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(72) Inventors:
 • **Hanazono, Masaya**
Osaka, 540-6207 (JP)
 • **Fukushima, Minoru**
Osaka, 540-6207 (JP)
 • **Nakamura, Morio**
Osaka, 540-6207 (JP)

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(74) Representative: **Appelt, Christian W.**
Boehmert & Boehmert
Anwaltpartnerschaft mbB
Pettenkofenstrasse 22
80336 München (DE)

(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**
Osaka-shi, Osaka 540-6207 (JP)

(54) **ACOUSTIC DEVICE AND ACOUSTIC SYSTEM**

(57) An acoustic device (1) for alarm sound includes a vibration member (11) and a housing (12). The vibration member (11) has a first resonance frequency. The vibration member (11) is housed in the housing (12). The housing (12) has a second resonance frequency. The housing (12) produces an alarm sound which is one of two or more kinds of alarm sounds having different fundamental frequencies and corresponds to a frequency of vibration of the vibration member (11). The acoustic device (1)

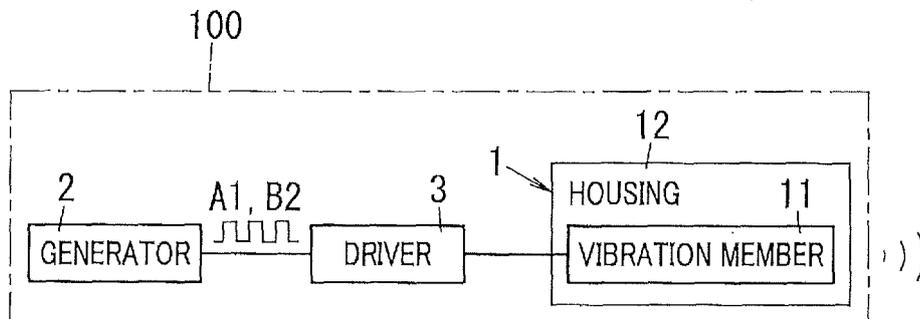
satisfies a following equation (eq1):

$$f \leq |Fp - Fc| \quad (\text{eq1})$$

where

f denotes a highest one of the fundamental frequencies of the two or more kinds of alarm sound, Fp denotes the first resonance frequency, and Fc denotes the second resonance frequency.

FIG. 1



Description

Technical Field

[0001] The present disclosure relates generally to acoustic devices and alarm systems and, more particularly, to an acoustic device configured to resonantly vibrate a vibration member and an acoustic system including the acoustic device.

Background Art

[0002] It has been known an alarm unit including a resonance chamber resonating to a sound wave having a predetermined resonance frequency, an output means (piezoelectric vibration plate) capable of outputting a sound wave of an arbitrary frequency, and a frequency variation means configured to vary the frequency of the sound wave output from the outputting means (for example, JP2009-157447A, hereinafter referred to as "Document 1"). The frequency variation means varies the frequency of the sound wave output from the outputting means within a frequency range including the resonance frequency of the resonance chamber, and thereby a maximum sound pressure is achieved. The resonance chamber forms a resonance space for the resonance to the sound wave generated by the output means.

[0003] However, for example in a case where outputting two or more kinds of alarm sounds having different fundamental frequencies is desired, it is difficult for the alarm unit of Document 1 to increase the sound pressure of an alarm sound of which fundamental frequency is different from the resonance frequency of the resonance chamber.

Summary of Invention

[0004] In view of the above circumstances, an object of the present disclosure would be to provide an acoustic device and an acoustic system, which are capable of increasing sound pressures of two or more kinds of alarm sounds having different fundamental frequencies.

[0005] An acoustic device according to an aspect of the present disclosure includes a vibration member and a housing. The vibration member has a first resonance frequency. The housing accommodates the vibration member. The housing has a second resonance frequency. The housing produces an alarm sound which is one of two or more kinds of alarm sounds having different fundamental frequencies and corresponds to a frequency of vibration of the vibration member. The acoustic device satisfies a following equation (eq1):

$$f \leq |f_p - f_c| \quad (\text{eq1})$$

where f denotes a highest one of the fundamental fre-

quencies of the two or more kinds of alarm sound, f_p denotes the first resonance frequency, and f_c denotes the second resonance frequency.

[0006] An acoustic system according to an aspect of the present disclosure includes the acoustic device of the above, and a generator configured to generate two or more kinds of electric signals individually corresponding to the two or more kinds of alarm sounds.

10 Brief Description of Drawings

[0007]

FIG. 1 is a block diagram of an acoustic device according to an embodiment of the present disclosure. FIG. 2A is an exploded perspective view of a main part of the acoustic device. FIG. 2B is a cross-sectional view of the acoustic device.

FIG. 3 is a graph illustrating frequency characteristics of acoustic devices.

FIG. 4A is a graph illustrating a relationship among a frequency characteristic of the acoustic device, a resonance frequency of a vibration member, and a resonance frequency of a housing, according to the embodiment of the present disclosure. FIG. 4B is graphs illustrating sound pressure levels of a first alarm sound and a second alarm sound emitted from the acoustic device.

FIG. 5A is a graph illustrating a relationship among a frequency characteristic of an acoustic device, a resonance frequency of a vibration member, and a resonance frequency of a housing, according to a comparative example. FIG. 5B is graphs illustrating sound pressure levels of a first alarm sound and a second alarm sound emitted from the acoustic device.

Description of Embodiments

[0008] An acoustic device 1 for alarm sounds and an acoustic system 100 according to an embodiment of the present disclosure will be described with reference to FIG. 1 to FIG. 4B. However, the present embodiment described herein is mere an example of the present disclosure. Various modifications may be derived from the present embodiment depending on design and the like without departing from the technical concept of the present disclosure.

[0009] Figures mentioned in the present embodiment are schematic, and thus the sizes, the thicknesses and the like of components and ratios thereof illustrated for example in FIG. 2A and FIG. 2B may not reflect actual dimensional ratios thereof.

55 (1) Outline of Acoustic System

[0010] The acoustic system 100 is, for example, a system for outputting an alarm sound announcing an occur-

rence of a fire. The acoustic system 100 is configured to individually output two or more kinds of alarm sounds having different fundamental frequencies. The two or more kinds of alarm sounds having different fundamental frequencies include, for example, two kinds of alarms sounds, namely a first alarm sound generated in response to a first signal A1 (see FIG. 4B) and a second alarm sound generated in response to a second signal B2 (see FIG. 4B). In the present embodiment, a fundamental frequency of the second alarm sound is higher than a fundamental frequency of the first alarm sound. For example, the alarm system 100 is configured to output alternately the first alarm sound and the second sound each for a predetermined period of time (for example, one second).

(2) Configuration of Acoustic System

[0011] As shown in FIG. 1, the acoustic system 100 includes the acoustic device 1, and a generator 2. In the present embodiment, the acoustic system further includes a driver 3.

[0012] For example, the generator 2 includes a signal generation circuit configured to output a rectangular Alternating-Current (AC) voltage in accordance with a Pulse Width Modulation (PWM) method. The generator 2 is configured to individually generate the first signal A1 and the second signal B2, which are each an electric signal. The first signal A1 is a rectangular AC voltage signal, for example. The first signal A1 includes a fundamental wave having a frequency fA (fundamental frequency fA), and optionally includes one or more harmonic waves each having an integer multiple of the fundamental frequency fA . As shown in FIG. 4B, the harmonic waves may include a second harmonic wave having a frequency $2*fA$, a third harmonic wave having a frequency $3*fA$, a fourth harmonic wave having a frequency $4*fA$, a fifth harmonic wave having a frequency $5*fA$, a sixth harmonic wave having a frequency $6*fA$, and a seventh harmonic wave having a frequency $7*fA$.

[0013] The second signal B2 is a rectangular AC voltage signal, for example. The second signal B2 includes a fundamental wave having a frequency fB (fundamental frequency fB) higher than the fundamental frequency fA of the first signal A1, and optionally includes one or more harmonic waves each having an integer multiple of the fundamental frequency fB . As shown in FIG. 4B, the harmonic waves may include a second harmonic wave having a frequency $2*fB$, and a third harmonic wave having a frequency $3*fB$. The generator 2 is configured to alternately output the first signal A1 and the second signal B2 each for a predetermined period of time (for example, one second) to the driver 3, for example.

[0014] The driver 3 includes a resonance circuit including an inductor and a capacitor, for example. The driver 3 receives the electric signals from the generator 2, and cause an electric signal of a specific frequency range of the electric signals to electrically resonate with the res-

onance circuit to amplify the component of the AC voltage corresponding to the specific frequency range. The specific frequency range may be determined depending on some factors such as the shape, the material and the like of the vibration member 11. Selected as the specific frequency range is a frequency range which allows the vibration member 11 to be less likely to vibrate than other frequency ranges. The driver 3 is configured to output the amplified AC voltage to the vibration member 11 to vibrate the vibration member 11.

(3) Configuration of Acoustic Device

[0015] As shown in FIG. 1, FIG. 2A and FIG. 2B, the acoustic device 1 includes the vibration member 11 and a housing 12.

[0016] The vibration member 11 has a bimorph structure including two plate-shaped piezoelectric devices and a diaphragm disposed between the piezoelectric devices. The vibration member 11 has a plate shape, and more particularly a disk shape. The two piezoelectric devices expand and contract in response to the AC voltage supplied from the driver 3, and this causes the vibration member 11 to vibrate in a thickness direction of the vibration member 11. That is, the vibration member 11 mechanically vibrates with a frequency of the AC voltage from the driver 3.

[0017] The housing 12 includes a base 13, a lid 14, and an attachment frame 16.

[0018] The attachment frame 16 has a ring shape. The attachment frame 16 is attached along an edge of the vibration member 11. The attachment frame 16 is sandwiched between the base 13 and the lid 14, and thereby the vibration member 11 is attached to the housing 12 (base 13 and lid 14).

[0019] As shown in FIG. 2A, the base 13 has a bottomed circular tube shape having an outer diameter substantially same as that of the attachment frame 16. The base 13 is formed of synthetic resin material, for example. As shown in FIG. 2B, the base 13 has an opening in a surface facing the attachment frame 16. The vibration member 11 is attached to the base 13 by use of the attachment frame 16 such that the opening of the base 13 is occluded by the vibration member 11. As a result, a first air chamber 131 is formed between the base 13 and the vibration member 11.

[0020] As shown in FIG. 2A, the lid 14 has a bottomed circular tube shape having an outer diameter substantially same as that of the attachment frame 16. The lid 14 is formed of synthetic resin material, for example. As shown in FIG. 2B, the lid 14 has an opening in a surface facing the attachment frame 16. The vibration member 11 is attached to the lid 14 by use of the attachment frame 16 such that the opening of the lid 14 is occluded by the vibration member 11. As a result, a second air chamber 141 is formed between the lid 14 and the vibration member 11.

[0021] The lid 14 has a bottom plate 15 provided with

multiple through holes 151 that pierce the bottom plate 15 in the thickness direction. The through holes 151 allow emission of the sound generated in the second air chamber 141 to an outside of the housing 12. That is, the sound passing through the through holes 151 and traveling to the outside of the housing 12 serve as the alarm sound. In the example shown in FIG. 2B, the bottom plate 15 is an integral part with the lid 14 but is not limited thereto. The bottom plate 15 may be a separate part from the lid 14. For example, the lid 14 may have a circular tube shape having openings on both ends, and one of the openings on an opposite side of the lid 14 from a side in contact with the attachment frame 16 may be occluded by the bottom plate 15.

[0022] Here, it will be assumed that a distance between the vibration member 11 and the bottom plate 15 of the housing 12 is adjustable. In such a case, an increase in a volume of the second air chamber 141 resulting from an increase in the distance between the bottom plate 15 and the vibration member 11 causes an increase in the sound pressure level of the sound corresponding to comparatively high frequency region and a decrease in the sound pressure level of the sound corresponding to comparatively low frequency region, within a certain frequency range of the sound emitted through the bottom plate 15 of the housing 12. On the other hand, a decrease in the volume of the second air chamber 141 causes a decrease in the sound pressure level of the sound corresponding to comparatively high frequency region and an increase in the sound pressure level of the sound corresponding to comparatively low frequency region, within the certain frequency range of the sound emitted from the bottom plate 15 of the housing 12. In the embodiment, the sound pressure level is defined based on a ratio of a sound pressure to a reference sound pressure (for example, 20×10^{-6} Pa).

[0023] Hereinafter, more detailed descriptions are given with reference to a case where the above mentioned certain frequency range is a frequency range between a frequency Fg and a frequency Fh shown in FIG. 3. The broken line in FIG. 3 shows a frequency characteristic curve of a housing 12 according to the first example, and the solid line in FIG. 3 shows a frequency characteristic curve of a housing 12 according to the second example in which a volume of the second air chamber 141 is smaller than that of the housing 12 of the first example. As seen from FIG. 3, in a low frequency region within the frequency range between the frequency Fg and the frequency Fh , the first example having a smaller volume of the second air chamber 141 of the housing 12 exhibits a sound pressure level larger than that of the second example. Accordingly, an average of sound pressure levels over the frequency range between the frequency Fg and the frequency Fh is larger in the first example than in the second example. It can be understood that the sound pressure within the certain frequency range of the sound emitted from the bottom plate 15 of the housing 12 can be increased by adjusting the volume of the second air

chamber 141.

(4) Frequency Characteristic of Acoustic Device

[0024] Descriptions referring to FIG. 4A and FIG. 4B are made to a relationship (hereinafter, referred to as "frequency characteristic") between the sound pressure level and the frequency of the alarm sound of the acoustic device 1.

[0025] FIG. 4A shows an emission property curve 50 that indicates the frequency characteristic of the acoustic device 1. The emission property curve 50 indicates the frequency characteristic, and is defined by a resonance characteristic curve (first resonance characteristic curve) 51 of the vibration member 11 and a resonance characteristic curve (second resonance characteristic curve) 52 of the housing 12.

[0026] The resonance characteristic curve 51 shows the sound pressure level of the sound emitted from the vibration member 11 with respect to the frequency of the vibration of the vibration member 11. The sound pressure level of the resonance characteristic curve 51 exhibits a peak at a resonance frequency (first resonance frequency) Fp which is determined according to the shapes, the materials and the like of the piezoelectric devices and the diaphragm of the vibration member 11, for example. The resonance characteristic curve 51 exhibits that the sound pressure level has the peak at the resonance frequency Fp and decreases sharply as the frequency departs from the resonance frequency Fp .

[0027] The resonance characteristic curve 52 shows the sound pressure level of the sound emitted from the housing 12 in response to the vibration of the vibration member 11 with respect to the frequency of the vibration of the vibration member 11. The sound pressure level of the resonance characteristic curve 52 exhibits a peak at a resonance frequency (second resonance frequency) Fc which is determined according to the volume of the second air chamber 141, for example. The resonance characteristic curve 52 exhibits that the sound pressure level has the peak at the resonance frequency Fc and decreases sharply as the frequency departs from the resonance frequency Fc . In the acoustic device 1 of the present embodiment, the resonance frequency (second resonance frequency) Fc is a frequency smaller than the resonance frequency (first resonance frequency) Fp (namely, $Fc < Fp$), but not limited thereto. The resonance frequency Fc may be a frequency larger than the resonance frequency Fp .

[0028] The emission property curve 50 is the sum of the resonance characteristic curve 51 and the resonance characteristic curve 52. Therefore, as a decrease in a difference between the resonance frequency Fp and the resonance frequency Fc , a peak value of the sound pressure level according to the emission property curve 50 would increase. Accordingly, in the emission property curve 50, as a decrease in the difference between the resonance frequency Fp and the resonance frequency

F_c , the sound pressure level of the sound corresponding to a frequency range between the resonance frequency F_p and the resonance frequency F_c would become higher than a certain target sound pressure level f_N (for example 60 dB). On the other hand, in the emission property curve 50, as a decrease in the difference between the resonance frequency F_p and the resonance frequency F_c , a width of the frequency range corresponding to the sound pressure level larger than the above target sound pressure level f_N would become small.

[0029] On the other hand, in the emission property curve 50, as an increase in the difference between the resonance frequency F_p and the resonance frequency F_c , a width of the frequency range between the resonance frequency F_p and the resonance frequency F_c would increase. In the emission property curve 50, if the difference between the resonance frequency F_p and the resonance frequency F_c is larger than a certain width, there is a frequency range between the resonance frequency F_p and the resonance frequency F_c of which sound pressure level corresponding thereto is smaller than the peak value (see the emission property curve 50 of FIG. 4A). As an increase in the difference between the resonance frequency F_p and the resonance frequency F_c , the width of the frequency range of which sound pressure level corresponding thereto is smaller than the peak value would increase, in the emission property curve 50. Also, as an increase in the difference between the resonance frequency F_p and the resonance frequency F_c , a minimum sound pressure level within the frequency range between the resonance frequency F_p and the resonance frequency F_c would decrease. Consequently, as an increase in the difference between the resonance frequency F_p and the resonance frequency F_c in the emission property curve 50, it may cause a frequency range that corresponds to the sound pressure level smaller than the target sound pressure level f_N within the frequency range between the resonance frequency F_p and the resonance frequency F_c .

[0030] Hereinafter, it will be explained a relationship among the first resonance frequency F_p , the second resonance frequency F_c , the sound pressure level of the first alarm sound, and the sound pressure level of the second alarm sound according to the acoustic device 1 with reference to FIG. 4A and FIG. 4B. Hereinafter, only for the convenience of the explanation, the frequency range between the resonance frequency F_p and the resonance frequency F_c may be referred to as "specified frequency range F100".

[0031] In the present embodiment, the resonance frequency F_p and the resonance frequency F_c of the acoustic device 1 are set such that an absolute value of a difference between the resonance frequency F_p and the resonance frequency F_c is equal to or larger than the frequency f_B of the fundamental wave of the second alarm sound. In other words, the acoustic device 1 satisfies the following equation:

$$f \leq |F_p - F_c|,$$

where f denotes the highest one of the fundamental frequencies of the two or more kinds of alarm sounds (" f_B " in the present embodiment), F_p denotes the first resonance frequency (resonance frequency of the vibration member 11), and F_c denotes the second resonance frequency (resonance frequency of the housing 12). Accordingly, at least any one of the fundamental wave and the harmonic waves of the second alarm sound is included in the specified frequency range F100 (in the frequency range between the resonance frequency F_p and the resonance frequency F_c).

[0032] As shown in FIG. 4B, in the present embodiment, the third harmonic wave having a frequency " $3 \cdot f_B$ " of the second alarm sound is included in the specified frequency range F100. Thus, in a case where the acoustic device 1 generates the second alarm sound in response to the second signal B2, even when the sound pressure levels of the sound corresponding to the fundamental wave and the second harmonic wave of the second alarm sound are around the target sound level f_N (around 60 dB), the sound pressure level of the sound corresponding to the third harmonic wave can be larger (for example, around 90 dB) than the target sound pressure level f_N . The acoustic device 1 thus can increase the sound pressure of the second alarm sound.

[0033] As shown in FIG. 4B, in the present embodiment, the fifth to seventh harmonic waves of the first alarm sound are included in the specified frequency range F100. Thus, in a case where the acoustic device 1 generates the first alarm sound in response to the first signal A1, even when the sound pressure levels of the sounds corresponding to the fundamental wave and the first to fourth harmonic waves of the first alarm sound are around the target sound level f_N , the sound pressure levels of the sounds corresponding to the fifth to seventh harmonic waves can be higher (for example, around 90 to 95 dB) than the target sound pressure level f_N . The acoustic device 1 can also increase the sound pressure of the first alarm sound.

[0034] Note that in the explanation with reference to FIG. 4B, the sound pressure levels of the sounds corresponding to the fundamental wave and the harmonic waves excluded from the specified frequency range F100 of the first alarm sound are around the target sound pressure level f_N , but may be lower than the target sound pressure level f_N . Also, the sound pressure levels of the sounds corresponding to the fundamental wave and the harmonic waves excluded from the specified frequency range F100 of the second alarm sound may be lower than the target sound pressure level f_N .

[0035] Furthermore, in the present embodiment, the resonance frequency F_p and the resonance frequency F_c of the acoustic device 1 are set such that the absolute value of the difference between the resonance frequency

F_p and the resonance frequency F_c is smaller than the frequency of the second harmonic wave of the second alarm sound. In other words, the absolute value of the difference between the resonance frequency F_p and the resonance frequency F_c is smaller than the double of the frequency f_B of the fundamental wave of the second alarm sound. That is, the acoustic device 1 satisfies the following equation:

$$|F_p - F_c| < 2f,$$

where $2f$ denotes the double of the highest one of the fundamental frequencies of the two or more kinds of alarm sounds (" $2 \cdot f_B$ " in the present embodiment), F_p denotes the first resonance frequency, and F_c denotes the second resonance frequency. In the present embodiment, therefore, only one or two frequencies of the sounds from among the sounds corresponding to the fundamental wave and the harmonic waves of the second alarm sound are included in the specified frequency range F100. As described above, according to the emission property curve 50, as an increase in a width of the specific frequency range F100 (frequency range between the resonance frequency F_p and the resonance frequency F_c), a width of a frequency range of which the sound pressure level corresponding thereto is lower than the target sound pressure level f_N increases. It is therefore difficult to increase the sound pressure of the alarm sound in this case. However, in the present embodiment, since the absolute value of the difference between the resonance frequency F_p and the resonance frequency F_c is smaller than the frequency $2 \cdot f_B$ of the second harmonic wave of the second alarm sound, it is possible to avoid a significant increase in the difference between the resonance frequency F_p and the resonance frequency F_c . Therefore, the minimum sound pressure level within the specified frequency range F100 doesn't become so small. Therefore, the acoustic device 1 can increase the sound pressure of one or two sounds, which are selected from the sounds of the fundamental wave and the harmonic waves of the second alarm sound and of which the frequency is included in the specified frequency range F100. In this case, since the fundamental frequency of the first alarm sound is lower than the fundamental frequency of the second alarm sound, at least one of the fundamental wave and the harmonic waves of the first alarm sound must be included in the specified frequency range F100. Therefore, the acoustic device 1 can increase the sound pressure of the sound corresponding to the at least one of the fundamental wave and the harmonic waves of the first alarm sound. Accordingly, the acoustic device 1 can increase both the sound pressures of the first alarm sound and the second alarm sound having different frequencies.

[0036] An acoustic device according to a comparative example will be described with reference to FIG. 5A and

FIG. 5B in order to explain the advantageous effect of the acoustic device 1 of the present embodiment. The acoustic device according to the comparative example is configured such that an absolute value of a difference between a resonance frequency F_p and a resonance frequency F_c is smaller than the value of the frequency f_B of the fundamental wave of the second acoustic sound. Hereinafter, only for the convenience of the explanation, a frequency range between the resonance frequency F_p and the resonance frequency F_c according to the comparative example may be referred to as "specified frequency range F200". Note that types of graphs of FIG. 5A and FIG. 5B and the reference signs used therein are used in the same manner as FIG. 4A and FIG. 4B.

[0037] In the acoustic device of the comparative example, a peak value of an emission property curve 50 increases as a decrease in the absolute value of the difference between the resonance frequency F_p and the resonance frequency F_c . According to the comparative example, as shown in FIG. 5B, the sound pressure level of the sound corresponding to the fifth harmonic wave of the first alarm sound, which is included in the specified frequency range F200 (frequency range between the resonance frequency F_p and the resonance frequency F_c), would be higher (around 100 dB, for example) than the target sound pressure level f_N , even when the sound pressure levels of the sounds corresponding to the fundamental wave and the other harmonic waves of the first alarm sound are around the target sound level f_N (around 60 dB). However, neither the harmonic waves nor the fundamental wave of the second alarm sound are included in the specified frequency range F100, and therefore it is difficult for the acoustic device of the comparative example to increase the sound pressure of the second alarm sound.

[0038] Next, an acoustic device according to an additional comparative example will be described. The acoustic device according to the additional comparative example is configured such that an absolute value of a difference between a resonance frequency F_p and a resonance frequency F_c is equal to or larger than the frequency $2 \cdot f_B$ of the second harmonic wave of the second acoustic sound. In this case, at least one harmonic wave (or fundamental wave) of the first alarm sound and at least one harmonic wave (or fundamental wave) of the second alarm sound are included in the frequency range between the resonance frequency F_p and the resonance frequency F_c . However, as an increase in the difference between the resonance frequency F_p and the resonance frequency F_c , a minimum sound pressure level of the emission property curve 50 would decrease and also a value of the sound pressure level at the minimum sound pressure level would decrease. Thus, it is difficult for the acoustic device according to the additional comparative example to increase both the sound pressures of the first alarm sound and the second alarm sound, although (the harmonic and/or fundamental waves of) the first alarm sound and the second alarm sound are included in the

frequency range between the resonance frequency F_p and the resonance frequency F_c .

(5) Summary

[0039] As described above, the acoustic device (1) according to the first aspect includes the vibration member (11) and the housing (12). The vibration member (11) has a first resonance frequency. The housing (12) accommodates the vibration member (11). The housing (12) has a second resonance frequency. The housing (12) produces an alarm sound which is one of two or more kinds of alarm sounds having different fundamental frequencies and corresponds to a frequency of vibration of the vibration member (11). The acoustic device (1) satisfies a following equation (eq1):

$$f \leq |F_p - F_c| \quad (\text{eq1})$$

where

f denotes a highest one of the different fundamental frequencies of the two or more kinds of alarm sounds, F_p denotes the first resonance frequency, and F_c denotes the second resonance frequency.

[0040] The acoustic device (1) according to the second aspect would be realized in combination with the first aspect, and satisfies a following equation (eq2):

$$|F_p - F_c| < 2f \quad (\text{eq2}).$$

[0041] The acoustic device (1) according to the third aspect would be realized in combination with the first or second aspect, and each of the two or more kinds of alarm sounds includes a fundamental wave corresponding to the fundamental frequency and one or more harmonic waves each of which corresponds to an integer multiple of the fundamental frequency. At least one of the one or more harmonic waves has a frequency between the first resonance frequency and the second resonance frequency.

[0042] The acoustic system (100) according to the fourth aspect includes the acoustic device (1) of any one of the first to third aspects, and the generator (2). The generator (2) is configured to generate two or more kinds of electric signals (A1, B2) individually corresponding to the two or more kinds of alarm sounds.

[0043] The acoustic system (100) according to the fifth aspect would be realized in combination with the fourth aspect, and the vibration member (11) is configured to resonate to each frequency of the two or more kinds of electric signals.

[0044] In one aspect, the acoustic device (1) for producing alarm sounds of the present embodiment includes

the vibration member (11) having a plate shape, and the housing (12). The vibration member (11) resonates at the resonance frequency (F_p). The housing (12) houses therein the vibration member (11), and resonates at a resonance frequency (F_c) in response to the vibration of the vibration member (11) to emit two or more kinds of alarm sounds (first alarm sound and second alarm sound, in the present embodiment). The two or more kinds of alarm sounds have different fundamental frequencies (frequency f_A and frequency f_B , respectively) from each other. The fundamental frequency (f) (frequency f_B , in the present embodiment) which is the highest among the fundamental frequencies of the two or more kinds of alarm sounds, the resonance frequency F_p , and the resonance frequency F_c satisfy the relation:

$$f \leq |F_p - F_c|.$$

[0045] With this configuration, the resonance frequency (F_p) and the resonance frequency (F_c) are set such that the absolute value of the difference between the resonance frequency (F_p) and the resonance frequency (F_c) is equal to or larger than the value of the fundamental frequency (f) (frequency f_B) which is the highest of the fundamental frequencies of the two or more kinds of alarm sounds. Therefore, at least any one of the fundamental wave and the harmonic waves of the alarm sound is included in the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) (in the specified frequency range F100). The wave included in the specified frequency range (F100) is the fundamental wave or the harmonic wave of the alarm sound having the highest fundamental frequency (f) of the fundamental frequencies of the two or more kinds of alarm sounds. Furthermore, since the frequency (frequency f_A , in the present embodiment) of the fundamental wave of another alarm sound among the two or more kinds of alarm sounds is lower than the fundamental frequency (f) (frequency f_B , in the present embodiment) of the above, the difference between frequencies of harmonic waves of the another alarm sound (first alarm sound) is smaller than the difference between the resonance frequency (F_p) and the resonance frequency (F_c). Therefore, at least one harmonic wave (or fundamental wave) of another alarm sound (first alarm sound) is included in the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) (i.e., included in the specified frequency range F100). Thus, the acoustic device (1) for alarm sounds can increase the sound pressure of the two or more kinds of alarm sounds having different frequencies.

[0046] In the acoustic device (1) for producing alarm sounds according to the present embodiment, preferably, the double ($2f$) of the fundamental frequency (f) (namely, frequency $2 \cdot f_B$ in the present embodiment), the resonance frequency (F_p), and the resonance frequency

(F_c) satisfy the relation:

$$|F_p - F_c| < 2f.$$

[0047] With this configuration, the resonance frequency (F_p) and the resonance frequency (F_c) are set such that the absolute value of the difference between the resonance frequency (F_p) and the resonance frequency (F_c) is smaller than the double of the fundamental frequency (f) (frequency fB) which is the highest of the fundamental frequencies of the two or more kinds of alarm sounds. Within the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) (namely, within the specified frequency range F100), one of harmonic waves (for example, third harmonic wave) of the alarm sound (second alarm sound) which has the highest fundamental frequency (f) (frequency fB) of the fundamental frequencies of the two or more kinds of alarm sounds. The acoustic device (1) for alarm sounds can increase the sound pressures of the two or more kinds of alarm sounds having different frequencies. Note that, as an increase in the absolute value of the difference between the resonance frequency (F_p) and the resonance frequency (F_c), a minimum sound pressure in the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) decreases, and the difference between the minimum sound pressure and the peak value of the sound pressure increases. However, by satisfying the relation $|F_p - F_c| < 2f$, a harmonic wave (or the fundamental wave) of the two or more kinds of alarm sounds can be included within the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) (within the specified frequency range F100) and also the difference between the minimum sound pressure and the peak value of the sound pressure within this frequency range can be minimized.

[0048] In the acoustic device (1) for producing alarm sounds according to the present embodiment, preferably, each of the two or more kinds of alarm sounds (first alarm sound and second alarm sound) has a fundamental wave and at least one harmonic wave. The at least one harmonic wave (fifth to seventh harmonic wave of first alarm sound and third harmonic wave of second alarm sound, in the present embodiment) has a frequency between the resonance frequency (F_p) and the resonance frequency (F_c).

[0049] With this configuration, a sound pressure of an alarm sound of which the fundamental frequency (f) is out of the frequency range between the resonance frequency (F_p) and the resonance frequency (F_c) can be increased by amplifying the sound pressure of the harmonic wave.

[0050] The acoustic system (100) according to present embodiment includes the acoustic device (1) for producing alarm sounds of the above, and the generator (2). The generator (2) is configured to generate two or more

kinds of electric signals (first signal A1 and second signal B2) individually corresponding to the two or more kinds of alarm sounds (first alarm sound and second alarm sound). The vibration member (11) resonates to each frequency of the two or more kinds of electric signals.

[0051] With this configuration, the acoustic system (100) can emit the two or more kinds of alarm sounds having different fundamental frequencies from the housing (12) of the acoustic device (1) according to the frequencies of the two or more kinds of electric signals generated by the generator (2). Furthermore, the acoustic system (100) can increase the sound pressures of the two or more kinds of alarm sounds (first alarm sound and second alarm sound) having different fundamental frequencies. The acoustic system (100) can thus increase the sound pressures of the two or more kinds of alarm sounds having different frequencies.

(6) Modifications

[0052] The acoustic device (1) is not limited to acoustic devices outputting the first alarm sound and the second alarm sound alternately, but may output the first alarm sound only, or output the second alarm sound only. The acoustic device (1) can increase a sound pressure of any of the first alarm sound and the second alarm sound. Therefore, there is no need to produce acoustic devices individually corresponding to desired types of alarm sounds, and this can lead to a decrease in the production cost.

[0053] Each of the two or more kinds of alarm sounds are not limited to sounds having such a frequency characteristic that harmonic wave is between the resonance frequency (F_p) and the resonance frequency (F_c). Alternatively, the fundamental wave may be between the resonance frequency (F_p) and the resonance frequency (F_c).

[0054] The number of the two or more kinds of alarm sounds is not limited to two, but may be three or more.

[0055] The acoustic system (100) is not limited to acoustic devices announcing the occurrence of a fire, but may emit an alarm sound for the purpose of the security, for example. The acoustic system (100) may output the alarm sound in response to presence or absence of a human, opening or closing of a door, or the like.

Reference Signs List

[0056]

1	Acoustic Device
11	Vibration Member
12	Housing
2	Generator
100	Acoustic System
A1	First Signal
B2	Second Signal

Claims

1. An acoustic device (1), comprising:

a vibration member (11) having a first resonance frequency; and
 a housing (12) accommodating the vibration member (11), having a second resonance frequency, and producing an alarm sound which is one of two or more kinds of alarm sounds having different fundamental frequencies and corresponds to a frequency of vibration of the vibration member (11), wherein the acoustic device (1) satisfies a following equation (eq1):

$$f \leq |Fp - Fc| \quad (\text{eq1})$$

where

f denotes a highest one of the different fundamental frequencies of the two or more kinds of alarm sounds, Fp denotes the first resonance frequency, and Fc denotes the second resonance frequency.

2. The acoustic device (1) of claim 1, wherein

the acoustic device (1) satisfies a following equation (eq2):

$$|Fp - Fc| < 2f \quad (\text{eq2}).$$

3. The acoustic device (1) of claim 1 or 2, wherein:

each of the two or more kinds of alarm sounds includes

a fundamental wave corresponding to the fundamental frequency, and
 one or more harmonic waves each of which corresponds to an integer multiple of the fundamental frequency; and

at least one of the one or more harmonic waves has a frequency between the first resonance frequency and the second resonance frequency.

4. An acoustic system (100), comprising:

the acoustic device (1) of any one of claims 1 to 3; and
 a generator (2) configured to generate two or more kinds of electric signals (A1, B2) individually corresponding to the two or more kinds of

alarm sounds.

5. The acoustic system (100) of claim 5, wherein the vibration member (11) resonates to each of frequencies of the two or more kinds of electric signals.

FIG. 1

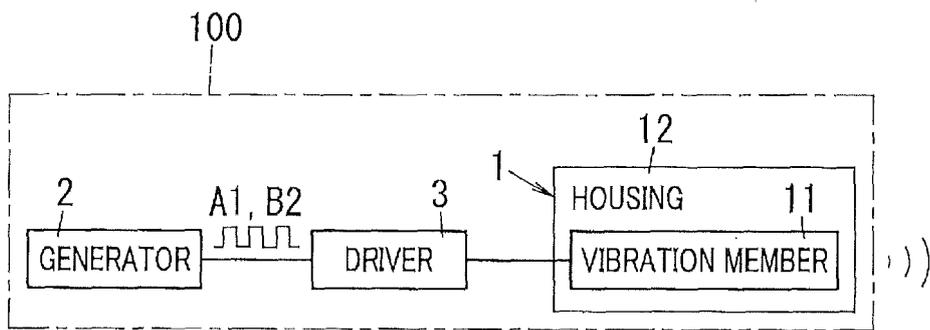


FIG. 2A

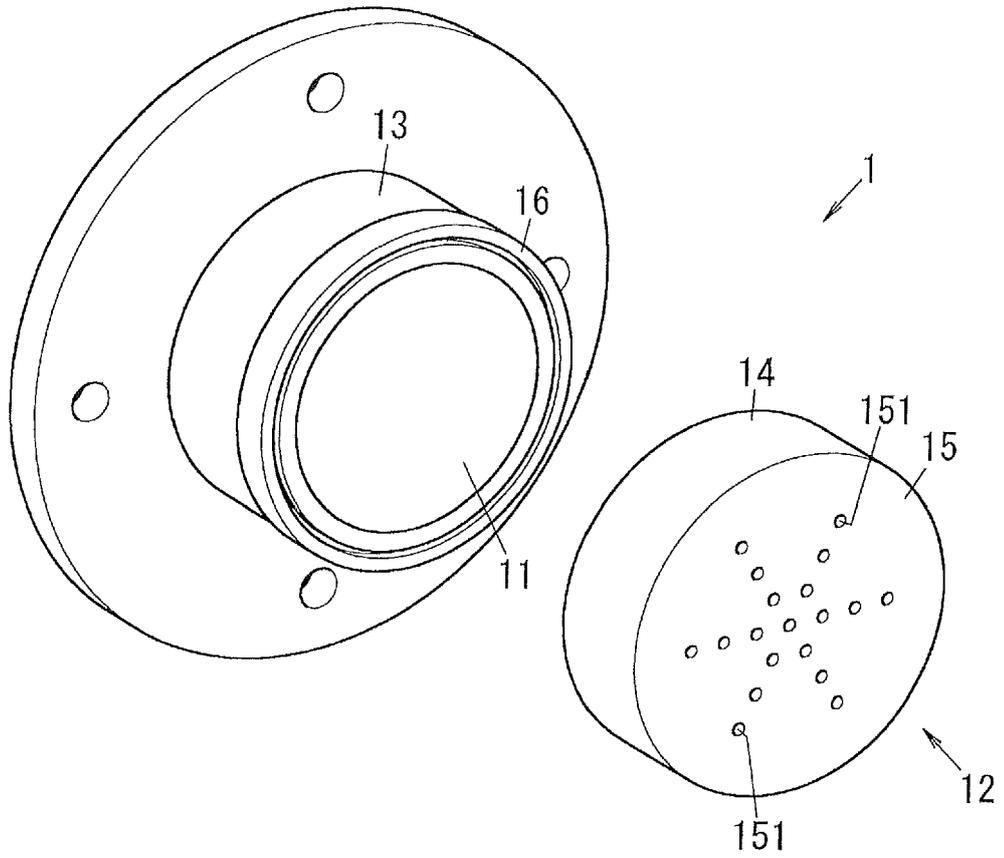


FIG. 2B

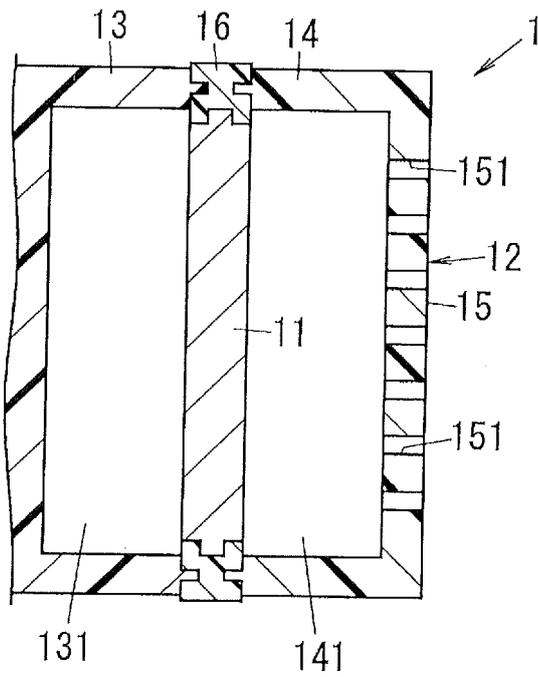


FIG. 3

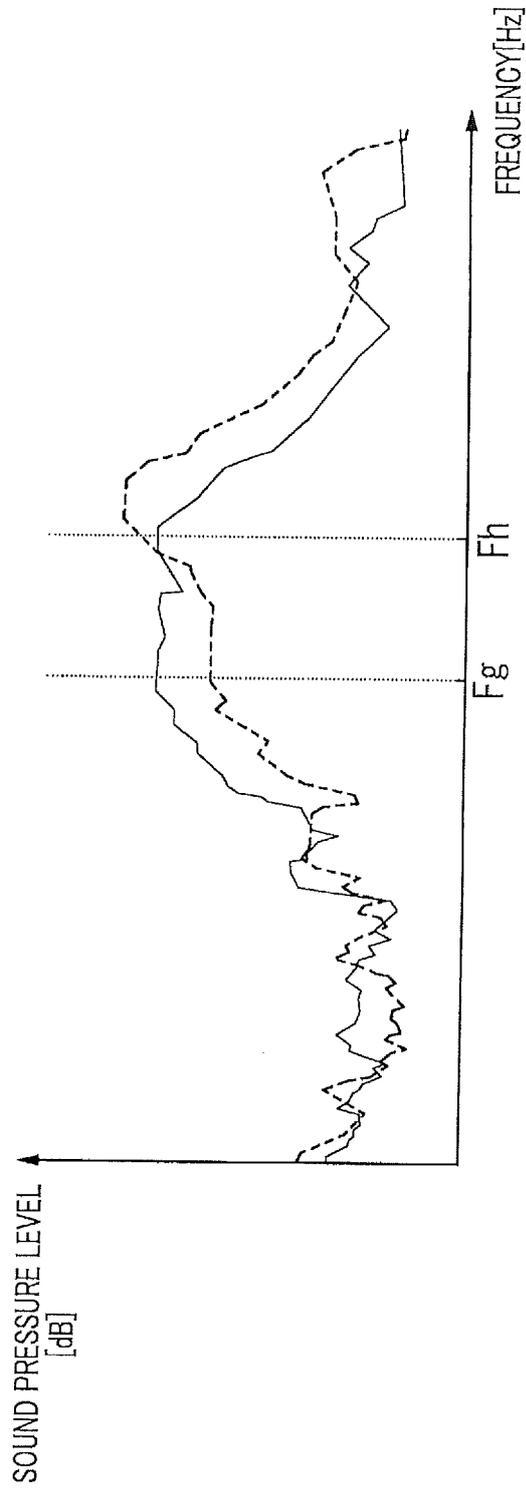


FIG. 4A

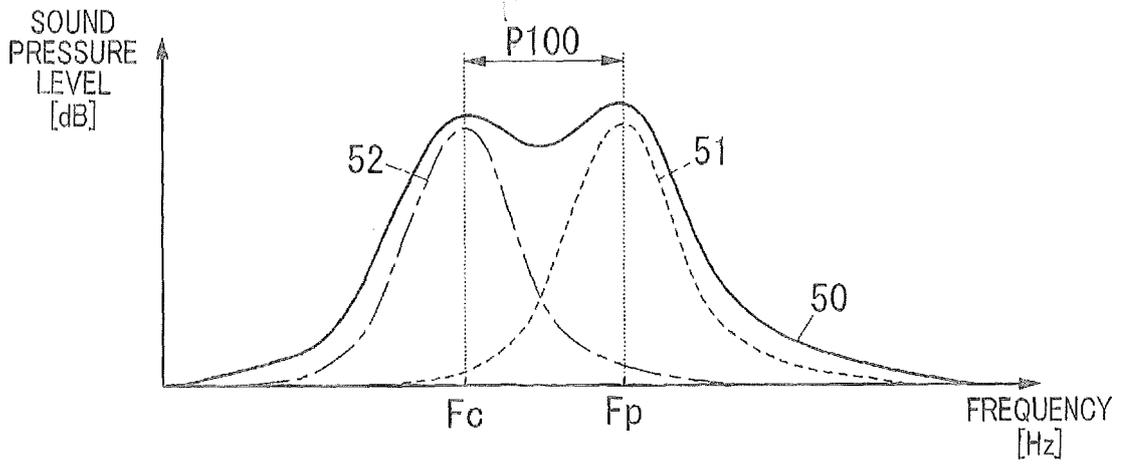


FIG. 4B

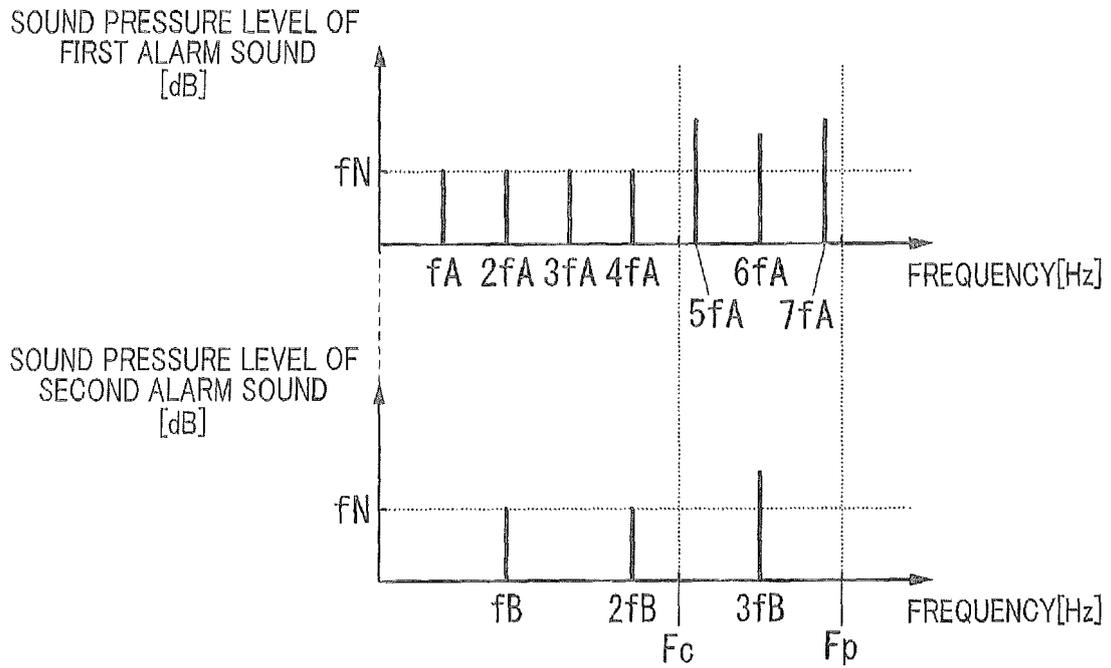


FIG. 5A

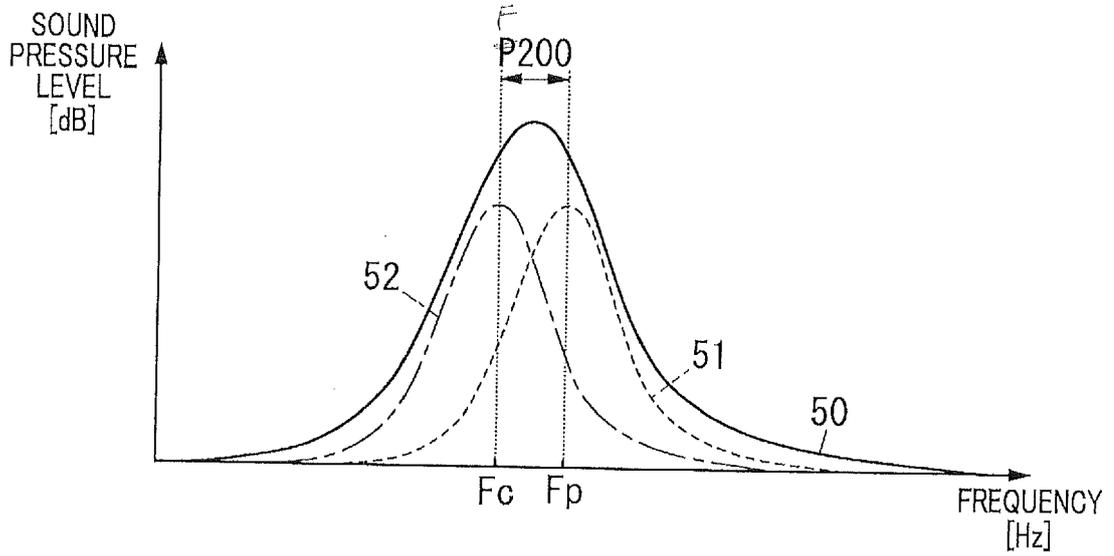
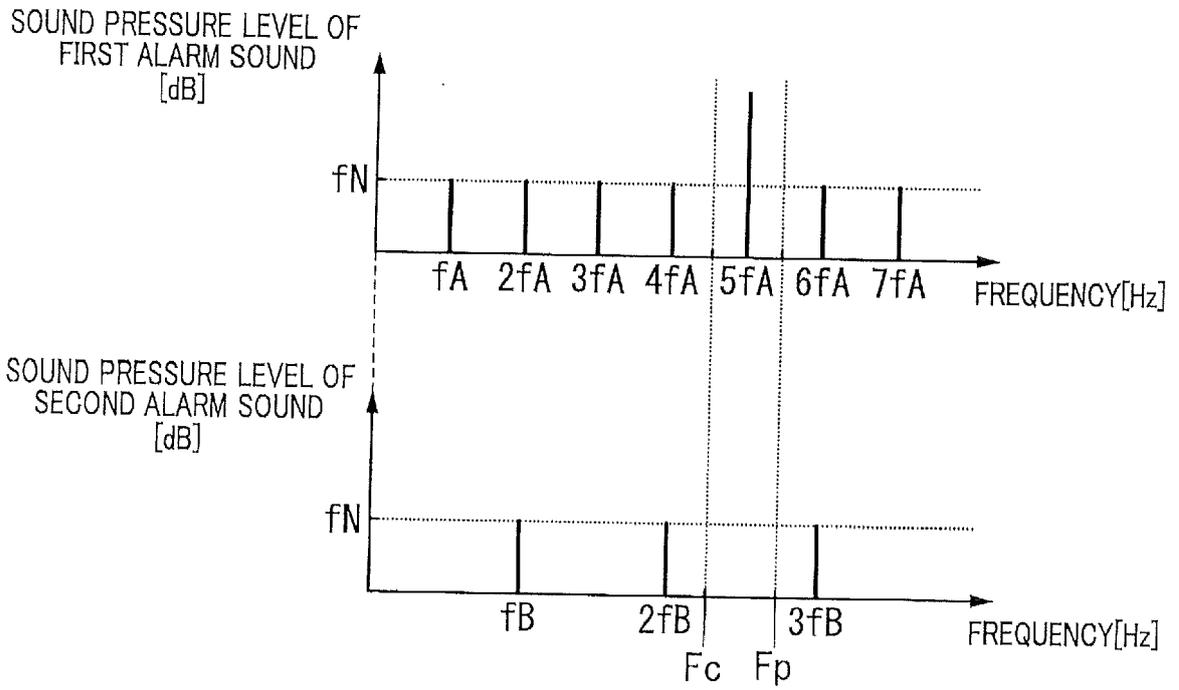


FIG. 5B





EUROPEAN SEARCH REPORT

Application Number
EP 18 15 3868

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			G08B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 15 June 2018	Examiner La Gioia, Cosimo
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ON EUROPEAN PATENT APPLICATION NO.

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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15-06-2018

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		WO 2011108441 A1	09-09-2011

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