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(54) **SOUND PROCESSING APPARATUS**

(57) The invention provides a sound processing apparatus is capable of performing failure diagnosis while performing sound processing.

A sound processing apparatus D includes a microphone 200, a band-pass filter 300, an audio signal processor 400, a Fourier transformer 500, and a signal level determiner 600. The microphone 200 is configured to simultaneously acquire an audible sound and an inaudible sound, and to convert the acquired audible and inaudible sounds into electric signals, and to output the electric signals. The band-pass filter 300 receives the electrical signals outputted from the microphone 200 and removes components of the electrical signals that are outside the audible range. The audio signal processor 400 apply predetermined signal processing to the electric signals that have passed through the band-pass filter 300. The Fourier transformer 500 obtains frequency components in an inaudible range on the basis of the electric signals outputted from the microphone 200. The signal level determiner 600 performs a first determination as to whether the frequency components in the inaudible range have a signal level being equal to or greater than a threshold value.

D

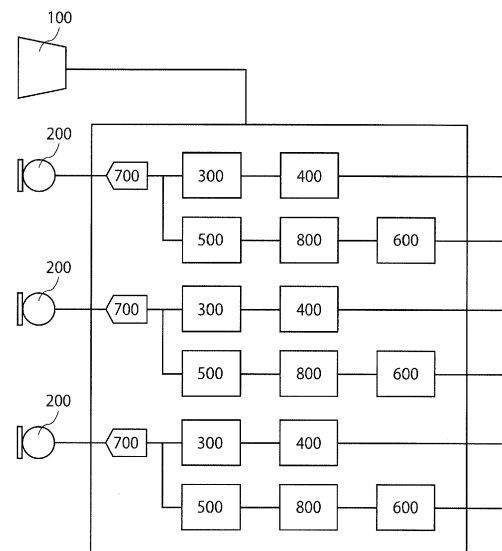


FIG.1

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Description

Solution to Problem

Technical Field

[0001] The invention relates to a sound processing apparatus.

Background Art

[0002] Some conventional vehicles are provided with a sound processing apparatus that allows an occupant of a vehicle to talk with an operator of an emergency notification center when an accident or other emergency arises in the vehicle. Such a sound processing apparatus is disclosed in Japanese Unexamined Patent Application Publication 2016-107972.

[0003] The sound processing apparatus includes a loudspeaker, a signal output unit, a microphone, a failure diagnosis part, a signal processor, and a wireless communication part. Using a diagnostic signal of frequencies outside the voice band, the signal output unit modulates diagnostic data and allows the modulated signal to be outputted from the loudspeaker. The output modulated signal is acquired by the microphone and converted into an electric signal. The failure diagnosis part demodulates the electric signal inputted from the microphone to generate data and determines whether the generated data includes any data that matches the diagnostic data. When determined that the demodulated data includes data that matches the diagnostic data, the failure diagnosis part determines that the loudspeaker is not in failure. When determined that the demodulated data does not include data that matches the diagnostic data, the failure diagnosis part determines that the loudspeaker is in failure. The modulated signal, which is of frequencies outside the voice band, is difficult to be heard by the occupant of the vehicle. When the failure diagnosis part determines that the loudspeaker is not in failure, the signal processor subsequently generates sound data based on the voice of the occupant acquired by the microphone and transmits the sound data through the wireless communication part, while processing the sound data received from the operator through the wireless communication part to output the processed sound data to the loudspeaker. This allows the occupant to talk to the operator.

Summary of Invention

Technical Problem

[0004] In the above conventional sound processing apparatus, the occupant cannot talk with the operator until the failure diagnosis part completes the failure diagnosis for the loudspeaker.

[0005] The invention provides a sound processing apparatus capable of performing failure diagnosis while performing sound processing.

[0006] In order to solve the above problem, a sound processing apparatus of a first aspect of the invention includes a microphone, a first band-pass filter, an audio signal processor, a Fourier transformer, and a signal level determiner. The microphone is configured to simultaneously acquire an audible sound having a frequency in an audible range and an inaudible sound having a frequency in an inaudible range, to convert an acquired audible and inaudible sound into electric signals, and to output the electric signals. The first band-pass filter is configured to receive the electrical signals outputted from the microphone and remove components of the electrical signals that are outside the audible range. The audio signal processor is configured to apply predetermined signal processing to the electric signals that have passed through the first band-pass filter. The Fourier transformer is configured to receive the electrical signals outputted from the microphone and perform a frequency analysis on the received electric signals so as to obtain frequency components of the electric signals. The obtained frequency components include frequency components in the inaudible range. The signal level determiner is configured to perform a first determination as to whether the frequency components in the inaudible range have a signal level being equal to or greater than a threshold value. In the sound processing apparatus of this aspect, the signal level determiner can perform the first determination while the audio signal processor is performing the signal processing. If it is determined in the first determination that the signal level of the frequency components in the inaudible ranges is not equal to or greater than the threshold value, the sound processing apparatus is able to detect failure of the loudspeaker.

[0007] The signal level determiner may be further configured to perform a second determination when it is determined in the first determination that the frequency components in the inaudible range is equal to or greater than the threshold value. The second determination may be made such that it is determined whether the frequency components in the inaudible range have a signal level within a predetermined range, the predetermined range being equal to or greater than the threshold value. In the sound processing apparatus of this aspect, the signal level determiner can perform the first and second determinations while the audio signal processor is performing the signal processing. If it is determined in the first and second determinations that the signal level of the frequency components in the inaudible ranges is equal to or greater than the threshold value and is not within the predetermined range equal to or greater than the threshold value, the sound processing apparatus is able to detect deterioration of the loudspeaker.

[0008] A plurality of the microphones may be provided. Also, a plurality of the Fourier transformers may be provided, and each of the Fourier transformers may be configured to perform a frequency analysis on the electric

signals outputted from a corresponding one of the microphones so as to obtain frequency components of the electric signals. The obtained frequency components include frequency components in the inaudible range. A plurality of the signal level determiners may be provided, and each of the signal level determiners may be configured to perform the first determination. In the sound processing apparatus of this aspect, if all the signal level determiners each determine in the first determination that the signal level of the frequency components in the inaudible ranges is not equal to or greater than the threshold value, the sound processing apparatus is able to detect failure of all the microphones or a speaker connected to or installed in the sound processing apparatus. Also, if at least one of the signal level determiners each determine in the first determination that the signal level of the frequency components in the inaudible ranges is not equal to or less than the threshold value, the sound processing apparatus is able to detect failure of the at least one of the microphones or a speaker.

[0009] The signal level determiners may be configured such that, when at least one of the signal level determiners determines in the first determination that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value, the at least one of the signal level determiners further performs the second determination. In the sound processing apparatus of this aspect, if all the signal level determiners each determine in the first and second determinations that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value but not within a predetermined range equal to or greater than the threshold value, the sound processing apparatus is able to detect deterioration of a loudspeaker. Also, if at least one of the signal level determiners each determine in the first and second determinations that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value but not within the predetermined range equal to or greater than the threshold value, the sound processing apparatus is able to detect deterioration of the at least one of the microphones or a speaker.

[0010] The microphones may be disposed at different distances from a loudspeaker capable of emitting inaudible sounds. The respective threshold values for the signal level determiners may differ from one another according to the respective distances from the corresponding microphones to the loudspeaker. In the sound processing apparatus of this aspect, each threshold value is set according to the distance from the corresponding microphone to the loudspeaker, improving the accuracy of determination by the plurality of signal level determiners.

[0011] The respective threshold values and the predetermined ranges for the signal level determiners may differ from one another according to the respective distances from the corresponding microphones to the loudspeaker. In the sound processing apparatus of this aspect, each threshold value and each predetermined

range is set according to the distance from the corresponding microphone to the loudspeaker, improving the accuracy of determination by the plurality of signal level determiners.

[0012] The sound processing apparatus according to any of the above aspects may further include a loudspeaker. The loudspeaker may be configured to emit an inaudible sound, or alternatively configured to simultaneously emit audible and inaudible sounds.

[0013] A sound processing apparatus according to a second aspect of the invention may include a second band-pass filter in place of the or each Fourier transformer. The second band-pass filter may be configured to receive the electrical signals outputted from the at least one microphone and remove frequency components of the electrical signals that are other than frequency components in the inaudible range. The signal level determiner may be configured to perform a first determination as to whether the frequency components in the inaudible range, which have passed through the second band-pass filter, have a signal level being equal to or greater than a threshold value. Also in the sound processing apparatus of this aspect, the signal level determiner can perform the first determination while the audio signal processor is performing the signal processing. If it is determined in the first determination that the signal level of the frequency components in the inaudible range is not equal to or greater than the threshold value, the sound processing apparatus is able to detect failure of the loudspeaker. It should be noted that the sound processing apparatus of the second aspect may have a similar configuration as that of various aspects of the signal processing apparatus of the first aspect described above.

Brief Description of Drawings

[0014]

Fig. 1 is a block diagram of a sound processing apparatus according to a first embodiment of the invention.

Fig. 2 is a graph showing results of a simulation performed with the sound processing apparatus.

Description of Embodiments

[0015] The following discussion is directed to various embodiments of the invention.

First embodiment

[0016] The following is a description of a sound processing apparatus D according to a plurality of embodiments including the first embodiment of the invention, with reference to Fig. 1. Fig. 1 shows the sound processing apparatus D according to the first embodiment. The sound processing apparatus D can be in-

stalled in an electronic equipment that requires sound processing. For example, the sound processing apparatus D may be installed in an emergency notification device, a telephone conference device, a television receiver or other acoustic devices, an automatic teller machine, a ticket vending machine, a personal computer, or a smartphone or a tablet computer or other portable mobile terminals.

[0017] The sound processing apparatus D includes at least one loudspeaker 100, at least one microphone 200, at least one first band-pass filter 300, at least one audio signal processor 400, at least one Fourier transformer (FFT) 500, at least one signal level determiner 600, at least one analog-to-digital converter (A/D converter) 700, and at least one second band-pass filter 800. Each of these elements of the sound processing apparatus D will be described in detail below.

[0018] The loudspeaker 100 is configured to emit an inaudible sound, or alternatively configured to emit an audible sound and an inaudible sound simultaneously and individually. The inaudible sound is any sound of frequencies in an inaudible range and cannot be heard by humans. For example, the inaudible sound may be of frequencies in the range from 20 kHz to 24 kHz. The audible sound is any sound of frequencies in an audible range and can be heard by humans. For example, the audible sound may be of frequencies in the range from 300 Hz to 3 kHz.

[0019] The at least one microphone 200 is able to acquire an audible sound and an inaudible sound simultaneously and individually. The at least one microphone 200 is configured to acquire ambient sounds, convert the acquired sounds into electric signals, and output the electric signals. Ambient sounds include at least one of an audible sound and an inaudible sound. The audible sound acquired includes an audible sound emitted from the loudspeaker 100, a voice of a user of the sound processing apparatus D, and/or an ambient noise. The inaudible sound acquired includes an inaudible sound emitted from the loudspeaker 100 and/or an ambient noise. Specifically, when the at least one microphone 200 simultaneously acquires audible and inaudible sounds, the electric signals include signals corresponding to the audible sound (hereinafter referred to as "audible signal") and signals corresponding to an inaudible sound (hereinafter referred to as "inaudible signal"). When the at least one microphone 200 acquires audible sounds only, the electric signals are audible signals. When the at least one microphone 200 acquires inaudible sounds only, the electric signals are inaudible signals.

[0020] The electric signals (audible signals and/or inaudible signals) outputted from the at least one microphone 200 are converted into digital signals by the at least one A/D converter 700, and the converted digital electric signals are inputted into the at least one first band-pass filter 300 and the at least one Fourier transformer 500. The output of the first band pass filter 300 is fed to the audio signal processor 400, and the output of

the Fourier transformer 500 is inputted to the second bandpass filter 800. Accordingly, the processing by the at least one first band-pass filter 300 and the at least one audio signal processor 400 and the processing by the at least one Fourier transformer 500 and the signal level determiner 600 are performed as parallel processing to be described and as shown in Fig. 1.

[0021] The at least one first band-pass filter 300, the at least one audio signal processor 400, the at least one Fourier transformer (FFT) 500, the at least one signal level determiner 600, and the at least one A/D converter 700 may be constituted by respective logic circuits in an integrated circuit, or alternatively constituted by respective pieces of software to be processed by a processor, or alternatively constituted by discrete logic circuits.

[0022] The or each first band-pass filter 300 is configured to filter electric signals (audible signals and/or inaudible signals) inputted thereinto and output the filtered electric signals to the associated audio signal processor 400. Specifically, the at least one first band-pass filter 300 is configured to filter components of electric signals so as to pass components within the audible range (i.e. audible signals within the voice band, such as the range from 125 Hz to 8 kHz) only and remove components outside the audible range.

[0023] The at least one audio signal processor 400 is configured to generate a test signal according to predetermined information input and allow the test signal to be outputted from the loudspeaker 100. The loudspeaker 100 emits an inaudible sound on the basis of the inputted test signal. Some non-limiting examples of the predetermined information input are predetermined operation information input inputted to the at least one audio signal processor 400 through an input part of the electronic equipment, information inputted to the at least one audio signal processor 400 from a timer circuit in the electronic equipment or the sound processing apparatus D when a preset time expires, and an output signal from an impact sensor or other sensor in the electronic equipment.

[0024] The at least one audio signal processor 400 is also configured to receive audible signals that have passed through the at least one first band-pass filter 300, performs predetermined signal processing, generates sound data adapted for wireless or wired transmission, and causes a wireless or wired communication part of the electronic equipment to output the sound data. It should be appreciated that the above signal processing may be echo removal, equalization, noise removal, or other processing for making audible signals easier to hear when outputted from another loudspeaker than the loudspeaker 100. The signal processing may be hereinafter referred to as first audio signal processing.

[0025] The at least one audio signal processor 400 is further configured to process data received through the communication part of the electronic equipment to convert the data into audio signals (this processing may be hereinafter referred to as second audio signal processing), and transmit the audio signals to the loud-

speaker 100. Based on such audio signal input, the loudspeaker 100 emits audible sounds. The at least one audio signal processor 400 may also be configured to mix the test signal and the audio signals and transmit the mixed signals to the loudspeaker 100, so that the loudspeaker 100 can emit inaudible sounds and audible sounds simultaneously.

[0026] The or each Fourier transformer 500 is configured to perform fast Fourier transform (FFT) processing on electric signal inputs (audible signals and/or inaudible signals) from the corresponding A/D converter 700, thereby performing frequency analysis (spectrum analysis) of the electric signals to obtain the frequency components of the electric signals, which include frequency components within the audible range, i.e. frequency components of the audible signals, and/or frequency components in the inaudible range, i.e. the frequency components of the inaudible signals. The or each Fourier transformer 500 is further configured to output the obtained frequency components of the electric signals to the corresponding second band-pass filter 800.

[0027] The or each second band-pass filter 800 is configured to filter frequency components of electric signals inputted thereinto and output the filtered frequency components to the corresponding signal level determiner 600. Specifically, the or each second band-pass filter 800 is configured to filter frequency components of inputted electric signals so as to pass frequency components in the inaudible ranges (i.e. frequency components of the inaudible signals) and remove other frequency components.

[0028] The at least one signal level determiner 600 has configuration A) or B) described below, for example.

[0029] Configuration A): The or each signal level determiner 600 is configured to perform first determination processing and outputs the result to the electronic equipment. In the first determination processing, it is determined whether the inputted frequency components of the inaudible ranges have a signal level equal to or greater than a threshold value prestored in a memory in the corresponding logic circuit or processor. The threshold value is set to a signal level of the frequency components corresponding to the inaudible sound emitted by a loudspeaker 100 functioning normally.

[0030] Where the or each signal level determiner 600 has configuration A) described above, the result of the first determination processing is either A-1) or A-2) below.

Result A-1): When the or each signal level determiner 600 determines that the signal level of the frequency components in the inaudible ranges is equal to or greater than the threshold value, it is detected that the loudspeaker 100 is not in failure.

Result A-2): When the or each signal level determiner 600 determines that the signal level of the frequency components in the inaudible ranges is not equal to or greater than the threshold value (i.e. is

less than the threshold value), it is detected that that the loudspeaker 100 is in failure.

[0031] Configuration B): The or each signal level determiner 600 may be configured to additionally perform second determination processing when it is determined in the first determination processing that the signal level of the frequency components in the inaudible ranges is equal to or greater than the threshold value. In the second determination processing, it is determined whether the signal level is within a predetermined range prestored in a memory in the corresponding logic circuit or processor. This predetermined range is set as a range equal to or greater than the threshold value of frequency components corresponding to inaudible sounds emitted by a loudspeaker 100 functioning normally.

[0032] When the or each signal level determiner 600 of configuration B) described above performs the first and second determination processing, it is determined as one of B-1), B-2), or B-3) below.

Determination B-1): When the or each signal level determiner 600 determines that the signal level of the frequency components in the inaudible ranges is equal to or greater than the threshold value and within the predetermined range, it is detected that the loudspeaker 100 is not in failure.

Determination B-2): When the or each signal level determiner 600 determines that the signal level of the frequency components in the inaudible ranges is not equal to or greater than the threshold value (i.e. is less than the threshold value), it is detected that that the loudspeaker 100 is in failure.

Determination B-3): When the or each signal level determiner 600 determines that the signal level of the frequency components in the inaudible ranges is equal to or greater than the threshold value but not within the predetermined range, it is detected that that the loudspeaker 100 is deteriorated.

[0033] For reference purposes, the following is a result of a simulation performed. In this simulation, an inaudible sound of 20.5 kHz was emitted from a loudspeaker, the inaudible sound and ambient noises were acquired by a microphone, and the electric signals from the microphone were subjected to frequency analysis by the Fourier transformer 500 in a manner as described above. The simulation result is shown in Fig. 2. In this simulation, the signal level determiner 600 performs the first determination processing as to whether the signal level of the frequency components in an inaudible range from 20.0 kHz to 24.0 kHz is equal to or greater than a threshold value, namely -45 dB. Also, when the signal level determiner 600 determines in the first determination processing that the signal level is equal to or greater than the threshold value, the signal level determiner 600 performs the second determination processing as to whether the signal level of the frequency components in the inaudible range

is within a predetermined range, namely -40 dB to -10 dB, that is greater than the threshold value. If the signal level of the frequency components in the inaudible range is within the range from -40 dB to -10 dB, the loudspeaker is functioning normally (see Fig. 2); and if the signal level is less than -45 dB, the loudspeaker is in failure; and if the signal level is greater than or equal to -45 dB or less than -40 dB, the loudspeaker is deteriorated. In Fig. 2, frequency components of 2 kHz or lower are shown as frequency components of noises.

[0034] It should be noted that the or each signal level determiner 600 is only required to be configured to perform at least the first determination processing but not the second determination processing.

[0035] A plurality of the microphones 200 may be provided. The plurality of microphones 200 include at least two, namely first and second, microphones 200, but may be any number of microphones 200. In the embodiment of Fig. 1, the plurality of microphones 200 include first, second, and third microphones 200. The plurality of microphones 200 may be disposed in one of the following arrangements 1) to 3).

1) All of the microphones 200 are disposed at the same distance from the loudspeaker 100.

2) All of the plurality of microphones 200 are disposed at different distances from the loudspeaker 100. For example, where the microphones 200 include first and second microphones 200, the first microphone 200 is positioned at a smaller distance from the loudspeaker 100 than the second microphone 200 is. Where the microphones 200 include first to third microphones 200, the first microphone 200 is positioned at a shorter distance from the loudspeaker 100 than the second and third microphones 200 are, the second microphone 200 is positioned at a larger distance from the loudspeaker 100 than the first microphone 200 is, and the third microphone 200 is positioned at a larger distance from the loudspeaker 100 than the first and second microphones 200 are.

3) At least two of the plurality of microphones 200 are disposed at the same distance from the loudspeaker 100, whereas at least one other microphone 200 is disposed at a distance from the loudspeaker 100, the distance being different from that of the at least two of the microphones 200 from the loudspeaker 100. For example, where the microphones 200 include first to third microphones 200, the second and third microphones 200 are positioned at the same distance from the loudspeaker 100, whereas the first microphone 200 is disposed at a smaller or larger distance from the loudspeaker 100 than the second and third microphones 200 are.

[0036] It is preferable that the plurality of microphones 200 be fixed in position with respect to the loudspeaker 100 in accordance with one of the above aspects. This

arrangement establishes the distance between each microphone 200 and the loudspeaker 100, thereby establishing acoustic characteristics (signal level) of the microphones 200 in response to inaudible sounds emitted from the loudspeaker 100. The loudspeaker 100 may emit inaudible sounds at a constant volume level or at varying volume levels in response to the volume adjustment to the loudspeaker 100.

[0037] Where the volume level of inaudible sounds is always constant, it is preferable that the at least one audio signal processor 400 output a test signal including information on the (always constant) volume level of the inaudible sounds, and cause the loudspeaker 100 to emit inaudible sounds at an always constant volume on the basis of the test signal including such information. Also, such information may preferably be included in test signal also in a case where the at least one audio signal processor 400 is configured to mix the test signal and the audio signals. In this case, the audio signals may contain information on the volume level of the audible sounds, and the at least one audio signal processor 400 may cause the loudspeaker 100 to emit audible sounds at a volume level different from that of the inaudible sounds. If the information on the volume levels of the test signal and the audio signals are such that both the volume levels are the same, it is possible to emit the inaudible sounds and the audible sounds at the same volume level.

[0038] Where the volume level of inaudible sounds varies, the at least one signal level determiner 600 may preferably be further configured to raise or lower the threshold value on the memory according to the volume level of the loudspeaker 100. Alternatively, the at least one signal level determiner 600 may be configured to correct the signal level of the frequency components in the inaudible range according to the volume level of the loudspeaker 100, and perform the first determination processing, or the first and second determination processing.

[0039] Where a plurality of the microphones 200 is provided, in accordance with the number of the microphones 200, there may be provided a plurality of the A/D converters 700, the first band-pass filters 300, the audio signal processors 400, the Fourier transformers 500, the second band-pass filters 800, and the signal level determiners 600 (see Fig. 1). In this case, each of the A/D converter 700, each of the band-pass filters 300, each of the audio signal processors 400, each of the Fourier transformers 500, each of the band-pass filters 800, and each of the signal level determiners 600 operate corresponding to each of the microphones 200 and perform processing in one of the manners described above.

[0040] Where some (at least two) of the microphones 200 are disposed at different distances from the loudspeaker 100, the corresponding ones (at least two) of the signal level determiners 600 may refer to different threshold values, according to the distances between such microphones 200 and the loudspeaker 100. For example, where the distance between the first microphone 200 and the loudspeaker 100 is (i) smaller or (ii) larger

than the distance between the second microphone 200 and the loudspeaker 100, the signal level determiner 600 corresponding to the first microphone 200 may refer to a (i) smaller or (ii) larger, respectively, threshold value than the threshold value that the signal level determiner 600 corresponding to the second microphone 200 refers to. The plurality of signal level determiners 600 may refer to one and the same threshold value.

[0041] Where some (at least two) of the microphones 200 are disposed at different distances from the loudspeaker 100, the corresponding ones (at least two) of the signal level determiners 600 may refer to different predetermined ranges equal to or greater than the threshold values, according to the distances between such microphones 200 and the loudspeaker 100. For example, where the distance between the first microphone 200 and the loudspeaker 100 is (i) smaller or (ii) larger than the distance between the second microphone 200 and the loudspeaker 100, the signal level determiner 600 corresponding to the first microphone 200 may refer to a (i) smaller or (ii) larger, respectively, predetermined range equal to or greater than threshold value than the predetermined range that the signal level determiner 600 corresponding to the second microphone 200 refers to. The plurality of signal level determiners 600 may refer to one and the same predetermined range equal to or greater than threshold value (s).

[0042] Where a plurality of signal level determiners 600 is provided each having configuration A) described above, the result of the first determination processing is one of A-1-1) to A-1-3) below.

Result A-1-1): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value, it is detected that the loudspeaker 100 is not in failure.

Result A-1-2): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is not equal to or greater than the threshold value (less than the threshold value), it is detected that the loudspeaker 100 is in failure.

Result A-1-3): When at least one of the signal level determiners 600 determines that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value, and the remaining one or ones of the signal level determiners 600 determines that is not equal to or greater than the threshold value (less than the threshold value), it is detected that the loudspeaker or loudspeakers 100 corresponding to such remaining one or ones of the signal level determiners 600 is in failure.

[0043] Where a plurality of signal level determiners 600 is provided each having configurations A) and B) described above, the result of the first and second determination processing is one of B-1-1) to B-1-6) below.

Result B-1-1): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value and within the predetermined range, it is detected that the loudspeaker 100 is not in failure.

Result B-1-2): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is not equal to or greater than the threshold value (less than the threshold value), it is detected that the loudspeaker 100 or all the microphones 200 are in failure.

Result B-1-3): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value but not within the predetermined range, it is detected that the loudspeaker 100 or all the microphones 200 are deteriorated.

Result B-1-4): When all the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value, and the at least one of the signal level determiners 600 determines that the signal level of the frequency components in the inaudible range equal to or greater than the threshold value is within the predetermined range, and the remaining one or ones of the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range equal to or greater than the threshold value is not within the predetermined range, it is detected that the microphone or microphones 200 corresponding to such remaining one or ones of the signal level determiners 600 are deteriorated.

Result B-1-5): When at least one of the signal level determiners 600 determines that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value and within the predetermined range, and when the remaining one or ones of the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is not equal to or greater than the threshold value (less than the threshold value), it is detected that the microphone or microphones 200 corresponding to such remaining one or ones of the signal level determiners 600 are in failure.

Result B-1-6): When at least one of the signal level determiners 600 determines that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value but not within the predetermined range, and when the remaining one or ones of the signal level determiners 600 determine that the signal level of the frequency components in the inaudible range is not equal to or greater than the threshold value (less than the threshold value), it is detected that the microphone or microphones 200 corresponding to the at

least one of the signal level determiners 600 are deteriorated, and that the microphone or microphones 200 corresponding to such remaining one or ones of the signal level determiners 600 are in failure.

[0044] It is possible to unitize all of, or some of, the at least one loudspeaker 100, the at least one microphone 200, the at least one first band-pass filter 300, the at least one audio signal processor 400, the at least one Fourier transformer (FFT) 500, the at least one second band-pass filter 800, the at least one signal level determiner 600, and the at least one A/D converter 700 may be unitized. If a plurality of microphones 200 is provided, it is also possible to unitize only the at least one loudspeaker 100 and the microphones 200.

[0045] In accordance with the determinations A-1) to A-2), B-1) to B-3), A-1-1) to A-1-3), and B-1-1) to B-1-6), it is possible to notify or transmit the determination result, particularly, the failure or deterioration of the loudspeaker 100, or the failure or deterioration of the at least one microphone 200. Such notification or transmission may be provided in one of the following manners (1) to (4). (1) The electronic equipment may include a display part or the like configured to display the notification. (2) The electronic equipment may be configured to transmit the determination result via its communication part. (3) The sound processing apparatus D may include a display part or the like configured to display the notification. (4) The sound processing apparatus D may include a notification part configured to operate the electronic equipment to display the notification via a display part or the like of the electronic equipment. (5) The sound processing apparatus D may include a notification part configured to operate the electronic equipment to transmit the determination result via a communication part of the electronic equipment. The notification part can also be implemented by a logic circuit, or by software to be processed by a processor.

[0046] The sound processing apparatus D configured as described above provide at least the following technical features and effects.

[0047] Technical features and effects 1): The sound processing apparatus D can detect a failure of the loudspeaker 100 as described for determinations A-1) to A-2) by carrying out the first determination processing at the at least one signal level determiner 600 while performing the first and/or second audio signal processing at the at least one audio signal processor 400 (i.e. while allowing a user to carry out audio communication). This is because the processing by the at least one audio signal processor 400 and the first determination processing by the at least one signal level determiner 600 can be performed in parallel.

[0048] Technical features and effects 2): the sound processing apparatus D can detect a failure and a deterioration of the loudspeaker 100 as described for determinations B-1) to B-3) by carrying out the first and second determination processing at the at least one signal level determiner 600 while performing the first and/or second

audio signal processing at the at least one audio signal processor 400 (i.e. while allowing a user to carry out audio communication). This is because the processing by the at least one audio signal processor 400 and the first and second determination processing by the at least one signal level determiner 600 can be performed in parallel.

[0049] Technical features and effects 3): Where the sound processing apparatus D includes a plurality of the microphones 200, the Fourier transformers 500, the second band-pass filters 800, the signal level determiners 600, and the A/D converters 700, when each of the signal level determiners 600 performs the first determination processing, it is possible to detect not only a failure of the loudspeaker 100 but also a failure of the corresponding microphones 200 as described for determination A-1-1) to A-1-3).

[0050] Technical features and effects 4): Where the sound processing apparatus D includes a plurality of the microphones 200, the Fourier transformers 500, the second band-pass filters 800, the signal level determiners 600, and the A/D converters 700, when each of the signal level determiners 600 performs the first determination processing, and performs the second determination processing on the signal level of frequency components in the inaudible range which is equal to or greater than the threshold value, it is possible to detect not only a failure but also deterioration of the corresponding loudspeaker 100 and the microphone 200 as described for determinations B-1-1) to B-1-6).

[0051] Technical features and effects 5): The sound processing apparatus D provides improved accuracy of the detection of inaudible sounds of the at least two signal level determiners 600, in a case where the sound processing apparatus D includes a plurality of the microphones 200, the Fourier transformers 500, the second band-pass filters 800, the signal level determiners 600, and the A/D converters 700, and where the distances of at least two of the microphones 200 from the loudspeaker 100 differ from each other and threshold values of at least two signal level determiners 600, or threshold values and predetermined ranges of at least two signal level determiners 600 are individually set according to the distances of the corresponding microphone 200 from the loudspeaker 100.

[0052] It should be noted that the sound processing apparatus of the invention is not limited to the above embodiments and may be modified in any manner within the scope of the claims. Some modification examples will be described below.

[0053] The loudspeaker can be omitted in the invention. In this case, it is preferable to utilize a loudspeaker of the electronic equipment connected to the sound processing apparatus. Also, the loudspeaker of the invention may be configured to emit only inaudible sounds, but not audible sounds. In this case, as a substitute for a loudspeaker for audible sounds, it is possible to utilize a loudspeaker of the electronic equipment connected to the sound processing apparatus D. A plurality of loud-

speakers may be provided in the invention. In this case, all of the loudspeakers may be configured to emit audible and inaudible sounds, or at least one of the loudspeakers is configured to emit an audible sound, and at least one different loudspeaker may be configured to emit an inaudible sound.

[0054] The plurality of microphones of the invention may be disposed at the same distance, or at different distances, from the respective loudspeakers. In either case, as described above, the plurality of signal level determiners may refer to different threshold values, and/or different predetermined ranges equal to or greater than the threshold values, according to the distances between the corresponding microphones 200 and the respective loudspeakers 100.

[0055] The at least one A/D converter of the invention may be omitted in a case where the at least one microphone is configured for digital outputting. It is also possible to provide one or more D/A converters at a rear stage of the at least one audio signal processor of the invention.

[0056] The at least one Fourier transformer may be omitted in the invention. In this case, the at least one second band-pass filter 800 may preferably be configured to pass only the frequency components in the inaudible range (and remove frequency components of electric signals other than the frequency components in the inaudible range), and the at least one signal level determiner may preferably be at least configured to receive the frequency components in the inaudible range from the at least one second band-pass filter 800 and perform a first determination as to whether the signal level of the frequency components in the inaudible range is equal to or greater than a threshold value.

[0057] It should be appreciated that the above embodiments and variants of the sound processing apparatus are described above by way of examples only. The materials, shapes, dimensions, numbers, arrangements, and other configurations of the constituents of the sound processing apparatus may be modified in any manner if they can perform similar functions. The configurations of the embodiments and the variants described above may be combined in any possible manner.

Reference Signs List

[0058]

D: sound processing apparatus
100: loudspeaker
200: microphone
300: band-pass filter
400: audio signal processor
500: Fourier transformer
600: signal level determiner
700: A/D converter

Claims

1. A sound processing apparatus (D) comprising:

a microphone (200) to simultaneously acquire an audible sound having a frequency in an audible range and an inaudible sound having a frequency in an inaudible range, to convert an acquired sound into electric signals, and to output the electric signals;
a first band-pass filter (300) to receive the electrical signals outputted from the microphone (200) and remove components of the electrical signals that are outside the audible range;
an audio signal processor (400) to apply predetermined signal processing to the electric signals that have passed through the first band-pass filter (300);
a Fourier transformer (500) to receive the electrical signals outputted from the microphone (200) and perform a frequency analysis on the received electric signals so as to obtain frequency components of the electric signals, the obtained frequency components including frequency components in the inaudible range; and
a signal level determiner (600) to perform a first determination as to whether the frequency components in the inaudible range have a signal level being equal to or greater than a threshold value.

2. The sound processing apparatus (D) according to claim 1, wherein

the signal level determiner (600) is further configured to perform a second determination when it is determined in the first determination that the frequency components in the inaudible range is equal to or greater than the threshold value, and
the second determination is made such that it is determined whether the frequency components in the inaudible range have a signal level within a predetermined range, the predetermined range being equal to or greater than the threshold value.

3. The sound processing apparatus (D) according to claim 1, wherein

the microphone (200) comprises a plurality of microphones (200),
the Fourier transformer (500) comprises a plurality of Fourier transformers (500), and each of the Fourier transformers (500) is configured to perform a frequency analysis on the electric signals outputted from a corresponding one of the microphones (200) so as to obtain frequency components of the electric signals, the obtained frequency components including frequency components in the inaudible range, and
the signal level determiner (600) comprises a plural-

ity of signal level determiners (600), and each of the signal level determiners (600) is configured to perform the first determination.

4. The sound processing apparatus (D) according to claim 3, wherein the signal level determiners (600) are configured such that, when at least one of the signal level determiners (600) determines in the first determination that the signal level of the frequency components in the inaudible range is equal to or greater than the threshold value, the at least one of the signal level determiners (600) further performs a second determination, and the second determination is made such that it is determined whether the frequency components in the inaudible range have a signal level within a predetermined range, the predetermined range being equal to or greater than the threshold value. 5
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5. The sound processing apparatus (D) according to claim 3, wherein the microphones (200) are disposed at different distances from a loudspeaker (100) capable of emitting inaudible sounds, and the respective threshold values for the signal level determiners (600) differ from one another according to the respective distances from the corresponding microphones (200) to the loudspeaker (100). 15
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6. The sound processing apparatus (D) according to claim 4, wherein the microphones (200) are disposed at different distances from a loudspeaker (100) capable of emitting inaudible sounds, and the respective threshold values and the predetermined ranges for the signal level determiners (600) differ from one another according to the respective distances from the corresponding microphones (200) to the loudspeaker (100). 25
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7. The sound processing apparatus (D) according to any one of the preceding claims further comprising a loudspeaker (100) capable of emitting an inaudible sound. 45
8. The sound processing apparatus (D) according to any one of claims 1 to 6 further comprising a loudspeaker (100) capable of simultaneously emitting audible and inaudible sounds. 50
9. The sound processing apparatus (D) according to any one of the preceding claims further comprising a second band-pass filter (800) to filter the frequency components of the electric signals obtained by the frequency analysis so as to remove frequency components other than the frequency components in the inaudible range and to output the filtered frequency 55

components to the signal level determiner (600).

10. The sound processing apparatus (D) according to any one of claims 3 to 6 further comprising a loudspeaker (100), the loudspeaker (100) being configured to emit at least an inaudible sound, wherein the plurality of microphones (200) is fixed in position with respect to the loudspeaker (100), and the microphones (200) and the loudspeaker (100) are unitized.
11. A sound processing apparatus (D) comprising:
 - a microphone (200) to simultaneously acquire audible sound having a frequency in an audible range and an inaudible sound having a frequency in an inaudible range, to convert the acquired audible and inaudible sounds into electric signals, and to output the electric signals;
 - a first band-pass filter (300) to receive the electrical signals outputted from the microphone (200) and remove frequency components of the electrical signals that are outside the audible range;
 - an audio signal processor (400) to apply predetermined signal processing to the electric signals that have passed through the first band-pass filter (300);
 - a second band-pass filter (800) to receive the electrical signals outputted from the microphone (200) and remove components of the electrical signals that are other than frequency components in the inaudible range; and
 - a signal level determiner (600) to perform a first determination as to whether the frequency components in the inaudible range, which have passed through the second band-pass filter (800), have a signal level being equal to or greater than a threshold value.
12. An electronic equipment comprising the sound processing apparatus (D) according to any one of the preceding claims.

D

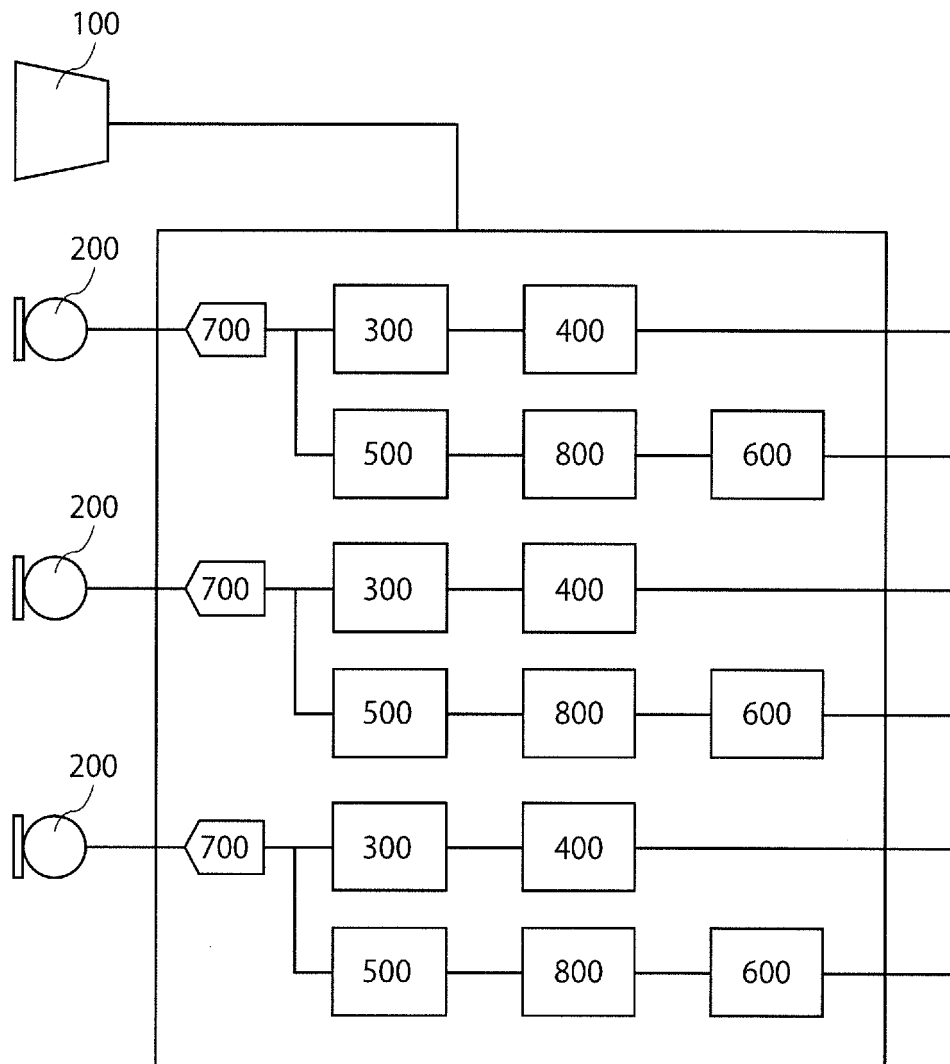


FIG.1

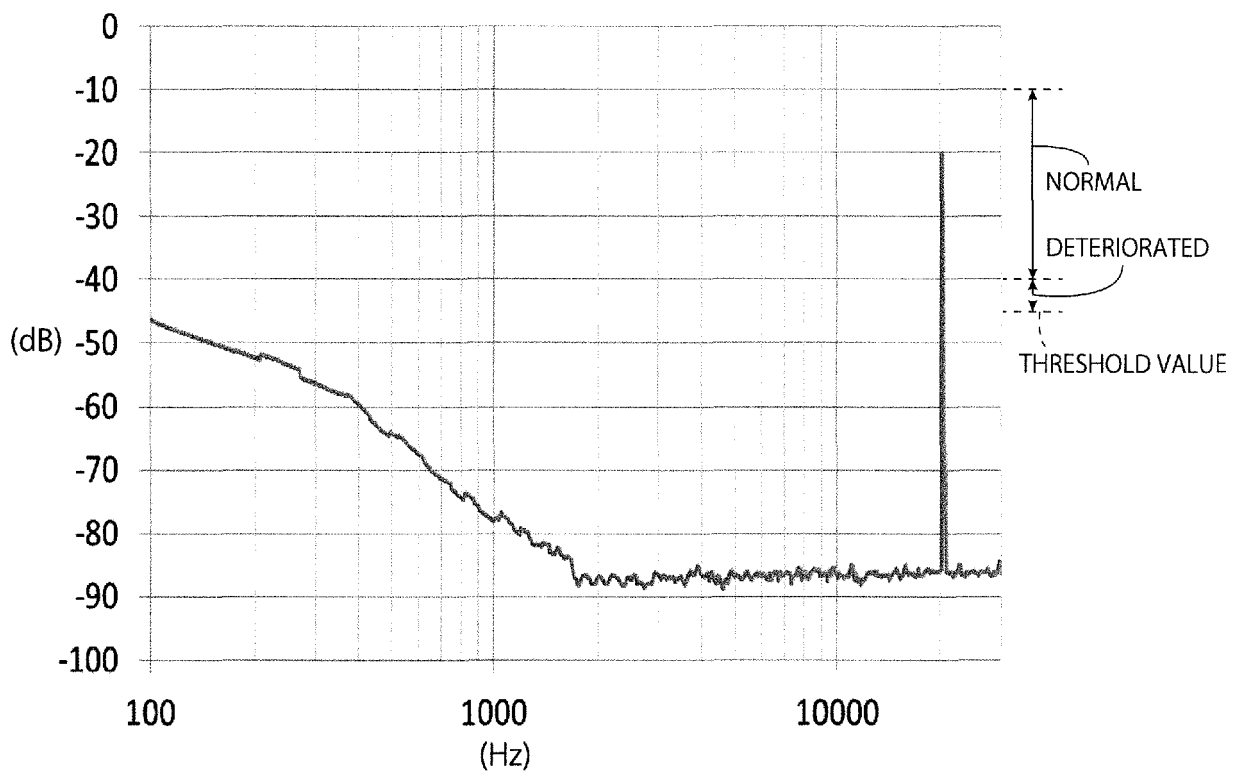


FIG. 2



EUROPEAN SEARCH REPORT

Application Number
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