reception of a configuration of the microphone of FIGURE 1.

FIGURE 6 shows the principal of operation of the microphone of FIGURE 1 for allowing cardioid sound reception.

FIGURE 7 is a schematic diagram of the microphone of FIGURE 1 for illustrating example dimensions.

Detailed Description of the Embodiments

FIGURE 1 shows a microphone 101 of the present invention having a cardioid sound reception pattern. A microphone transducer 103 is embedded in a sound guide housing or mount 105. The microphone transducer 103, within a port 108, has a front face 107 and a rear face 109 allowing sound to impact a front surface 111 and rear surface 113 of a diaphragm 115, respectively. The soundguide 105 has openings or ports 117. Sound passes from the openings 117 through a channel 119 leads allowing sound access to the rear surface 113 of the diaphragm 115.

FIGURE 6 shows the principal of operation of the microphone 101 allowing cardioid sound reception. Sound produced by a sound source 601 at the rear of the microphone 101 travels along a path 603 around the outside of the microphone 101, through the port 108 to the diaphragm front surface 111. Sound produced by the source 601 also travels along the path 605 through the ports 117 and along the channel 119 to the diaphragm rear surface 113. The channel 119 can be filled with acoustic damping material 607 such as felt or foam used to fine-tune the delay of sound traveling through the channel 119. The dimensions of the soundguide 105 and the acoustic damping material 607 are optimized so that the time for the sound to travel the path 605 to the diaphragm rear surface 113 is about the same as the time for the sound to travel the path 603 to the diaphragm front surface 111. Thus, the sounds from the sound source 601 arrive at the front and rear of the diaphragm at about the same time, in phase. The sounds push on opposite sides of the diaphragm 115, also in phase. The diaphragm cannot move, so these sounds from the rear make a very weak signal. Sounds from the rear substantially cancel out.

On the other hand, sounds coming from a sound source 609 at the front do not cancel out. Sound produced by the sound source 609 travels along a path 611 around the outside of the microphone 101, through the ports 117 and along the channel 119 to the diaphragm rear surface 113. Sound produced by the sound source 609 also travels along the path 613 through the port 118 to the diaphragm front surface 111. The time for the sound to travel along the path 611 is longer than that for the path 613. Since there is a big delay or phase shift between the signals at the diaphragm's front and rear, the frontal sound makes a strong signal.

For other sound source locations and other sound travel paths the same principle applies. FIGURE 5 illustrates the polar pattern for a preferred embodiment of the invention. The polar pattern of the amount of sound picked up by the microphone is substantially a cardioid pattern. The microphone picks up more sound from the direction it is pointed at, less sound from the sides, and even less sound from the rear. Referring to FIGURE 7, in a preferred embodiment the dimensions are D = 10mm, H1 = 6.5mm, H2 = 1.5mm, L = 38mm and W = 15mm. These dimensions can be scaled up or down or varied depending on the particular microphone transducer 103 used, the acoustic damping material 607, the environment, etc. In the preferred embodiment the sound guide is rectangular having three ports and one microphone transducer, but in other embodiments other shapes, numbers of ports and numbers of microphones can be used. The sound guide can be made of plastic or other materials.

The microphone 101 has a variety of applications. Because the ports 117 are located at the side of the microphone 101 rather than at the rear of the microphone, the cardioid microphone properties can be maintained even when the microphone is placed on a flat panel or when the space at the rear of the microphone is blocked. One particularly advantageous use of the microphone 101 is within a facemask as described in the next embodiment.

FIGURES 2a and 2b show an inside and outside view, respectively, of a full-face protection facemask 201. The facemask 201 provides a reduced noise and hands free communication system which is wirelessly connected to other communication systems for full-duplex communication as well as providing speech recognition functions for voice activation of command and control. The facemask 201 has an inside compartment 203 covering at least the mouth of a wearer. A transparent window 205 allows the wearer to see the outside world from within the inside compartment 203. The facemask 201 typically form an airtight seal with the face of the wearer. This makes it difficult for the wearer to communicate directly through the facemask. Also, the acoustics within the inside compartment 203 are very poor. Therefore, the invention makes use of the microphone 101 to provide low noise detection of sounds voiced by the wearer. Even with the use of the inventive microphone 101, the poor acoustics within the inside compartment 203 makes it desirable to perform additional signal processing on the signals produced by the microphone 101.

In order to perform the preferred signal processing to create clear voice signals from the wearer, a plurality of the microphones 101 (two are illustrated in the embodiment of FIGURE 2) are mounted within the facemask 201, preferably with the diaphragm front surfaces 111 generally facing towards the mouth of the wearer. The microphones 101 communicate with a digital signal processor for performing additional signal processing in the time and frequency domain on the audio signal generated by the microphones. The signal processor can include at least one adaptive filter to enhance a wanted signal in the audio signal and at least one adaptive filter to reduce an unwanted signal in the audio signal.

In different embodiments various signal processing methods can be used to reduce the noise in the signals produced by the microphone 101. One such method is described in PCT Publication Number WO 00/30264 (published 25 May 2000) entitled “Signal Processing Apparatus and Method” to the same assignees as the present invention. Another such method is described in PCT International Application Number PCT/SG02/00149 filed 2 July 2002 entitled “System and Apparatus for Speech Communication and Speech Recognition” also to the same assignees as the present invention. In these methods a digital signal processor processes the audio signal generated by a plurality of microphones in the time and frequency domain. The signal processor includes at least one adaptive filter to enhance a wanted signal in the audio signal and at least one adaptive filter to reduce an unwanted signal in the audio signal. The descriptions of both of these applications are hereby incorporated by reference in their entirety into the present disclosure. By using the plurality of microphones 101 illustrated in FIGURES 2a, 2b, 3 and 4, together with the signal processing methods described above, noise, especially that caused by the breathing of the wearer, is greatly reduced. The use of the plurality of cardioid microphones of the present invention together with the above signal processing even greater reduction of the breathing noise.

Because the inside compartment 203 is small it is desirable to minimize the electronics within this small space. Therefore, while the microphones 101 should be inside the compartment 203, it is better if the signal processor (described above) is outside of the inside compartment. However, it is desirable to avoid the use of wires for connecting the electronics components within the inside compartment 203 to the outside world. In hazardous environments, it is dangerous if wires pass between the mask and the face of the wearer, breaking the airtight seal. Also, wires can get in the way. Therefore, in one embodiment of the present invention, the audio signals of the voiced sounds of the wearer are converted into electromagnetic radiation and transmitted across the window 205 to a receiver. In more general embodiments, transmission can be across any solid barrier rather than the transparent window 205. The electromagnetic radiation can be infrared radiation or RF radiation, for example. Alternatively, sonic waves can be used to transmit the audio signals.

FIGURE 3 shows an embodiment of the invention in which light, infrared radiation (IR) in particular, is used to transmit the audio signal across the window 205. Signals from each of the microphones are amplified, modulated, and supplied to IR diode emitters 301. The IR radiation is transmitted from the inside compartment 203 through the window 205 and to the outside where it is detected by corresponding IR diode detectors 303. The signals are then demodulated, filtered and again amplified before being fed into a signal processor 305. The diode emitters 301 and diode detectors 303 can be mounted on the inner and outer surfaces of the window 205, respectively. The signal processor 305 can be mounted on the outside of the facemask 201 or carried by the wearer in other ways.

FIGURE 4 shows an embodiment of the invention in which RF radiation is used to transmit the audio signal across the window 205. Signals from each of the microphones are amplified and supplied to an FM stereo transmitter IC 401. The FM stereo transmitter IC 401 modulates the microphone signals and the signals are transmitted from the inside compartment 203 through the window 205 using a transmitting antennae 405 and to the outside where they are detected by an FM receiver 403 using a receiving antennae 407. The signals are then demodulated before being fed into the signal processor 305. The antennae 405, 407 can be mounted on the inner and outer surfaces of the window 205, respectively. The signal processor 305 can be mounted on the outside of the facemask 201 or carried by the wearer in other ways.

These methods are not limited to wireless transmission of audio signals across the window of a facemask, but can be used in other applications where audio signals need to be wirelessly transmitted from within a closed region through a window.

The communication system can utilize the speech recognition described in PCT International Application Number PCT/SG02/00149 filed 2 July 2002 entitled "System and Apparatus for Speech Communication and Speech Recognition" (see above), to allow the signal processor 305 or separate processor to recognize voiced sounds made by the wearer in order to perform automated functions. For example, if the wearer is a firefighter, the firefighter can issue a command "water on" from within the facemask 201. The command, despite the poor acoustics within the inside compartment 203, would be recognized by speech recognition software of the signal processor 305 and converted via an electromechanical system into an action that would automatically supply water to a fire hose.

Many other particular configurations and applications can also be used. Thus, although the invention has been described above using particular embodiments, many variations are possible within the scope of the claims, as will be clear to a skilled reader.

Claims

We claim:

1. A facemask communication system comprising:

a facemask having an inside compartment covering at least the mouth of a wearer;

a microphone within the facemask for detecting the voiced sounds of the wearer and converting the sounds to signals; and

a transmitter for wirelessly transmitting the signals from the microphone to a receiver outside of the inside compartment.

2. The facemask communication system of Claim 1, further comprising a plurality of microphones within the facemask for detecting the voiced sounds of the wearer and converting the sounds to signals.

3. The facemask communication system of Claim 2, wherein the signals from the microphones are transmitted to at least one receiver mounted on the facemask outside of the inside compartment.

4. The facemask communication system of Claim 1, wherein the voiced sounds of the wearer are converted into electromagnetic radiation and transmitted across a window of the facemask.

5. The facemask communication system of Claim 4, wherein the electromagnetic radiation is infrared radiation.

6. The facemask communication system of Claim 4, wherein the electromagnetic radiation is RF radiation.

7. The facemask communication system of Claim 2, wherein the microphones have a cardioid sound reception pattern.

8. The facemask communication system of Claim 7, wherein each of the microphones includes:

a microphone transducer comprising a diaphragm with front and rear surfaces; and

a mount supporting the transducer and channeling sound to the rear surface of the diaphragm.

9. The facemask communication system of Claim 8, wherein the mount is a sound guide having a channel running substantially parallel to the rear surface.

10. The facemask communication system of Claim 1, wherein noise in the signals is reduced using signal processing performed by a signal processor external to the inside compartment.

11. The facemask communication system of Claim 10, further comprising a plurality of microphones and wherein the signal processor processes the signals generated by the plurality of microphones in the time and

frequency domain, the signal processor including at least one adaptive filter to enhance a wanted signal in the signals and at least one adaptive filter to reduce an unwanted signal in the signals.

12. The facemask communication system of Claim 10, wherein breathing noise in the signals is reduced using a plurality of microphones to provide signals to the signal processor for processing.

13. The facemask communication system of Claim 9, wherein the length of the sound guide is determined to allow sound from a source at the rear of the soundguide arriving at the diaphragm rear surface through the soundguide to cancel sound from the source arriving at the diaphragm front surface from outside of the soundguide.

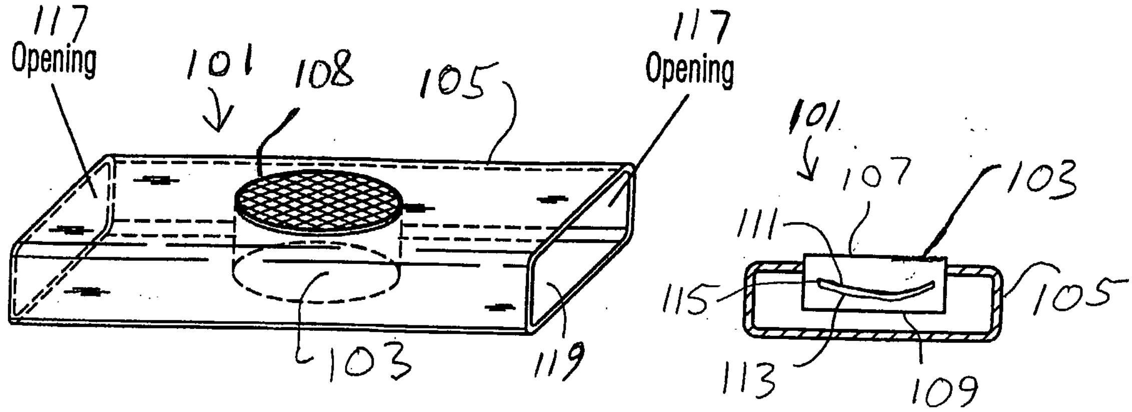
14. A microphone having a substantially cardioid sound reception pattern comprising:

a microphone transducer including a diaphragm with front and rear surfaces; and

a mount supporting the transducer and channeling sound to the rear surface of the diaphragm.

15. The microphone of Claim 14, wherein the mount is a sound guide having a channel running substantially parallel to the rear surface.

16. The microphone of Claim 15, wherein the length of the sound guide is determined to allow sound from a source at the rear of the soundguide arriving at the diaphragm rear surface through the soundguide to cancel sound from the source arriving at the diaphragm front surface from outside of the soundguide.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101
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105
113
109

Fig. 1

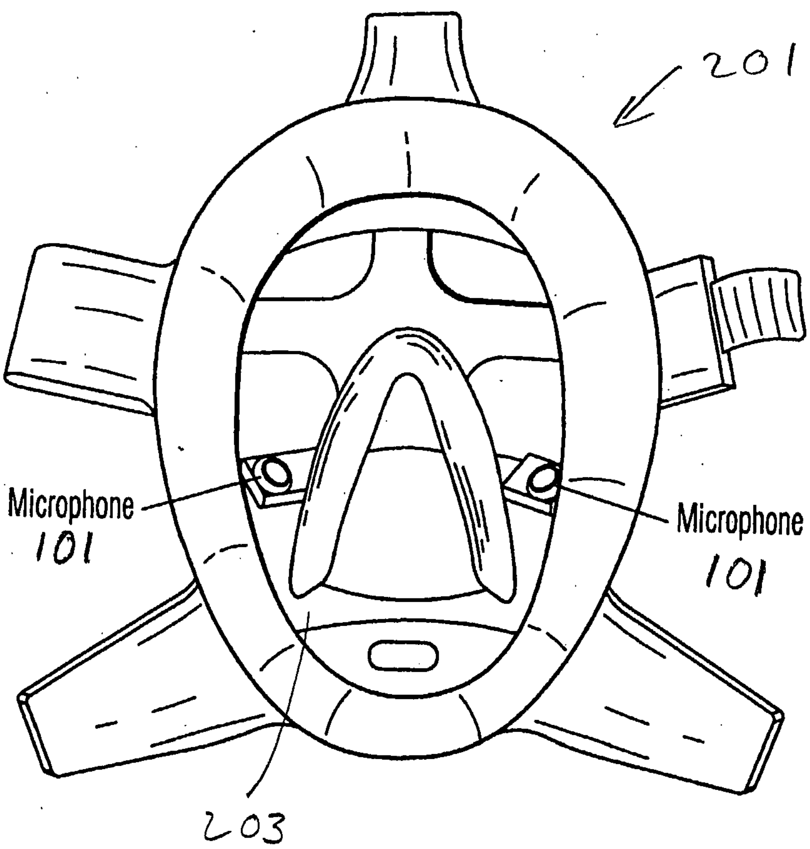

201
Microphone
101
Microphone
101
203

Fig. 2a

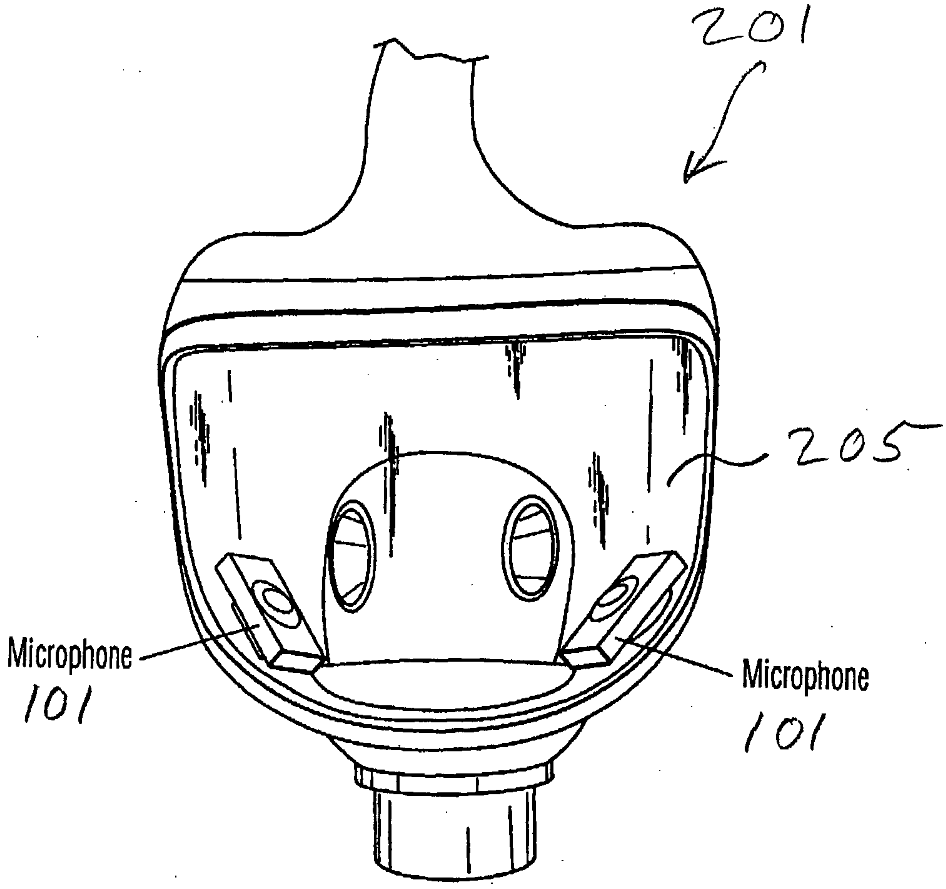
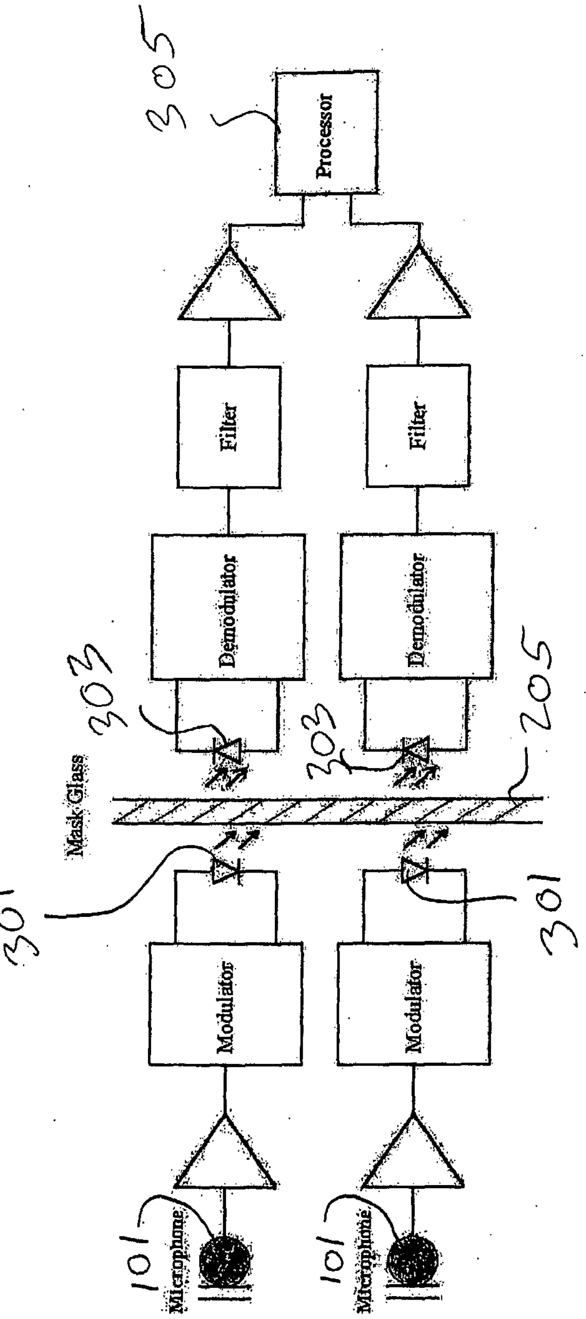


Fig. 2b


305
Processor
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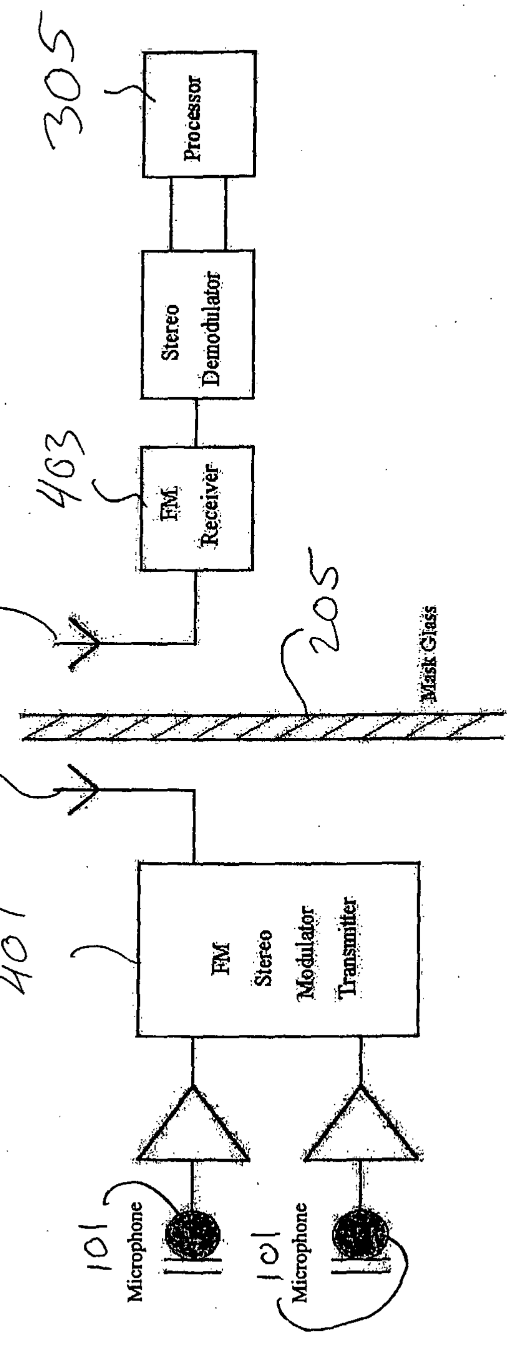
Filter
Demodulator
Demodulator
303
303
205
Mask Glass
301
301
Modulator
Modulator
101
101
Microphone
Microphone

Fig. 3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205
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401
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Stereo
Modulator
Transmitter
101
Microphone
101
Microphone

Fig. 4

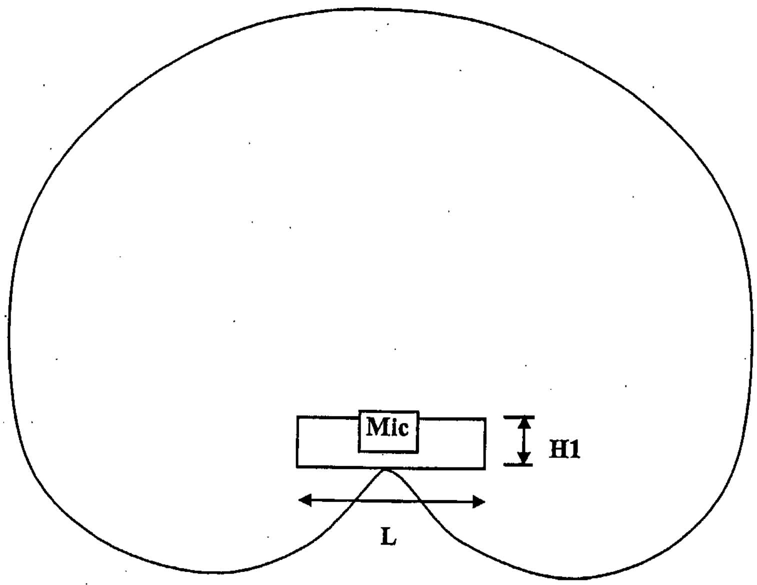
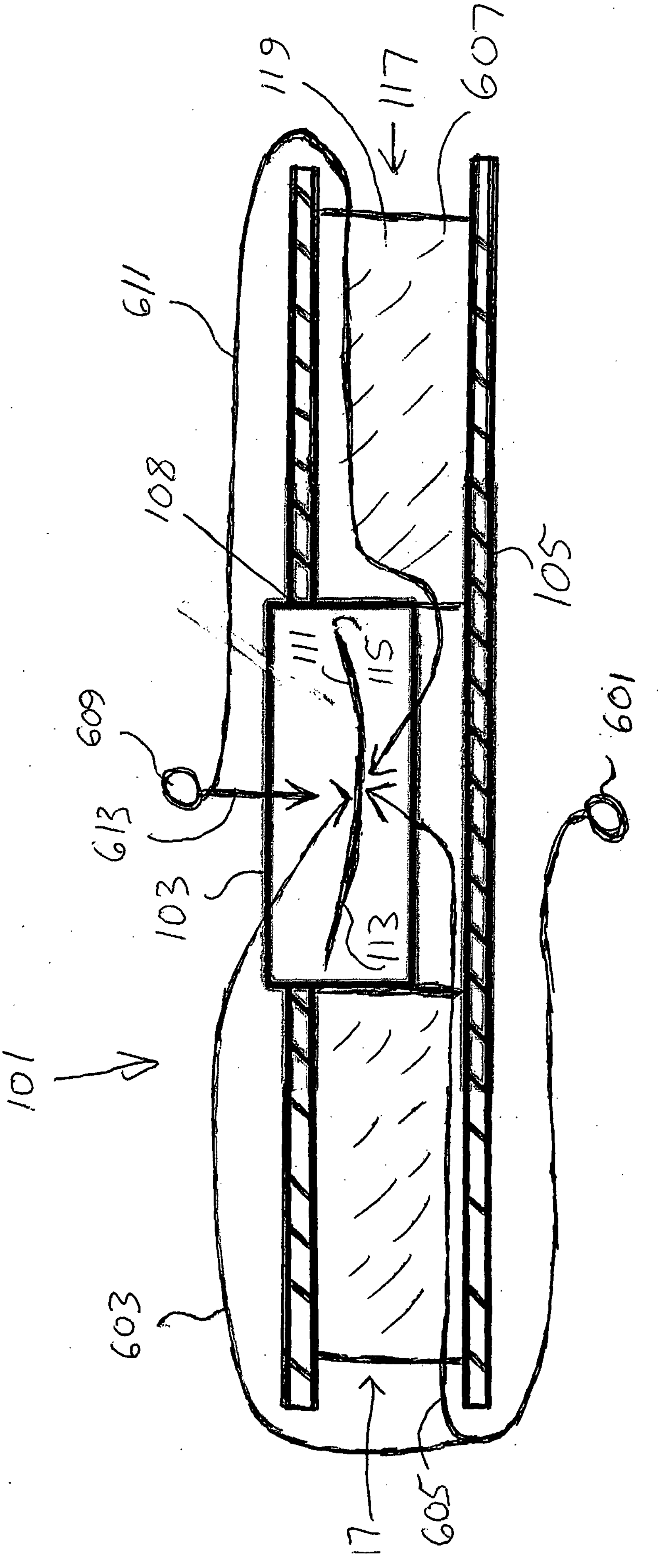


Fig. 5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605

Fig. 6

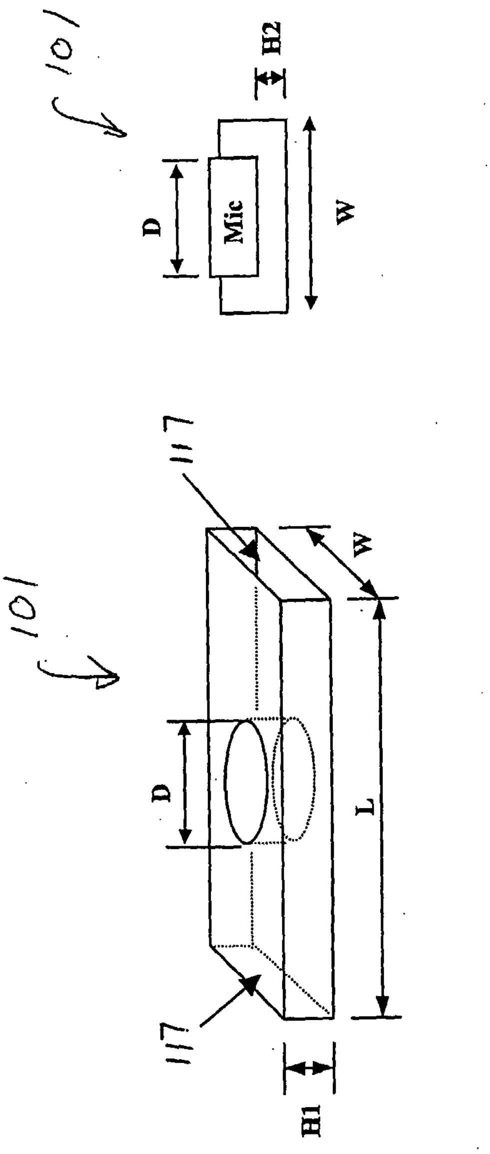

Fig. 7