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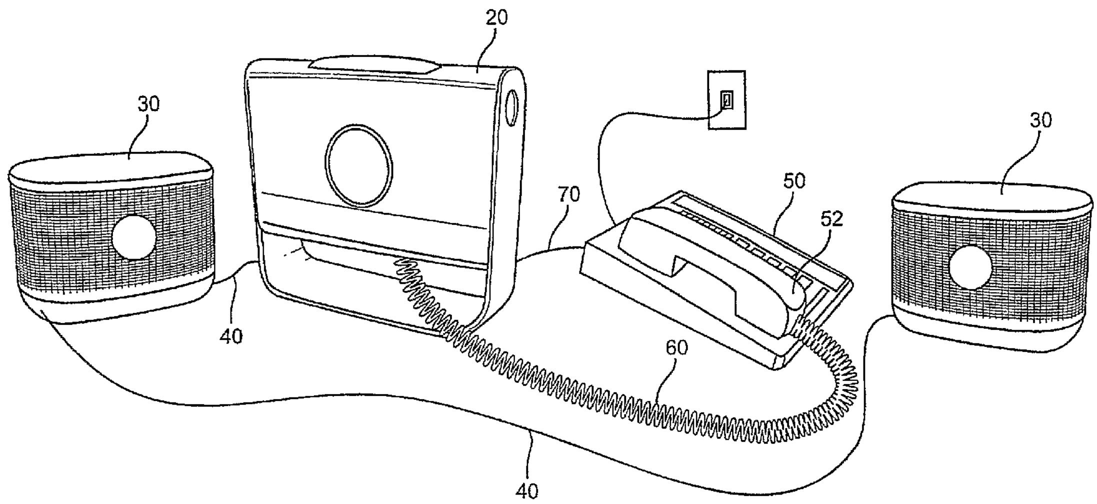
(54) Title: LOUDSPEAKER DESIGN



(57) Abstract: A loudspeaker unit includes a housing and a first and second sound driver disposed within the housing. The first sound driver converts a first electronic input signal into a first sound output signal. The second sound driver converts a second electronic input signal into a second sound output signal. The first and second electronic input signals are independent and different from each other. The loudspeaker unit also includes a back volume shared by the first and second sound drivers.

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LOUDSPEAKER DESIGN

BACKGROUND

[0001] Sound masking has been accomplished in the past by a variety of different methods. In one type of sound masking, a target sound is overcome by adding a sufficient amount of energy to the overall signal reaching the ear to mask the target sound. However, there have been problems in the past when attempting to design and install effective background sound masking systems. For example, sound masking signals should be uniformly distributed throughout a work space. The masking sound should be of uniform intensity across the workspace without substantial variation therein. If the masking sound is not uniformly distributed or diffused throughout the work space, the masking sound can have areas of greater or lesser effectiveness. As a result, a person moving or changing position within the work space may find the masking sound having greater or lesser effectiveness depending their particular location therein.

[0002] These same issues also relate to voice privacy where the privacy of a conversation is at issue. The voice privacy signal should be uniformly distributed and diffused outward from an area adjacent the person speaking. Use of conventional loudspeakers systems could lead to a voice privacy signal that was not uniformly distributed. Also, conventional loudspeaker systems would fail to properly distribute the voice privacy signal so as to maximize the sound output in front of the loudspeaker and minimize the sound output behind the loudspeaker.

[0003] Therefore, there is need for an improved loudspeaker configuration that is more readily capable of providing a more uniform voice privacy signal output while having the proper directional characteristics.

BRIEF SUMMARY

[0004] A loudspeaker design is provided, particularly for use in a voice privacy system. A voice privacy system is also provided. In various aspects, the voice privacy system maximizes the sound output in front of a loudspeaker and minimizes the footprint of the loudspeaker.

[0005] In one aspect, a loudspeaker unit includes a housing and a first and second sound driver disposed within the housing. The first sound driver converts a first electronic input signal into a first sound output signal. The second sound driver converts a second electronic input signal into a second sound output signal. The first and second electronic input signals are independent and different from each other. The loudspeaker unit also includes a back volume shared by the first and second sound drivers

[0006] In another aspect, a voice privacy system includes a voice privacy signal generator and one or more loudspeaker units. The voice privacy signal generator generates at least two independent electronic signals. Each loudspeaker unit includes a housing and a first and second sound driver disposed within the housing. The first sound driver converts a first electronic input signal into a first sound output signal. The second sound driver converts a second electronic input signal into a second sound output signal. The first and second electronic input signals are independent and different from each other.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 shows the components of one embodiment of a voice privacy system.

[0008] Fig. 2 shows a block diagram of one embodiment of a voice privacy system.

[0009] Fig. 3a is a perspective view of one embodiment a loudspeaker.

[0010] Fig. 3b is a bottom view of the loudspeaker of Fig. 3a.

[0011] Fig. 3c is an exploded view of the loudspeaker of Fig. 3a.

[0012] Fig. 4 is a top sectional view of one embodiment of a loudspeaker.

DETAILED DESCRIPTION

[0013] The contents of commonly assigned and copending U.S. applications serial number, 10/659,754, entitled "Communications device with sound masking system," and 60/642,865, entitled "Method and apparatus for speech masking," are hereby incorporated herein by reference.

[0014] The present invention is directed to a loudspeaker design. In particular, it is directed to a loudspeaker design for use in a voice privacy system. The loudspeaker unit includes a housing and two sound drivers disposed within the housing.

[0015] A voice privacy system is also provided. In one embodiment, the voice privacy system adds a signal sound into the environment that closely matches the characteristics of the source (person speaking), thereby confusing listeners as to which of the sounds is the real source. The voice privacy system is based on a user's own voice. This permits disruption of the ability to understand the source speech of the user by eliminating segregation cues that humans use to interpret human speech. The voice privacy system provides privacy for a user while on the telephone, for example. A sample of the user's voice signal is picked off the telephone handset line, scrambled into an unintelligible audio stream, and played over a set of loudspeakers.

[0016] Fig. 1 shows the components of a voice privacy system. The voice privacy system includes a base unit 20 and loudspeakers 30. The voice privacy system is adapted to be attached to a telephone 50. The base unit 20 includes a voice privacy signal generator to provide electronic input signals to the loudspeakers. The voice privacy signal generator provides at least two channels of electronic signals, which are independent and different from each other. The base unit 20 also includes controls and displays for the voice privacy system. Controls can include switches to turn the power to the base unit 20 on/off, to activate the voice privacy system, and to adjust the settings of the voice privacy system. Displays can include the voice input volume, the speaker volume, and power status. The base unit 20 can also include a microphone for receiving input sounds. The voice privacy system includes a connection 60 from the phone handset 52 to the base unit 20, and a connection 70 from the base unit 20 to the phone 50.

[0017] The base unit 20 is connected to the loudspeakers 30 by lines 40. The lines 40 provide electronic signals and may also provide power. Alternatively, the loudspeakers 30 may be independently powered. Additional loudspeakers 30 may also be used, which may either be connected to the base unit 20, or connected from one of the loudspeakers 30, as described below in more detail. The loudspeakers 30 may also be integrated into the base unit 20 to provide a one piece voice privacy system.

[0018] Fig. 2 illustrates the general hardware in one embodiment of the voice privacy system 100. The voice privacy system 100 includes a digital signal processor (DSP) 102 which communicates with memory 104. A telephone interface 106 contains a microphone 106a, into which a user speaks, and preamplifier 106b that amplifies the signal from the microphone 106a. The signal from the telephone interface 106 is supplied to an analog-to-digital (A/D) converter 108 that converts the analog audio stream into a digital signal. The digital signal is fed to the DSP 102, processed by the DSP 102 to produce the desired voice privacy signal, and supplied to a digital-to-analog (D/A) converter 110 to convert the digital voice privacy signal back into an analog voice privacy signal. The volume of the analog voice privacy signal is controlled using a volume control 112 such as a variable resistor and a power amplifier 114 before being supplied to one or more loudspeakers 116. Power to various circuitry is supplied by a power supply 120.

[0019] The voice privacy signal may be generated by any suitable method. In one embodiment, the voice privacy signal is generated by a method disclosed in U.S. Patent Application 20040019479 A1, entitled "Method and system for masking speech," the contents of which are hereby incorporated herein by reference.

[0020] Figs. 3a-c show one embodiment of a loudspeaker 30. Fig. 3c shows the individual components of a loudspeaker 30. The loudspeaker includes a housing 90, and a left sound driver 80 and a right sound driver 82 disposed within the housing 90. The term driver includes any sort of device for producing sound. The left sound driver 80 converts a first electronic input signal from the voice privacy signal generator into a first sound output signal, and the right sound driver 82 converts a second electronic input signal from the voice privacy signal generator into a second sound output signal. The first and second electronic input signals are independent and different from each other. Although two sound drivers are preferred, three or more sound drivers in a single housing are also possible. The housing 90 serves both to house and orient the drivers 80, 82, as well as insulating the drivers 80, 82 to provide the desired sound output.

[0021] The housing 90 includes a grill 92, a front housing portion 94, a rear housing portion 96, and a base portion 98. The housing and housing components may be made of plastic or any suitable material. The housing components are held together by fasteners 88. The base portion may be attached to a base mount 112. The drivers are preferably two inches in diameter, rated at 10 W, with an 8 ohm impedance. Such drivers are available from GGEC. A printed circuit board (PCB) 100 is disposed within the housing adjacent the base portion 98. A housing gasket 102 is disposed adjacent the edge of rear housing portion 96. The driver brackets 106 hold the drivers 80, 82 in place within the front housing portion 94. The loudspeaker may also include a volume control, including a volume control knob 180. The housing may also include insulation. The gasket 102 is designed to minimize the sound leakage from the housing. Other soundproofing measures may be taken to minimize the leakage from the back volume and improve the sound output of the loudspeaker unit.

[0022] The loudspeakers 30 preferably incorporate internal power amplifiers and are fed with a line level (maximum 1 Vrms) signal from the base 100. DC power can be fed to the remote loudspeakers 30 from the base 100 over the same multi-conductor cable with the line level audio. A non-standard jack may be selected which provides a ground connection as well as signal leads for both audio channels. Additionally, a conductor may be provided for DC power feed to the remote loudspeakers 30. Each loudspeaker preferably has a 2-channel amplifier, two 6-conductor RJ11 style jacks 110 (signal in and return for each driver, and DC power in and out), and a volume control 108 that allows for adjusting the loudspeaker units output volume (both drivers), all of which are preferably disposed on the PCB 100. In one embodiment, an LED power indicator light may be provided on the back of the loudspeaker unit to show that the loudspeaker is properly connected.

[0023] The orientation of the sound drivers 80, 82 within the loudspeaker housing 90 is shown in Fig. 4. Each driver 80, 82 has a center axes 84, 86 respectively running through the center of the driver. The first sound driver 80 and second sound driver 82 are preferably oriented such that the center axes 84, 86 of the drivers are at an angle θ between about 100 degrees to about 130 degrees, more preferably about 110 degrees to about 120 degrees, and most preferably about 120 degrees, with respect to each other. This alignment provides a near uniform frequency response coverage on the front 180 degrees of the loudspeaker unit. In other words, beaming effect of the sound output is minimized. The drivers 80, 82 are preferably positioned in the same horizontal plane with the center axes of the drivers horizontally disposed, but other orientations of both placement and alignment are possible. For example, the drivers can be disposed in the same horizontal plane, with the center axis of one driver oriented slightly upward and the center axis of the other driver oriented slightly downward.

[0024] Each sound driver 80, 82 receives one channel of the two channel output from the voice privacy signal generator base unit 20. The two channel output is not conventional stereo sound. Rather, the two channel output is two different streams of voice privacy sounds, and the two electronic signals are separate and independent of each other. In one embodiment, the electronic signals are produced from a random arrangement of the voice segments from a bank of voice segments stored in non-volatile memory. If the two channels were the same signals or related signals, nulls would be created at certain angles with respect to the loudspeaker. Because the signals are independent, nulls are not created at certain angles with respect to the loudspeaker. Each channel is a different compilation of a plurality of voice streams, so that the output of each driver is never the same. Preferably, each channel includes two to five voice streams.

[0025] The placement of two drivers 80, 82 in a single loudspeaker unit allows the two drivers 80, 82 to share the same back volume 110, as shown in Fig. 4. The back volume 110 is the area of the housing 90 behind the drivers 80, 82. The size of the back volume 110 determines the low frequency cutoff of the loudspeaker 30. By using two drivers 80, 82 sharing the same back volume 110, the size or footprint of the loudspeaker can be made significantly smaller (by at about 50%) than would otherwise be possible. For a speaker housing use two two-inch diameter drivers, a back volume of 27 in^3 is preferably used. A smaller or larger back volume may be used, depending on the desired low frequency cutoff.

[0026] The use of two drivers 80, 82 with different signals allows the loudspeaker to produce a near uniform 180-degree output of voice privacy sound. Because two drivers are used, the directionality limitation of normal loudspeakers is overcome, thus giving us the ability to provide wide-angle coverage from a single speaker source. It can be seen that the housing has a center axis 88 equidistant from the two loudspeaker drivers, as shown in Fig. 4. The sound output signals in front of the loudspeaker unit are preferably louder than the sound output signals behind the loudspeaker unit. More specifically, the sound output signals in front of the loudspeaker unit (in the range from about -60 degrees to about 60 degrees, preferably from about -75 degrees to about 75 degrees, and most preferably from about -90 degrees to about 90 degrees, with respect to a central axis 88 of the housing) are louder than the sound output signals of the loudspeaker unit behind the loudspeaker in the range from about 90 degrees to about -90 degrees. The sound output signals in front of the loudspeaker unit are preferably at least 2 dB louder, more preferably at least 5 dB louder, than the sound output signals behind the loudspeaker unit.

[0027] Additionally, the frequency response versus angle in front of the loudspeaker is preferably relatively flat. By "relatively flat" is meant that the frequency response does not vary much with angular position, especially when compared to a speaker using only one driver. Such a loudspeaker allows the minimum number of loudspeaker units to be positioned to provide voice privacy in each user's environment.

[0028] The cabling that connects the loudspeakers 30 to the main unit and each other is preferably commonly available 6-conductor phone line cable with RJ11 connectors on each end. The main unit provides DC power on two of the conductors and there are two conductors for carrying each of the two signal channels. The signals are not amplified to drive the loudspeakers 30 but instead each loudspeaker uses the DC power provided to drive its on 2-channel amplifier that amplifies the supplied signal to drive the two loudspeaker drivers. The DC power and both signals can be passed onto multiple other loudspeaker units in by connecting the additional loudspeaker units to the two loudspeaker units 30. Therefore, while there are only two loudspeaker connection jacks on the main unit, additional loudspeakers 30 can be added to the system via connections to the first two loudspeakers 30. This connection approach allows for having a single cable coming to a loudspeaker unit that provides both power and 2 signals. Connecting sequential loudspeakers 30 reduces the installation difficulty and wire management problems of having to bring a cable from each loudspeaker back to the main unit.

[0029] The voice privacy system is preferably set up in a work environment as follows. The user places the voice privacy signal generator on a desktop behind or next to the telephone. The user connects the base unit 20 to the telephone using a phone-in connector and a handset-out connector. The user positions the loudspeakers 30 in areas that he wants to have privacy. The user then connects the loudspeakers 30 to the voice privacy signal generator with left and right loudspeaker connectors. A second person helps the user adjust the volume of the loudspeaker units so that the user has coverage from all directions at the lowest possible sound. If the loudspeakers 30 are too loud or placed too close to another co-worker, individual loudspeakers 30 can then be adjusted by the user to change the volume. The sound output signals of the loudspeaker units are preferably within a predetermined loudness from the voice of the person speaking. Additionally, the loudspeaker units are preferably arranged to minimize localization cues to a listener of the voice of the person speaking. For example, if the work environment has high cubicle walls, the speakers are preferably positioned at the top of the walls facing outward. An additional speaker may be placed at the doorway or entrance to the cubicle.

[0030] Turning now to the ability of the auditory system to determine individual sounds from a number of overlapping sounds, the auditory system exploits segregation cues to separate, for instance, different voices in a crowd.

These cues refer to differences between sound sources including differences in spatial localization, onset and offset time, and loudness. The voice privacy sound created by an voice privacy system minimizes these cues, thereby making the real source ambiguous.

[0031] The human auditory system uses the differences in timing and level between the input at each ear to perform spatial localization. By appropriate placement of loudspeakers 30 of the voice privacy system, the minimization of localization cues is controlled. The placement depends on whether there is a direct line of sight between the talker and listener (direct field) or whether there is a barrier (e.g., cubicle wall) between them (indirect field). For direct field applications, placing a loudspeaker on the line between the talker and listener minimizes localization cues. The ability of listeners to localize sources in the indirect field is much worse than in the direct field. In this case, the loudspeaker can be as much as 90 degrees off the direct line axis when there is a barrier between the talker and listener.

[0032] The auditory system can also segregate sources if the sources turn on or off at different times. The voice privacy system minimizes this cue by outputting multiple, random streams of speech elements so that it is difficult for a listener to distinguish individual onsets of the real source.

[0033] The auditory system is also known to exploit level differences between sources in order to segregate them. The voice privacy system controls level cues by insuring that the level is at most approximately 9 dB above the source level as measured at the listener. Above 9 dB, a loudness cue can be exploited if it is accompanied by another segregation cue (e.g., spatial difference). Although a loudness segregation cue has been shown with small (3-6 dB) level differences, the effect is minor and can be considered a secondary effect.

[0034] The voice privacy system can output between one and five noise streams (or "voices"). If multiple voices are output, they are output in parallel. These voices can be created using the entire chunk buffer. However, by varying the properties of each voice, the sound quality and privacy performance can be improved.

[0035] Additionally, although in a preferred embodiment the voice privacy system uses voice streams for the input signals of the speakers, other input signals, such as white or pink noise, may also be used in the present invention. Additionally, the speaker design of the present invention may find uses in other applications where two independent and different electronic signals are used in a single loudspeaker unit.

[0036] Although the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes may be made and formed in detail without departing from the spirit and scope of the invention. It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the scope of this invention.

CLAIMS

What is claimed is:

1. A loudspeaker unit comprising:

a housing;

a first sound driver disposed within the housing, wherein the first sound driver converts a first electronic input signal into a first sound output signal;

a second sound driver disposed within the housing, wherein the second sound driver converts a second electronic input signal into a second sound output signal, and wherein the first and second electronic input signals are independent and different from each other; and

a back volume shared by the first and second sound drivers.

2. The loudspeaker unit of claim 1, wherein each of the sound drivers has a center axis, and wherein the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle ranging from about 100 degrees to about 130 degrees with respect to each other.

3. The loudspeaker unit of claim 2, wherein the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle ranging from about 110 degrees to about 120 degrees with respect to each other.

4. The loudspeaker unit of claim 4, wherein the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle of about 120 degrees with respect to each other.

5. The loudspeaker unit of claim 1, wherein the first and second sound drivers are disposed in the same horizontal plane.

6. The loudspeaker unit of claim 1, wherein the loudspeaker unit has a front and a back, wherein the sound output signals in front of the loudspeaker unit is louder than the sound output signals behind the loudspeaker unit.

7. The loudspeaker unit of claim 1, wherein the housing has a center axis equidistant from the two loudspeaker drivers, and wherein the sound output signals of the loudspeaker unit in front of the loudspeaker unit in the range from about -90 degrees to about 90 degrees with respect to a central axis of the housing are louder than the sound output signals of the loudspeaker unit behind the loudspeaker in the range from about 90 degrees to about -90 degrees.

8. The loudspeaker unit of claim 1, wherein the loudspeaker unit has a relatively flat frequency response.

9. The loudspeaker unit of claim 1, wherein the housing has a center axis equidistant from the two loudspeaker drivers, and wherein the frequency response of the loudspeaker unit measured in the range from about -90 degrees to about 90 degrees with respect to a central axis of the housing is relatively flat.

10. The loudspeaker unit of claim 1, further comprising a volume control for the sound output of the sound drivers.

11. The loudspeaker unit of claim 1, wherein the first and second electronic input signals are produced from a random arrangement of digitized voice segments.

12. The loudspeaker unit of claim 1, wherein the unit is a component of a voice privacy system.

13. A voice privacy system comprising:

a voice privacy signal generator for generating at least two independent electronic signals; and

one or more loudspeaker units, each loudspeaker unit comprising:

a housing;

a first sound driver disposed within the housing, wherein the first sound driver converts a first electronic input signal into a first sound output signal; and a second sound driver disposed within the housing, wherein the second sound driver converts a second electronic input signal into a second sound output signal, and wherein the first and second electronic input signals are independent and different from each other.

14. The voice privacy system of claim 13, wherein each loudspeaker unit further comprises a back volume shared by the respective first and second sound drivers.

15. The voice privacy system of claim 13, wherein each of the sound drivers has a center axis, and wherein in each loudspeaker unit the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle ranging from about 100 degrees to about 130 degrees with respect to each other.

16. The voice privacy system of claim 15, wherein in each loudspeaker unit the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle ranging from about 110 degrees to about 120 degrees with respect to each other.

17. The voice privacy system of claim 15, wherein in each loudspeaker unit the center axis of the first sound driver and the center axis of the second sound driver are oriented at an angle of about 120 degrees with respect to each other.

18. The voice privacy system of claim 13, wherein each loudspeaker unit has a front and a back, wherein the sound output signals in front of the loudspeaker units are louder than the sound output signals behind the loudspeaker units.

19. The voice privacy system of claim 13, wherein the loudspeaker units are arranged in an area and the first and second sound output signals provide a substantially uniform frequency response throughout the area.

20. The voice privacy system of claim 13, wherein each of the loudspeaker units comprises a volume control.

21. The voice privacy system of claim 13, wherein the first and second electronic input signals are produced from a random arrangement of digitized voice segments.

22. A loudspeaker unit comprising:

a housing having a front portion and a rear portion, the front portion having a first sound driver and a second sound driver, the first sound driver and the second sound driver oriented at an angle of greater than 90 degrees, the rear portion sized substantially smaller than the front portion and defining an interior cavity.

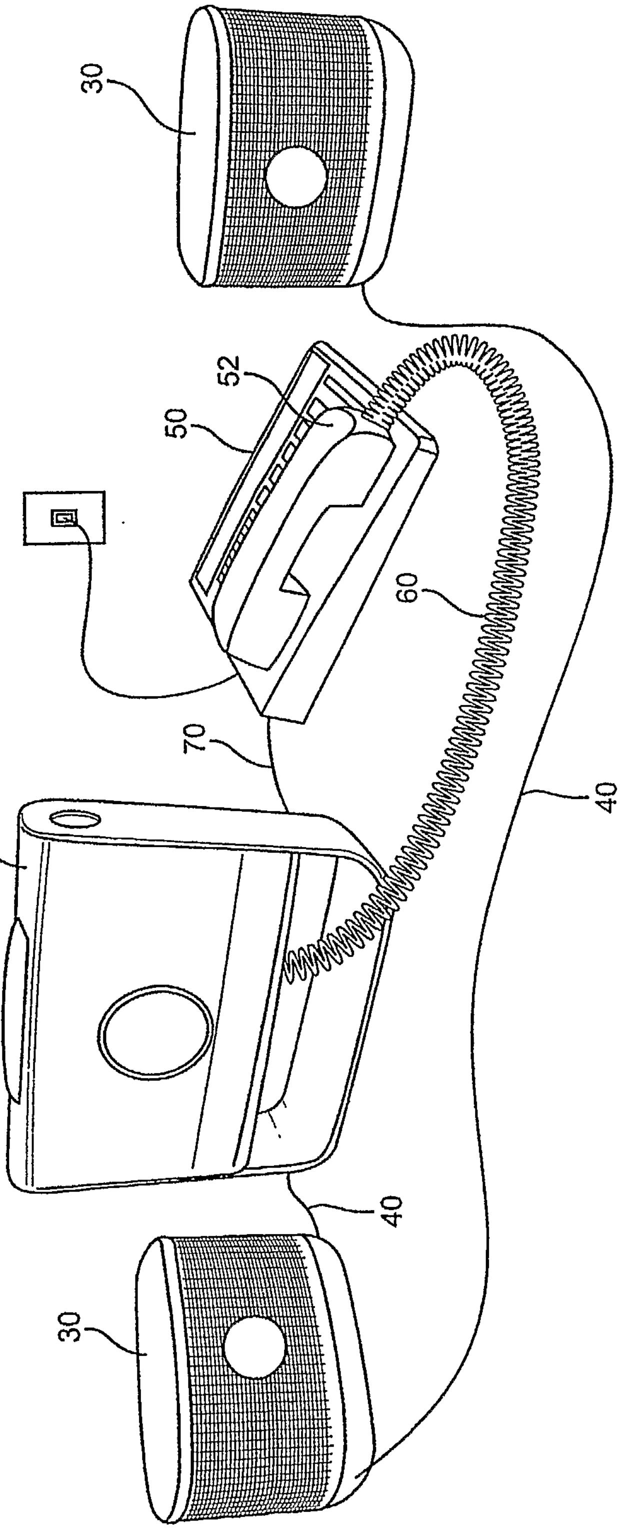
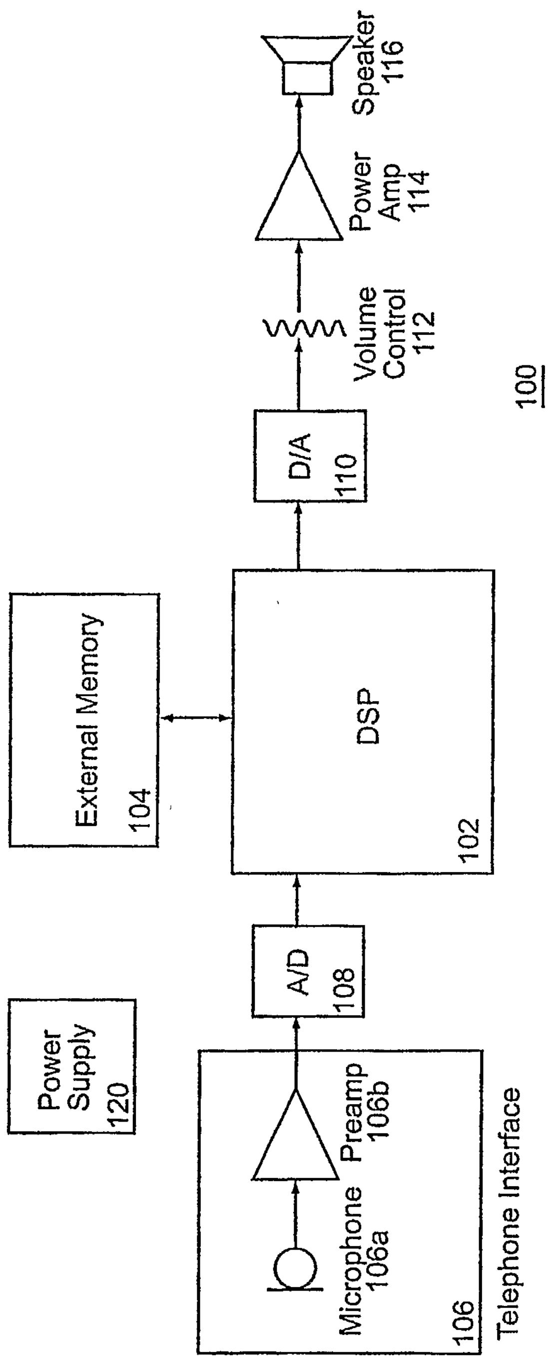


Fig.1


Speaker
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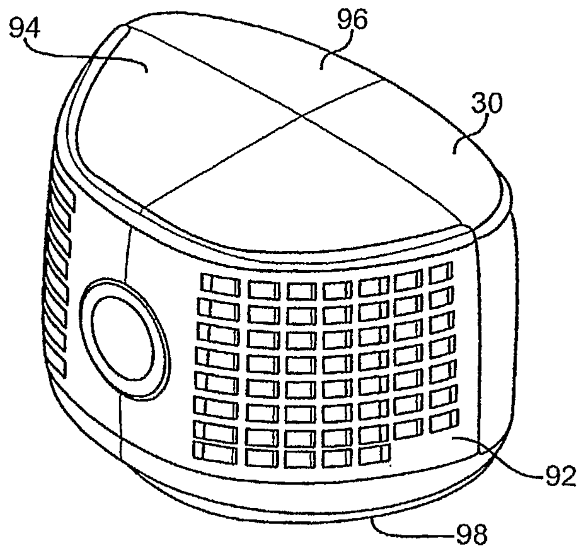

Fig.3a

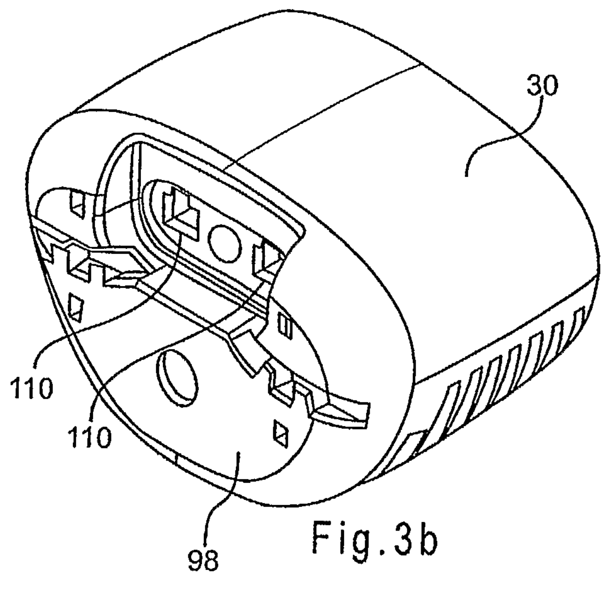

Fig.3b

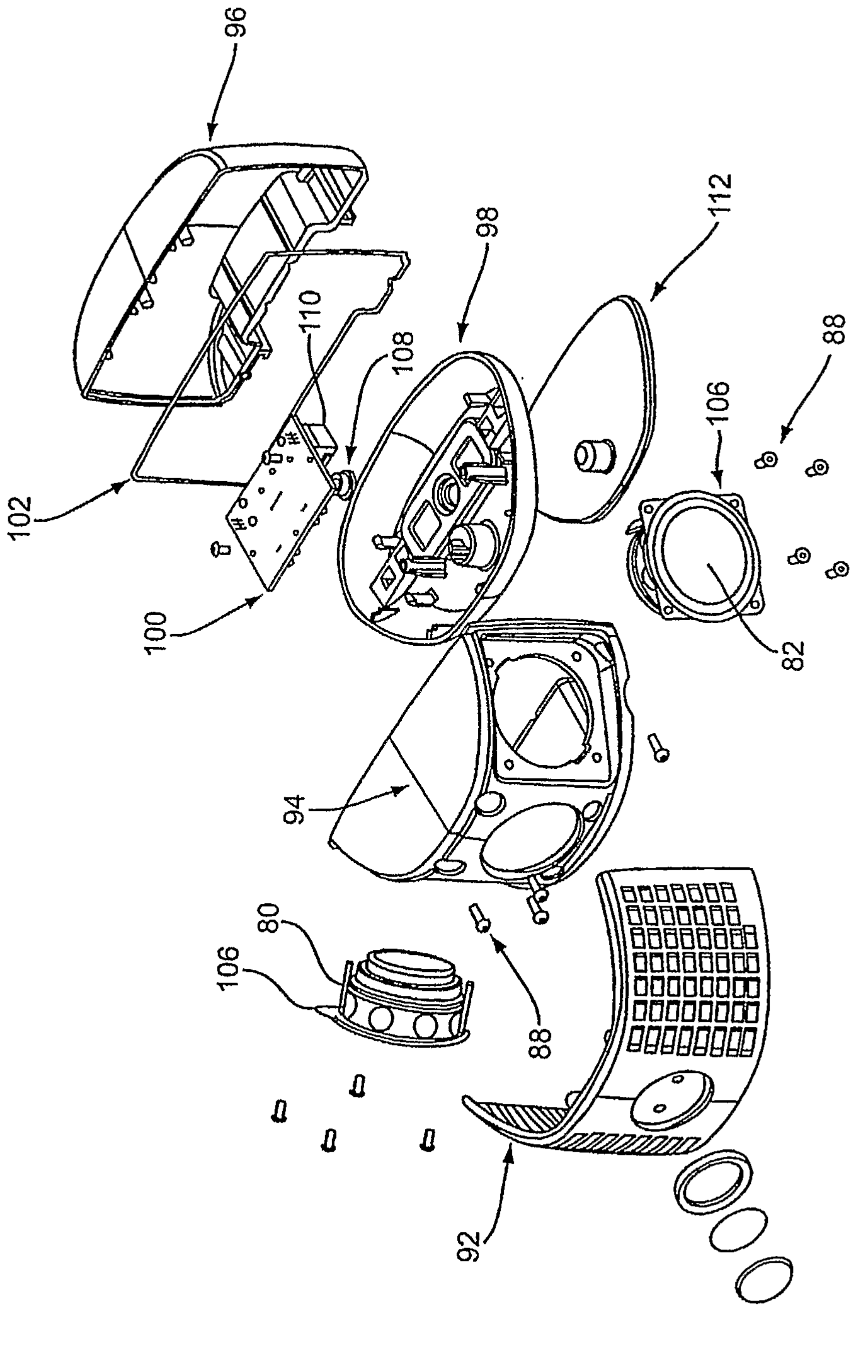

Fig.3c

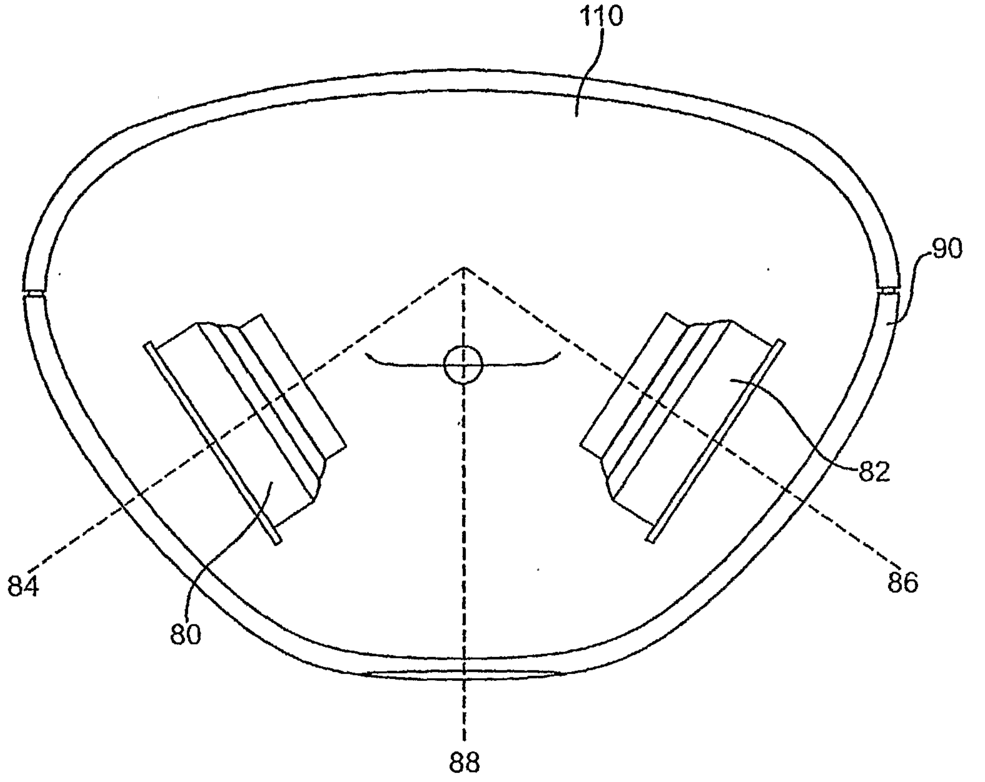

Fig.4