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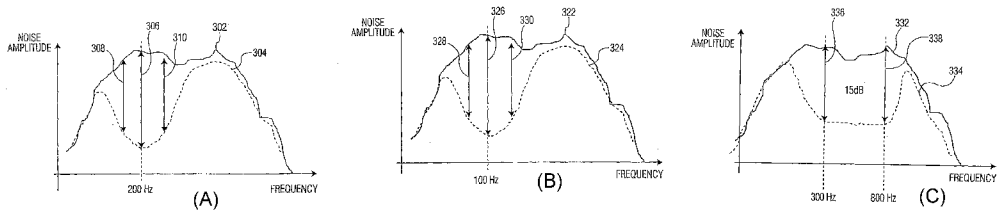
(54) Title: HEADPHONES WITH USER-SELECTABLE FILTER FOR ACTIVE NOISE CANCELLATION



(57) Abstract: A headphone system has a microphone for receiving noise; a first filter for providing active noise correction of the received noise for the headphone in a first frequency band, a second filter for providing active noise correction in a second frequency band; and a user-controlled selector for selecting one of the first and second filters.

HEADPHONE WITH USER-SELECTABLE FILTER FOR ACTIVE NOISE CANCELLATION

FIELD OF INVENTION

[0001] The present invention relates to headphones, and particularly to active noise cancellation for reducing ambient noise in headphones.

BACKGROUND

[0002] A headset including one or two headphones having active noise reduction typically has a microphone for receiving ambient noise, and one or more filters for providing active noise cancellation or compensation. In active noise compensation systems, digital or electronic circuits are provided that add an emulated noise signal. Active noise compensation systems that cover a wide range of noise frequencies are known. However, such active noise compensation systems are necessarily expensive, thereby making active noise reduction headphones less desirable.

SUMMARY OF THE INVENTION

[0003] According to an aspect of the present invention, a headphone system has a microphone for receiving ambient noise; a first filter for providing active noise correction of the received noise for the headphone in a first frequency band, a second filter for providing active noise correction in a second frequency band; and a user-controlled selector for selecting one of the first and second filters for providing active noise correction. An embodiment of the invention may include a third filter for providing active noise correction in a third frequency band; in such an embodiment, the user-controlled selector provides for selecting one of the first, second and third filters for providing active noise correction.

[0004] According to another aspect of the present invention, a method for providing noise correction in a headphone system includes receiving ambient noise at a microphone; and providing active noise correction of the received noise in accordance with a user selection, in one of a first frequency band and a second frequency band. In an embodiment of the invention, the method may include providing active noise correction of the received noise in accordance with a user selection, in one of a first frequency band, a second frequency band and a third frequency band.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Fig. 1 is a perspective view of a headphone system in accordance with an embodiment of the invention.

[0006] Fig. 1A is another view of a control box of the headphone system of Fig. 1.

[0007] Fig. 2 is a block diagram of components of a headphone system in accordance with an embodiment of the invention.

[0008] Figs. 3A, 3B and 3C illustrate detected noise and noise reduction in exemplary embodiments of the invention.

DETAILED DESCRIPTION

[0009] It is to be understood that the figures and descriptions of the present invention have been simplified to illustrate elements that are relevant for a clear understanding of the present invention, while eliminating, for the purpose of clarity, many other elements found in typical headphone systems. Those of ordinary skill in the art may recognize that other elements and/or steps are desirable and/or required in

implementing the present invention. However, because such elements and steps are well known in the art, a discussion of such elements and steps is not provided herein.

[0010] Further, it should be understood that the several views of the housings, displays and general configurations shown in the figures include many decorative or ornamental features, aspects of which the particulars may be changed while maintaining the device's utility and without departing from the scope and spirit of the present invention.

[0011] Referring to Fig. 1, there is provided a headphone system 10 in accordance with an embodiment of the present invention. Headphone system 10 is capable of being worn by the user on clothing and on the user's head. Headphone system 10 includes a control box 50 which houses such items as batteries, switches, control circuits, and active noise reduction circuits. Headphone system 10 also includes headset 20 having first and second headphones 22, 24, physically connected to headband 26. Control box 15 communicates with headset 20 through cables 30. Control box 50 comprises a housing 51, and inputs, including an on/off and volume selector 52 and an active filter selector 54. Referring to Fig. 1A, control box 50 is preferably adapted to be attached to the clothing of a user, such as via a clip 55. Control box 55 may have a door 57 covering an opening to a battery compartment. Control box 50 is thus a wearable component. As headset 20 mounts on the user's head, and control box 50 is attachable to the user's clothing, system 10 is a wearable headphone system. Control box 50 receives audio signals from a source (not shown) via cable 60.

[0012] Control box 50 has a variety of components for signal processing, including one or more analog and/or digital filters, and a power supply, including one or more

batteries. In one embodiment of the invention, the signal processing components and drivers, and power supplies therefor, are housed in control box 50. The control box may include appropriate display and user interface capabilities including software and/or hardware for enabling a user to control and view parameter settings including filter setting and selections, volume and programming options.

[0013] Referring to Fig. 2, there is illustrated a block diagram of components of an exemplary right channel of a headphone system in accordance with an embodiment of the invention. It will be understood that the system includes both a right noise reduction microphone 200 and a left noise reduction microphone (not shown). Right noise reduction microphone 200 may be mounted in or about right headphone 22 (Fig. 1) as is typically provided. The ambient noise signal output by right noise reduction microphone 200 is coupled to microphone amplifier 210. Microphone amplifier 210 may be located in control box 50, so that cable 30 of Fig. 1 carries the connection from the output of right noise reduction microphone 200 to microphone amplifier 210. Microphone amplifier 210 may be any one of a large number of amplifiers well known in connection with audio systems and devices, and provides as an output an amplified signal. A non-inverting amplifier may be employed. The output of microphone amplifier 210 is coupled to an input of level setting circuit 212. Level setting circuit 212 adjusts the levels of signals received from microphone amplifier, and may have fixed settings, or may be coupled to a user input. Level setting circuit 212 may include a potentiometer, by way of example. The output of level setting circuit 212 is coupled to an input of switch 260. Switch 260 is operatively coupled to a user input, such as active filter selector 54 shown in Fig. 1. Using active filter selector 54 to operate switch 260, the user may select one of noise reduction filters

250, 252, 254, or a direct connection, as at 262, in which case no active noise reduction filter is provided.

[0014] Each of noise reduction filters 250, 252, 254 is an active noise reduction filter. An active noise reduction filter provides, over at least a portion of the frequency range of a received signal, a generated signal that is, or is similar to, an inverted and phase-shifted copy of the received signal, so that addition of the signals results in an output signal having a reduced amplitude over at least a portion of the frequency range of the received signal. It will be appreciated that a filter constitutes an active noise reduction filter notwithstanding the fact that the generated signal is not perfectly opposite in phase, or a perfect inverse of the received signal. Active noise reduction is known by a variety of terms, including active noise cancellation, active noise control, and active noise compensation, and the term "active noise reduction" as used herein encompasses the same technique denoted by these and similar terms.

[0015] The filters are each directed to particular frequency bands, which bands may be selected for various environments, as discussed in more detail below.

[0016] The output of switch 261 is a filtered signal which is coupled to an input of buffer 265. Buffer 265 may provide buffering of the filtered signal. The output of buffer 265 is a buffered, filtered signal.

[0017] Jack 270 of a cable (not shown), provides left audio source material signals at 272 and right audio source material signals at 274. Left audio source material signals are coupled to a left channel, and processed in a manner similar to that of the right channel and is not shown. Right audio source material signals are coupled to an input of a volume control circuit 275, which is operatively coupled to a user volume selector. Volume adjusted right audio source material signals and buffered filter

signal both inputs to amplifier 280, which additively combines and amplifies the signals. Amplifier 280 outputs a combined amplified signal to drive right speaker 290.

[0018] It is understood that the block diagram shown in Fig. 2 is merely exemplary and additional signal conditioning and processing devices and steps may be included in a circuit implementing the invention. Moreover, the particular order of inclusion of devices in a circuit implementing the invention may be varied. By way of example, the filters may be implemented in one or more digital signal processors. The ambient noise signal received from the microphone may be converted into a digital noise signal by an analog-to-digital converter. The DSP system may perform a discrete Fourier transform on the digital noise signal to obtain the spectra and amplitudes of the ambient noise. The user may select one of a plurality of digital filters that provide filtering of the signal within a particular frequency band. The digital signal in the frequency domain is passed through the selected one of the filters; the filtered signal is inversely transformed into the time domain; the filtered signal in time domain is inverted by an inverter; the inverted signal is converted to an analog signal by a digital to analog converter, and the converted analog signal is then sent to a summing amplifier. The passed signal may also be inverted. At the summing amplifier, the inverted signal is added to an input audio signal, and the summed signal is used to drive a speaker. The filters implemented by the digital signal processor can be IIR or FIR filters as known in the art. The system can be implemented in a digital signal processor. If so, the analog-to-digital conversion, discrete Fourier transform calculation, applied filter, and summing function can all be performed in a DSP integrated circuit.

[0019] If a digital programmable filter array is used, the received ambient noise is converted into a digital signal, transformed into the frequency domain, and filtered by the selected one of the filters. The filtered frequency domain signal is inversely transformed to the time domain, inverted, and converted to an analog signal, as described above for using a digital signal processor.

[0020] One or more analog programmable filter arrays may be used, which arrays are suitably programmed to provide filtering in the selected frequency bands. If an analog programmable filter array is used, no analog to digital converter, digital to analog converter, or transformation between the time domain and the frequency domain is needed.

[0021] If a programmable filter array is used, the programmable array may include at least two filters, each having a particular frequency band in which the signal is filtered.

[0022] The inventors have discovered that noise characteristics of different common transportation environments vary. In particular, the inventors have discovered that the noise detected in a coach of an inter-city passenger train, and in particular in a coach of a French National Railways TGV, has a noise peak near 100 Hertz (Hz). The noise detected in a cabin of a jet passenger aircraft, and in particular a Boeing 747 during takeoff and landing, has a peak near 200 Hz. The noise in a carriage of an urban rail system, and in particular the Paris Metro, has noise peaks at about 300 Hz and about 800 Hz. Desirable characteristics of filters suitable for use in a jet aircraft passenger cabin, an inter-city passenger railroad coach, and an urban rail transit car, are provided.

[0023] An indicator may be provided in connection with control box 50 to identify to a user which filter is selected by manipulation of selector 54. Indicia may be provided adjacent each position on a selector 54. By way of example, the indicia may be wording such as METRO, PLANE, TRAIN. Another example of indicia is pictograms representing a metro, an airplane, and an intercity train, respectively. Any other suitable indicator technology, such as an LCD or other alphanumeric display, may be employed.

[0024] In the embodiment illustrated in Fig. 2, three active noise reduction filters are shown. It will be appreciated that two or more such filters may be provided in accordance with various implementations of the invention. Each noise reduction filter 250, 252, 254 provides active noise reduction in a selected frequency band. First noise reduction filter 250 provides active noise reduction in a first selected frequency band. The first selected frequency band corresponds to observed noise in a first environment. The first environment may be, for example, an inter-city passenger railroad coach during operation at normal speeds. Second noise reduction filter 252 provides active noise reduction in a second selected frequency band. The second selected frequency band corresponds to observed noise in a second environment different from the first environment. The second environment may be, for example, an aircraft passenger cabin during flight. The aircraft may be a high-capacity passenger jet aircraft commonly used by airlines, with the cabin configured for passenger travel with rows of cushioned seats. Third noise reduction filter 254 provides active noise reduction in a third selected frequency band. The third selected frequency band corresponds to observed noise in a third environment different from

the first and second environments. The third environment may be, for example, a car of an urban subway, elevated or metro transit system in operation.

[0025] It will be appreciated that filters corresponding to additional environments may be provided in addition to or in lieu of one or more of the disclosed filters. Such filters may correspond to other noise-specific frequency environments, including but not limited to other modes of transportation, such as buses and light rails, or other noisy environments.

[0026] Referring now to Figs. 3A, 3B and 3C, desirable characteristics of bandpass filters in an implementation of the invention in which filters suitable for use in a jet aircraft passenger cabin, an inter-city passenger railroad coach, and an urban rail transit car, are provided. In Fig. 3A, noise levels in decibels are plotted against frequency, in Hertz. Both values are plotted on a logarithmic scale. An exemplary detected noise signal for a jet aircraft passenger cabin is shown at 302. An exemplary noise signal for a jet aircraft passenger cabin after active noise reduction in accordance with an embodiment of the invention is shown at 304. Noise reduction is provided in a frequency band around 200 Hz. A noise reduction peak at about 200 Hz, of about 20 decibels (dB), is indicated at 306. Noise reduction at a non-peak frequency, about 180 Hz, is shown at 308. Noise reduction at a non-peak frequency, about 210 Hz, is shown at 310. Noise reduction at 308 and 310 is at least about 15 dB. It will be appreciated that the particular depth and width of the noise reduction band may vary in implementations of the invention. In the areas surrounding the noise reduction peaks, for example, the higher frequencies, noise reduction may be provided by additional elements of the headphone, for example, by padding provided on the headsets.

[0027]An exemplary detected noise signal with and without exemplary active noise reduction in accordance with an embodiment of the invention is shown for the interior of a coach of an inter-city train at Fig. 3B. Noise levels in decibels are plotted against frequency, in Hertz. Both values are plotted on a logarithmic scale. An exemplary detected noise signal for the interior of a coach of an inter-city train is shown at 322. An exemplary noise signal for the interior of a coach of an inter-city train is shown at 324. Noise reduction at about 100 Hz, of about 20 dB, is indicated at 326. Noise reduction at a non-peak frequency, about 80Hz, is shown at 328. Noise reduction at a non-peak frequency, about 110 Hz, is shown at 330. Noise reduction at 328 and 330 is at least about 15 dB. It will be appreciated that the particular depth and width of the noise reduction band may vary in implementations of the invention. As in Fig. 3A, in the areas surrounding the noise reduction peaks, for example, the higher frequencies, noise reduction may be provided by additional elements of the headphone, for example, by padding provided on the headsets.

[0028]An exemplary detected noise signal with and without exemplary active noise reduction in accordance with an embodiment of the invention is shown for the interior of a car of an urban rail transit system at Fig. 3C. Noise levels in decibels are plotted against frequency, in Hertz. Both values are plotted on a logarithmic scale. An exemplary detected noise signal for the interior of a coach of an inter-city train is shown at 332. An exemplary noise signal for the interior of a coach of an inter-city train is shown at 334. Noise reduction from about 300 Hz to about 800 Hz, of about 15dB, is shown at 336 and 338. It will be appreciated that the particular depth and width of the noise reduction band may vary in implementations of the invention. Again, in the areas surrounding the noise reduction peaks, noise reduction may be

provided by additional elements of the headphone, for example, by padding provided on the headsets.

[0029] The particular circuits implementing the invention may be selected by those of ordinary skill in the art. Either analog or digital circuits may be employed to implement the claimed filters. As discussed above, digital signal processing may be employed for implementation of the filters. Conventional analog circuits for active noise reduction may be employed, with the addition of switches and three band pass filters.

[0030] Various advantages are obtained by a system and method in accordance with the present invention. By way of example, the use of filters designed for relatively narrow bands permits the use of relatively less expensive circuits. The incorporation of filters, batteries, and other components in the control box provides additional room in the headphones, thereby permitting more options in location of microphones, and the use of larger drivers. The location of filters and other circuits in the control box permits batteries, and battery chambers with openings that may be closed with removable or openable doors, to be located exclusively in the control box, and not on the headphones. The absence of doors permits better sealing of the headphones, providing better control over air pressure within the headphones.

[0031] While the foregoing invention has been described with reference to the above, various modifications and changes can be made without departing from the spirit of the invention. Accordingly, all such modifications and changes are considered to be within the scope of the appended claims.

CLAIMS

1. A headphone system, comprising:

a microphone for receiving ambient noise;

a first filter for providing active noise correction of the received noise for the headphone in a first frequency band, and a second filter for providing active noise correction in a second frequency band; and

a user-controlled selector for selecting one of the first and second filters for providing active noise correction.

2. The headphone system of claim 1, wherein said first frequency band is associated with ambient noise in a first environment, and said second frequency band is associated with noise in a second environment.

3. The headphone system of claim 1, further comprising a third filter for providing active noise correction of the received noise for the headphone in a third frequency band, said selector being for selecting one of the first, second and third filters for providing active noise correction.

4. The headphone system of claim 3, wherein said first frequency band is centered at about 100 Hz, said second frequency band is centered at about 200 Hz, and said third frequency band extends from about 300 Hz to about 800 Hz.

5. The headphone system of claim 1, comprising a headset and a control box physically separated from said headset and in electrical communication with said headset, said control box housing said filters and said selector.

6. A method for providing noise correction in a headphone system, comprising the steps of:

receiving ambient noise at a microphone;

providing active noise correction of the received ambient noise in one of a first frequency band and a second frequency band in response to user selection.

7. The method of claim 6, wherein said first frequency band is associated with noise observed in a first environment, and said second frequency band is associated with noise observed in a second environment.

8. The method of claim 6, wherein said step of providing comprises providing active noise correction in one of said first frequency band, said second frequency band, and a third frequency band in response to user selection.

9. The method of claim 8, wherein said first frequency band is centered at about 100 Hz, said second frequency band is centered at about 200 Hz, and said third frequency band extends from about 300 Hz to about 800 Hz.

10. The method of claim 9, wherein said step of providing active noise correction, and a step of receiving said user selection, are performed at a control box physically separated from a headset of said headphone system.

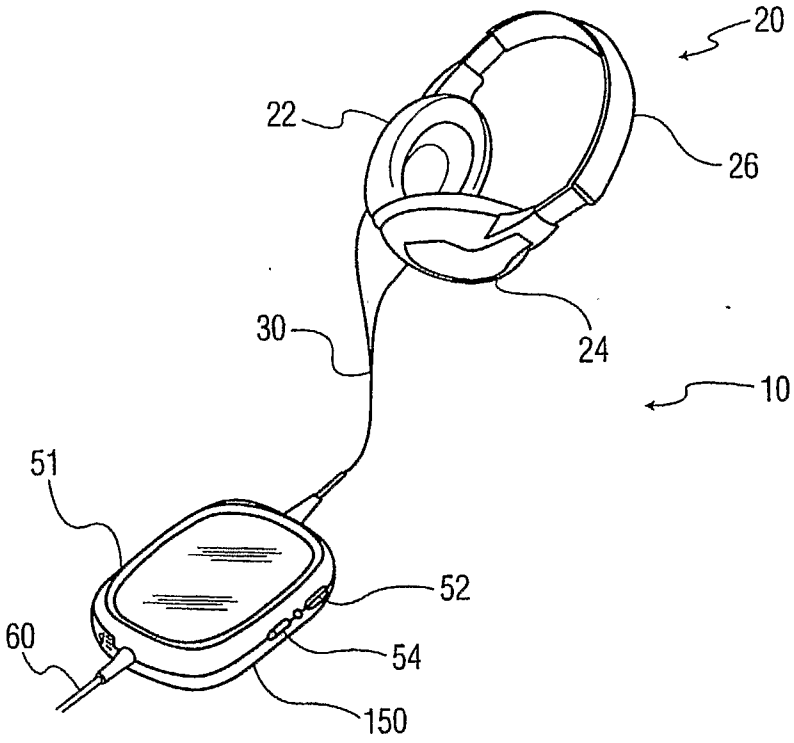


FIG. 1

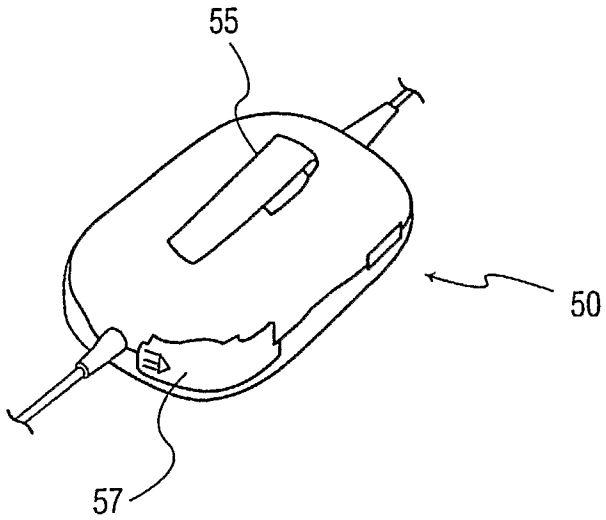


FIG. 1A

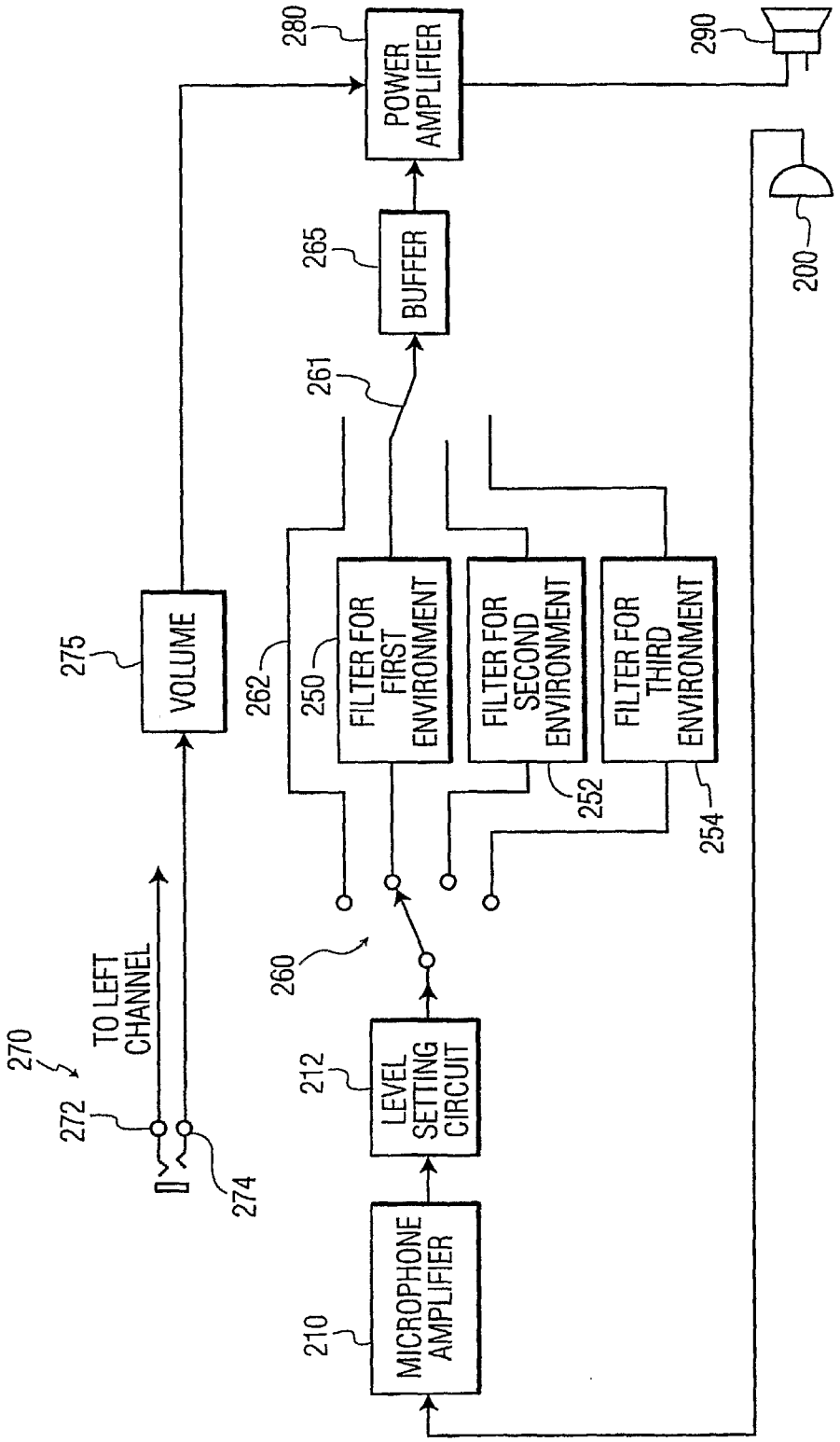

280
POWER AMPLIFIER
290
200
265
BUFFER
261
275
VOLUME
262
250
FILTER FOR FIRST ENVIRONMENT
FILTER FOR SECOND ENVIRONMENT
FILTER FOR THIRD ENVIRONMENT
252
254
260
270
TO LEFT CHANNEL
272
274
212
LEVEL SETTING CIRCUIT
210
MICROPHONE AMPLIFIER

FIG. 2

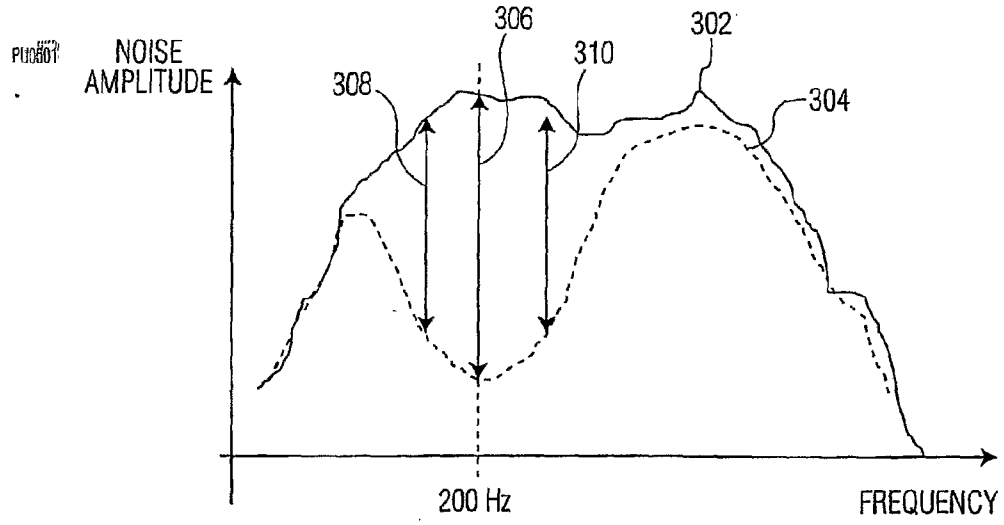
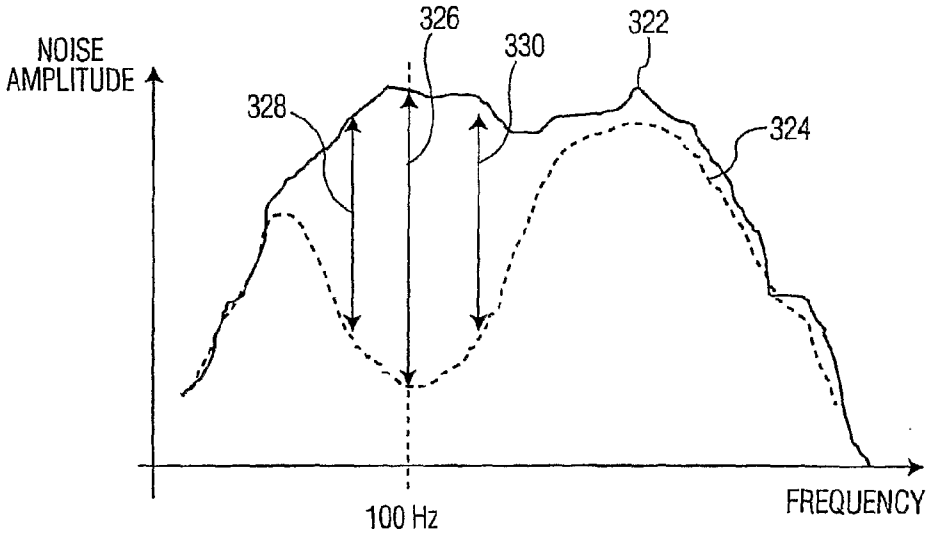
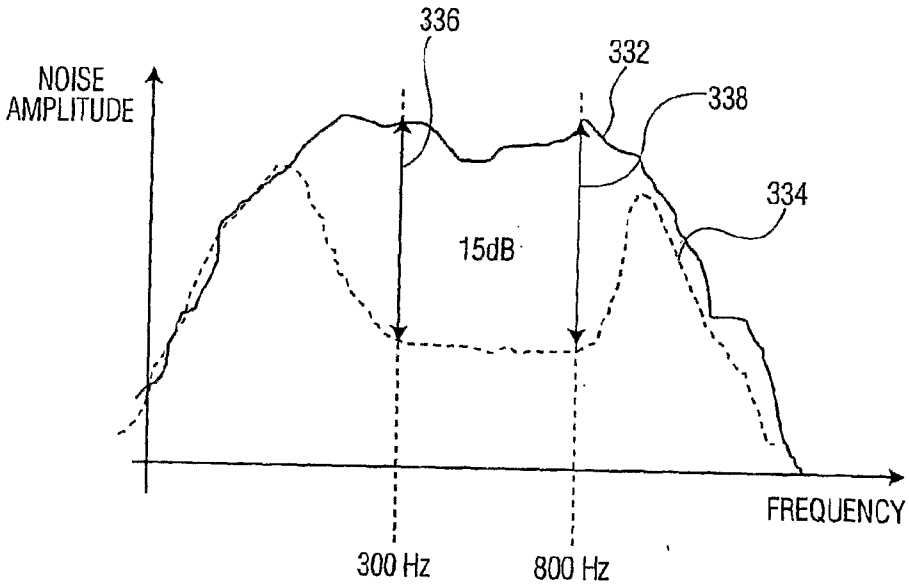

NOISE
AMPLITUDE
306
302
310
308
304
200 Hz
FREQUENCY

FIG. 3A


NOISE
AMPLITUDE
326
322
330
328
324
100 Hz
FREQUENCY


NOISE
AMPLITUDE
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332
338
334
15dB
300 Hz
800 Hz
FREQUENCY

FIG. 3C

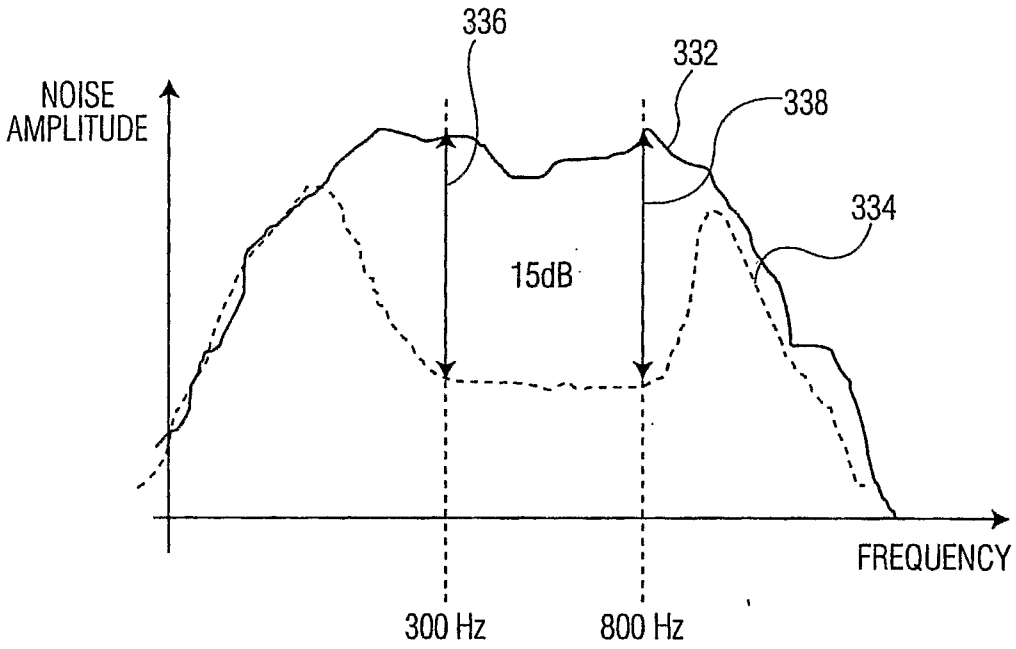

FIG. 3C

INTERNATIONAL SEARCH REPORT

International application No
/US2005/025061

A. CLASSIFICATION OF SUBJECT MATTER
H04R5/033 G10K11/175

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04R G10K A61F G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, COMPENDEX, INSPEC, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 160 893 A (SAUNDERS ET AL) 12 December 2000 (2000-12-12) column 1, line 5 - column 3, line 12 column 5, line 1 - column 6, line 7 column 8, line 5 - column 14, line 24	1-10
X	US 6 078 672 A (SAUNDERS ET AL) 20 June 2000 (2000-06-20) column 4, line 15 - column 6, line 7 column 6, line 54 - column 11	1-3,5-8, 10
X	WO 93/26085 A (NOISE CANCELLATION TECHNOLOGIES) 23 December 1993 (1993-12-23) page 1, line 3 - page 2, line 17 page 3, line 1 - page 7, line 8	1-3,5-8, 10

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2006	08/03/2006

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
/US2005/025061

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 761 260 A (API PROTECTION) 2 October 1998 (1998-10-02) page 2, line 8 - page 6, line 9	1-10
A	US 4 185 168 A (CAUSEY, G DONALD ET AL) 22 January 1980 (1980-01-22) column 3, line 39 - column 7, line 34	1,5,6,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
/US2005/025061

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6160893 A	12-12-2000	AU 5111899 A WO 0006066 A1	21-02-2000 10-02-2000
US 6078672 A	20-06-2000	US 6898290 B1	24-05-2005
WO 9326085 A	23-12-1993	NONE	
FR 2761260 A	02-10-1998	NONE	
US 4185168 A	22-01-1980	NONE	