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(54) **RADIATION ULTRASONIC WAVE
VISUALIZATION METHOD AND
ELECTRONIC APPARATUS FOR
PERFORMING RADIATION ULTRASONIC
WAVE VISUALIZATION METHOD**

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(57) **ABSTRACT**

A radiation ultrasonic wave visualization method in which an ultrasonic wave radiated by a sound source is visualized, comprises: heterodyne-converting ultrasonic signals in a band of at least 20 KHz or more, which are acquired by an ultrasonic sensor array constituted by a plurality of ultrasonic sensors and converting the ultrasonic signals into a low-frequency signal and thereafter, beamforming the converted low-frequency signals or beamforming the converted low-frequency signals based on resampling signals, thereby handling the low-frequency signals without distorting ultrasonic sound location information to reduce a data handling amount in the beamforming step.

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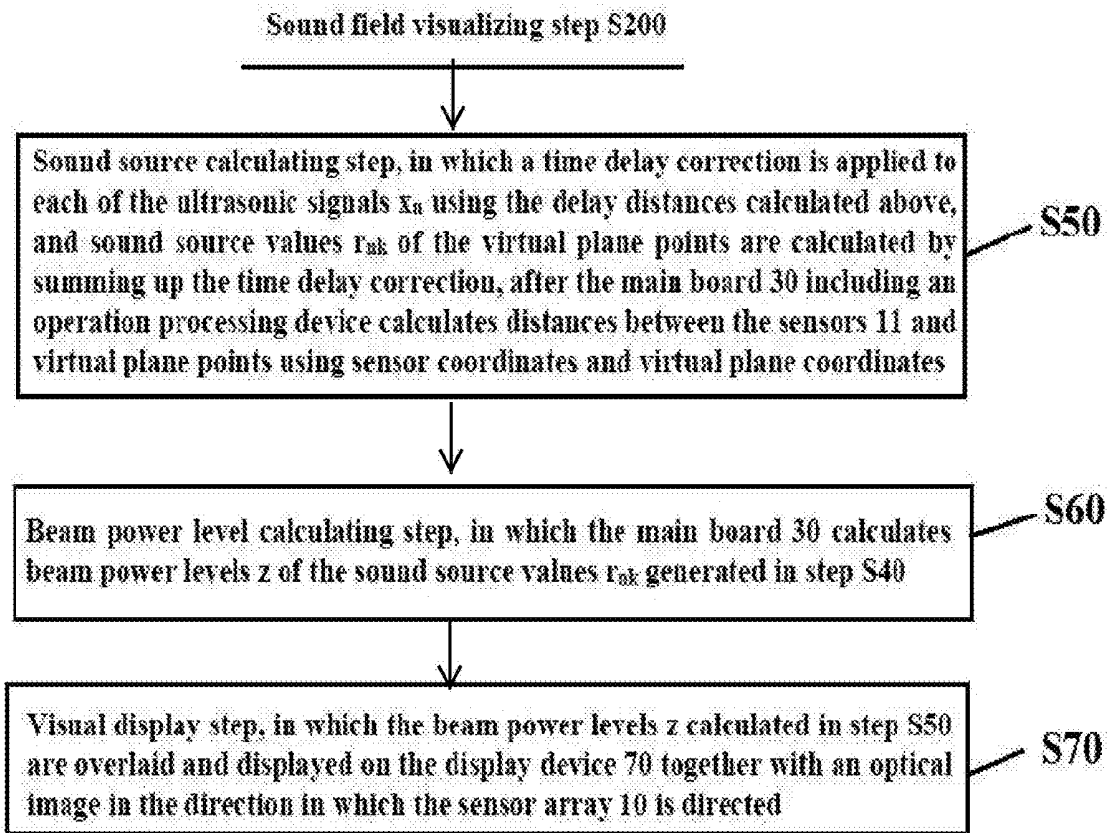


FIG. 1A

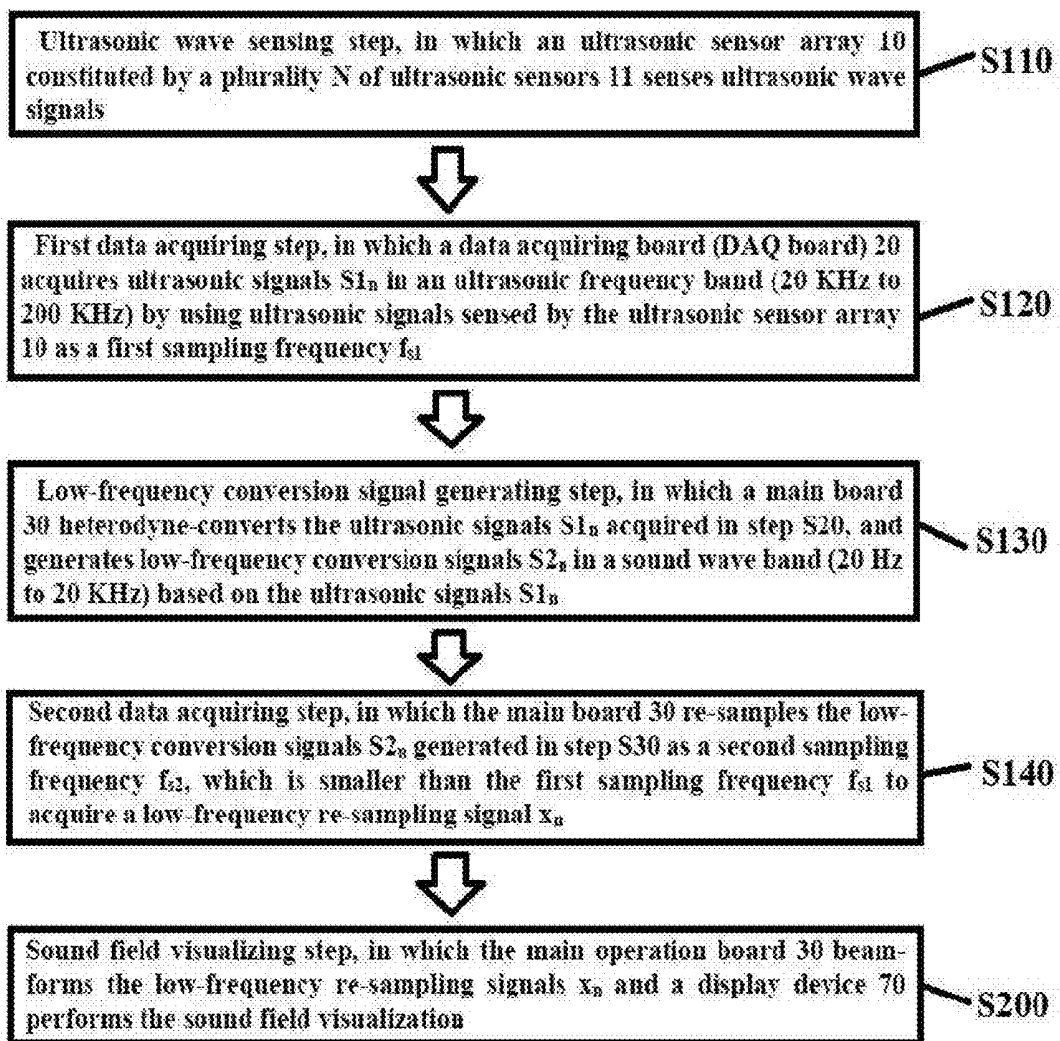


FIG. 1B

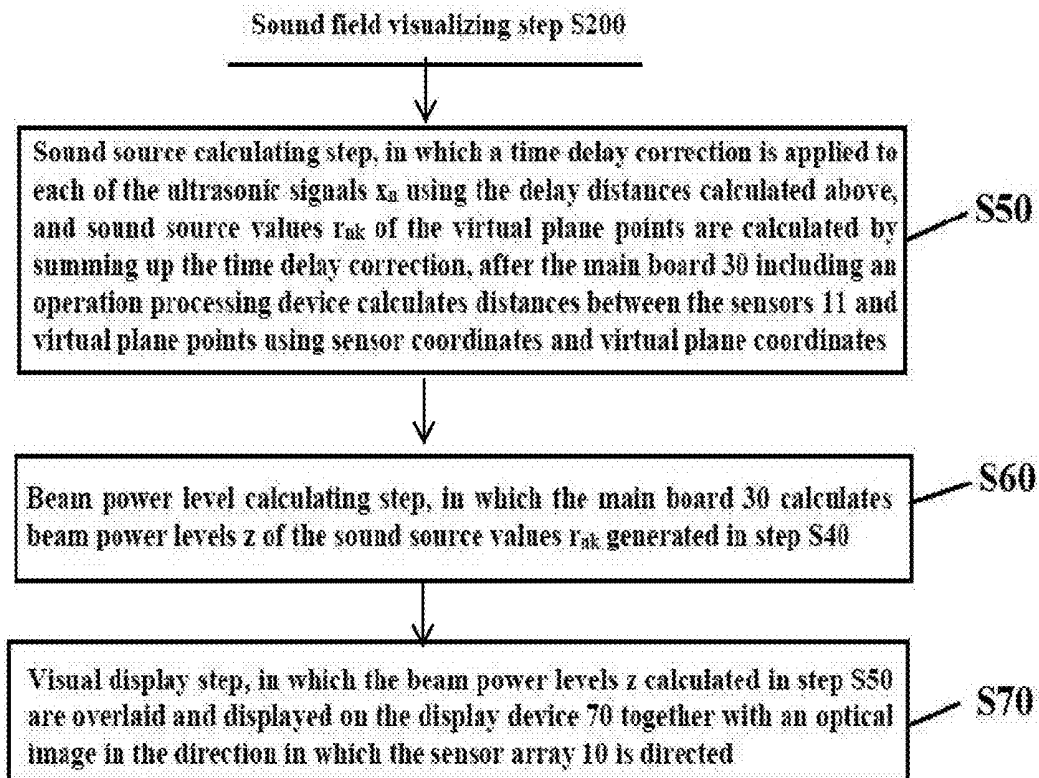


FIG. 2

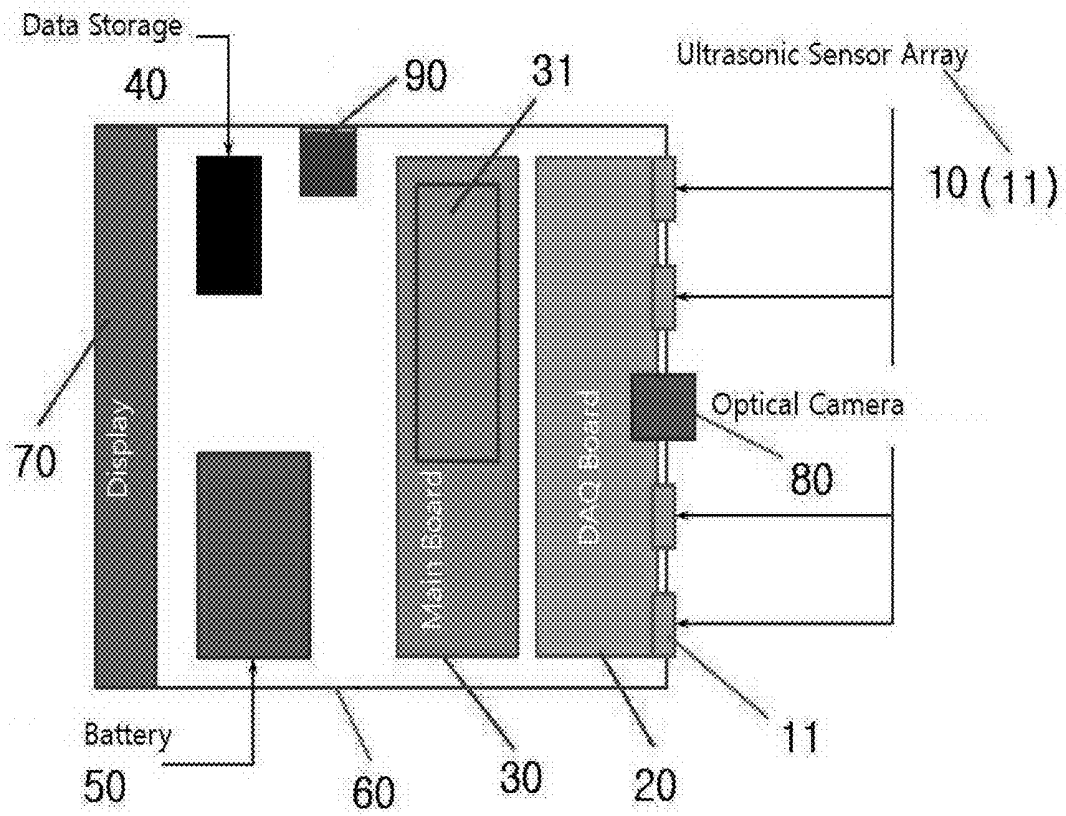


FIG. 3

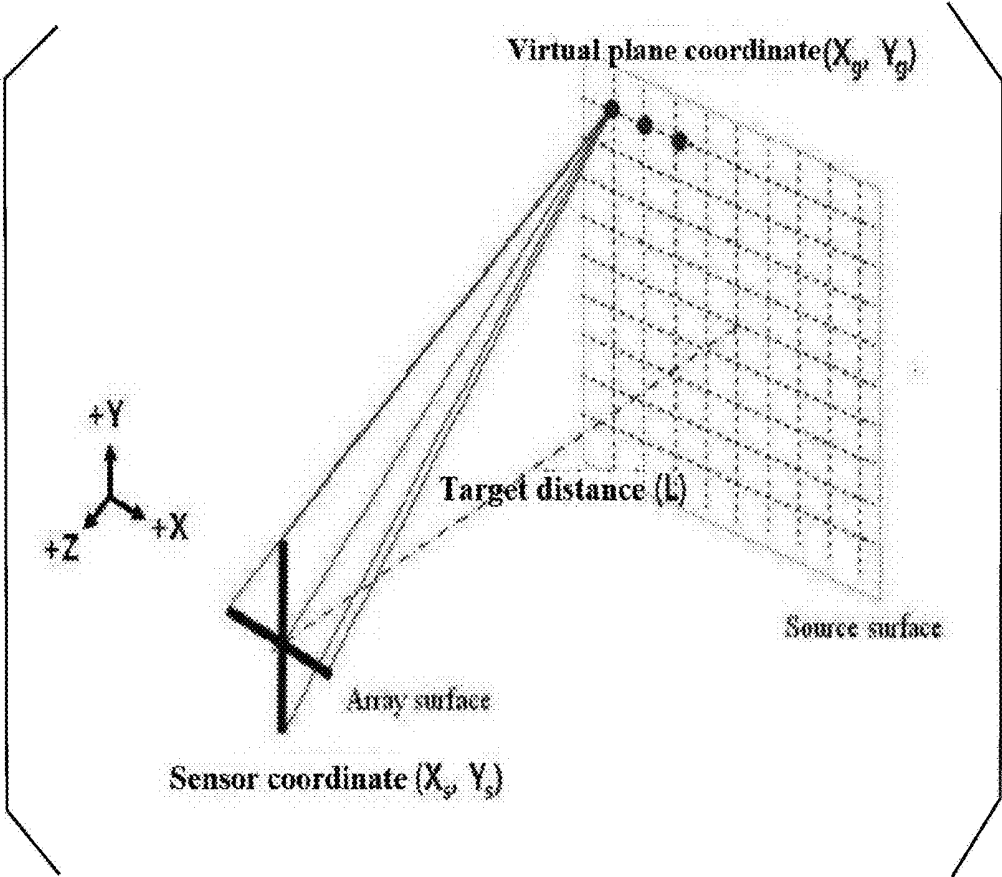
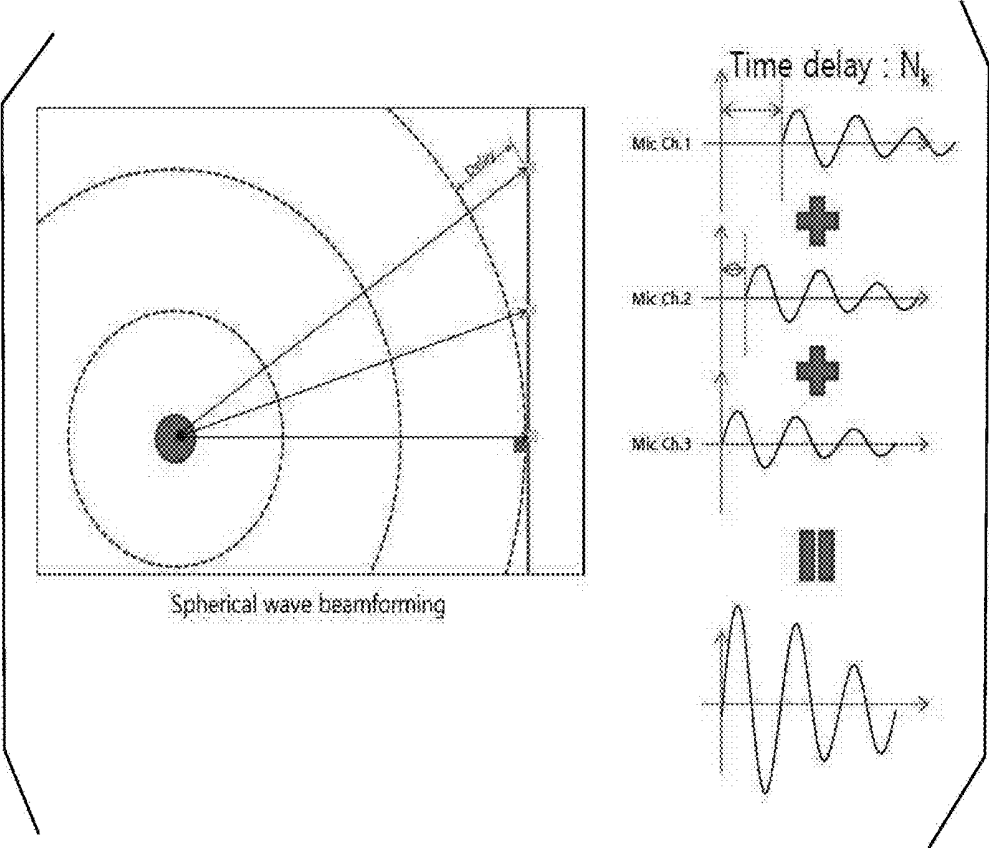


FIG. 4



**RADIATION ULTRASONIC WAVE
VISUALIZATION METHOD AND
ELECTRONIC APPARATUS FOR
PERFORMING RADIATION ULTRASONIC
WAVE VISUALIZATION METHOD**

CROSS REFERENCE

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0060418 filed in the Korean Intellectual Property Office on 16 May 2017, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] The present invention relates to a radiation ultrasonic wave visualization method and an electronic recording medium having a program for performing the radiation ultrasonic wave visualization method which is recorded therein, which are used for diagnosing a facility failure by not analyzing an echo-reflected ultrasonic wave with an ultrasonic wave transmitter and an ultrasonic wave receiver but showing a generation location of an ultrasonic wave (not an echo signal) naturally radiated from a machine or facility or a gas pipe as an image.

[0003] Patent Registration No. 10-1477755 provides a high-voltage board, a low-voltage board, a distribution board, and a motor control board equipped with an ultrasonic wave-based arc and corona discharge monitoring and diagnosing system which diagnoses a discharge state of arc or corona of a housing having the high-voltage board included therein, which include a sensor unit constituted by multiple ultrasonic sensors which contact or are installed proximate to a facility provided in the housing and which detect ultrasonic waves generated by the arc or corona discharge; and a monitoring device constituting an abnormality determining unit which senses arc or corona discharge generated in the facility and controls an internal state of the housing according to the sensed arc or corona discharge information, based on an ultrasonic signal detected by the sensor unit.

SUMMARY OF THE INVENTION

[0004] The present invention has been made in an effort to provide a radiation ultrasonic wave visualization electronic means visualizing ultrasonic waves naturally radiated by a mutual operation among components in a facility (apparatus), machines, etc. and a portable facility failure diagnosing device with a computer program, unlike a medical ultrasonic diagnosis apparatus visualizing an internal shape by a reflection wave after transmitting an ultrasonic wave by an ultrasonic apparatus in the related art.

[0005] Further, the present invention has been made in an effort to provide a radiation ultrasonic wave visualization method and an electronic recording medium having a program for performing the radiation ultrasonic wave visualization method which is recorded therein, which performs a data processing step for radiation ultrasonic wave visualization without losing ultrasonic sound source location size information in an ultrasonic area in which a data processing capacity is large and an operation processing step so as to be performed by an electronic means having appropriate performance and an operation processing capability by optimizing and minimizing a throughput.

[0006] The present invention has been made in an effort to provide a radiation ultrasonic wave visualization method and an electronic recording medium having a program for performing the radiation ultrasonic wave visualization method which is recorded therein, which can implement making as an image or output as a voice a sound of an ultrasonic area more efficient than a vibration sound which enables initial failure diagnosis in machine failure diagnosis or preliminary failure diagnosis, and monitoring the failure together with an image signal.

[0007] An exemplary embodiment of the present invention provides a radiation ultrasonic wave visualization method in which an ultrasonic wave radiated by a sound source is visualized, including: heterodyne-converting ultrasonic signals $S1_n$ in a band of at least 20 KHz or more, which are acquired by an ultrasonic sensor array **10** constituted by a plurality of (N) ultrasonic sensors **11** and converting the ultrasonic signals $S1_n$ into a low-frequency signal $S2_n$ and thereafter, beamforming the converted low-frequency signals or beamforming the converted low-frequency signals based on resampling signals x_n , thereby handling the low-frequency signals without distorting ultrasonic sound location information to reduce a data handling amount in the beamforming step.

[0008] Another exemplary embodiment of the present invention provides a radiation ultrasonic wave visualization method including: an ultrasonic wave sensing step (S110), in which an ultrasonic sensor array **10** constituted by a plurality N of ultrasonic sensors **11** senses ultrasonic wave signals; a first data acquiring step (S120), in which a data acquiring board (DAQ board) **20** acquires ultrasonic signals $S1_n$ in an ultrasonic frequency band (20 KHz to 200 KHz) by using ultrasonic signals sensed by the ultrasonic sensor array **10** as a first sampling frequency f_{s1} ; a low-frequency conversion signal generating step (S130), in which a main board **30** heterodyne-converts the ultrasonic signals $S1_n$ acquired in step S120, and generates low-frequency conversion signals $S2_n$ in a sound wave band (20 Hz to 20 KHz) based on the ultrasonic signals $S1_n$; a second data acquiring step (S140), in which the main board **30** re-samples the low-frequency conversion signals $S2_n$ generated in step S130 as a second sampling frequency f_{s2} , which is smaller than the first sampling frequency f_{s1} to acquire a low-frequency re-sampling signal x_n ; and a sound field visualizing step (S150), in which the main operation board **30** beam-forms the low-frequency re-sampling signals x_n and a display device **70** performs the sound field visualization, in which the ultrasonic sound source is visualized by converting an ultrasonic signal in a band of 20 KHz or more into a sound wave band signal without distorting sound source location information of the sound source of the radiation ultrasonic wave and then re-sampling and beam forming the converted ultrasonic signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIGS. 1A and 1B are flowcharts of a radiation ultrasonic wave visualization method according to the present invention.

[0010] FIG. 2 is a configuration diagram of a radiation ultrasonic wave visualization apparatus according to the present invention.

[0011] FIG. 3 is a conceptual view of a radiation ultrasonic wave visualization sensor coordinate and a virtual plane coordinate according to the present invention.

[0012] FIG. 4 is a conceptual view of a radiation time delay summation according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Hereinafter, a radiation ultrasonic wave visualization method and an electronic recording medium having a program for performing the radiation ultrasonic wave visualization method, which is recorded therein will be described in detail with reference to the accompanying drawings. FIG. 1 is a flowchart of a radiation ultrasonic wave visualization method according to the present invention, FIG. 2 is a configuration diagram of a radiation ultrasonic wave visualization apparatus according to the present invention, FIG. 3 is a conceptual view of a radiation ultrasonic wave visualization sensor coordinate and a virtual plane coordinate according to the present invention, and FIG. 4 is a conceptual view of a radiation time delay summation according to the present invention.

[0014] As illustrated in FIGS. 1 to 4, a radiation ultrasonic wave visualization method of the present invention as a method of visualizing an ultrasonic wave radiated by a sound source includes heterodyne-converting ultrasonic signals $S1_n$ in at least 20 KHz or more, which are acquired by an ultrasonic sensor array 10 constituted by a plurality of (N) ultrasonic sensors 11 and converts the ultrasonic signals $S1_n$ into a low-frequency signal $S2_n$ in a sound wave band (in detail, 20 Hz to 20 KHz) and thereafter, beamforming the low-frequency signal based on signals x_n acquired by re-sampling the low-frequency signal beamformed or converted by using the converted low-frequency signals, thereby handling the low-frequency signal without distorting ultrasonic sound location information to reduce a data handling amount in a beamforming step.

[0015] As illustrated in FIGS. 1 to 4, the radiation ultrasonic wave visualization method of the present invention includes an ultrasonic wave sensing step (S110), a first data acquiring step (S120), a low-frequency conversion signal generating step (S130), a second data acquiring step (S140), and a sound field visualizing step (S200).

[0016] First, in the ultrasonic wave sensing step (S110), an ultrasonic sensor array 10 constituted by a plurality N of ultrasonic sensors 11 senses ultrasonic signals. The ultrasonic sensor array 10 constituted by the plurality N of ultrasonic sensors 11 and orienting a radiation sound source senses the ultrasonic signals. The ultrasonic sensor array 10 constituted by the plurality N of ultrasonic sensors 11 and senses ultrasonic signals radiated from a facility while orienting the radiation sound source. The ultrasonic sensor array 10 may have a structure in which a plurality of MEMS microphones, ultrasonic transducers or ultrasonic sensors are mounted on a printed circuit board (PCB) on a planar surface or a flexible PCB on a curved surface. The ultrasonic sensor array 10 is exposed in front of the apparatus and arranged in a forward direction (one direction). Alternatively, the plurality of ultrasonic sensors 11 may be arranged at regular intervals on a sphere or a substantially ball-shaped polyhedron.

[0017] Next, in the first data acquiring step (S120), a data acquiring board (DAQ board) 20 acquires ultrasonic signals $S1_n$ in an ultrasonic frequency band (particularly, 20 KHz to 200 KHz) by using ultrasonic signals sensed by the ultrasonic sensor array 10 as a first sampling frequency f_{s1} .

[0018] Next, in the low-frequency conversion signal generating step (S130), a main board 30 heterodyne-converts the ultrasonic signals $S1_n$ acquired in step S120, and generates low-frequency conversion signals $S2_n$ in a sound wave band (20 Hz to 20 KHz) based on the ultrasonic signals $S1_n$.

[0019] Next, in the second data acquiring step (S140), the main board 30 re-samples the low-frequency conversion signals $S2_n$ generated in step S130 as a second sampling frequency f_{s2} , which is smaller than the first sampling frequency f_{s1} to acquire a low-frequency re-sampling signal x_n .

[0020] A detailed equation for the signal x_n is as follows.

$$x_n[nT] = \sum_{s=0}^{S-1} x_n(t) \cdot \delta\left(t - \frac{s}{f_s}\right)$$

[0021] Herein, S: Sample Number, and f_s : Sampling Rate (frequency).

[0022] A step of applying a band pass filter of predetermined ultrasonic frequency bands f_1 to f_2 (preset by the user) to the acquired ultrasonic signals x_n may be further performed. In a filtering data $x_n[s]$, $1 \leq s \leq N$.

$$x_n[s] = x_n[s] \cdot F[s]$$

[0023] Next, in the sound field visualizing step (S200), the main operation board 30 beam-forms the low-frequency re-sampling signals x_n and a display device 70 performs the sound field visualization. The ultrasonic sound source is visualized by converting an ultrasonic signal in a band of 20 KHz or more into a sound wave band signal without distorting sound source location information of the sound source of the radiation ultrasonic wave and then re-sampling and beam forming the converted ultrasonic signal.

[0024] In the radiation ultrasonic wave visualization method according to the exemplary embodiment of the present invention, the first sampling frequency f_{s1} is in a range of 20 KHz (40 KHz) to 200 KHz (400 KHz), and the second sampling frequency f_{s2} is in a range of 20 Hz (40 Hz) to 20 KHz (40 KHz), and it is preferable that the first sampling frequency f_{s1} is selected to be at least two times larger than the second sampling frequency f_{s2} in terms of reduction of a data throughput.

[0025] In the range of the first sampling frequency f_{s1} of 20 KHz (40 KHz) to 200 KHz (400 KHz), as the test result, it is possible to acquire ultrasonic sound source location information which is effective and required for the ultrasonic sensor detection performance and machinery failure currently released in this area, rotating machine breakdown, gas pipe gas leakage, and power equipment diagnosis monitoring. Further, as the test result, it can be seen that the data throughput may be appropriately reduced in the range of the sampling frequency f_{s2} of 20 Hz (40 Hz) to 20 KHz. If the sampling frequency is too large, more data processing is needed, and if the sampling frequency is too small, the ultrasonic area sound source information is lost.

[0026] <Sound Field Visualizing Step (S200)>

[0027] As described above, in the sound field visualizing step (S1200), the main operation board 30 beam-forms the low-frequency re-sampling signals x_n and the display device 70 performs the sound field visualization, and it will be described in more detail.

[0028] The sound field visualizing step (S200) largely includes a sound source value calculation step (S50) by a time delay sum, a beam power level calculating step (S60), and a visual display step (S70).

[0029] First, in the sound source value calculating step (S50), the main board 30 including an operation processing device calculates distances between the sensors 11 and virtual plane points using sensor coordinates and virtual plane coordinates. Thereafter, time delay correction is applied to each of the ultrasonic signals x_n using the delay distances calculated above, and sound source values r_{nk} of the virtual plane points are calculated by summing up the time delay corrections.

[0030] FIG. 3 is a diagram illustrating a relationship between the sensor coordinate and the virtual plane coordinate. As illustrated in FIG. 3, a distance d_k between the sensor coordinate (X_s, Y_s) and the virtual plane coordinate (X_g, Y_g) is calculated as follows. When the distance L is 1 m, the operation of $+L^2$ is represented by $+1$ operation.

$$d_k = X_s - X_g)^2 + (Y_s - Y_g)^2 + L^2$$

[0031] FIG. 4 is a conceptual diagram of a radiation ultrasonic wave visualization time delay summation of the present invention. Subsequently, in the sound source value calculating step (S50), first, a time delay correction is applied to each of the ultrasonic signals x_n using the calculated delay distances, and sound source values r_{nk} of M virtual plane points are calculated by summing up the time delay corrections.

[0032] First, a delay sample number is calculated. The time delay is calculated using a distance between the sensor and the virtual plane and a sound speed and the delay sample number is calculated by the calculated time delay. The details are as follows.

$$\tau_k = \frac{d_k}{c} \text{ (Time delay),}$$

$$N_k = f_s \cdot \tau_k = f_s \cdot \frac{d_k}{c} = \frac{f_s}{c} \cdot d_k = C_d \cdot d_k$$

$$C_d = \frac{f_s}{c}$$

[0033] Herein, C_d represents a time delay coefficient and c is a sound speed. N_k represents the delay sample number.

[0034] Next, the time delay is compensated by using the delay sample number and summed up. In this case, a correction coefficient for each sensor is applied.

$$r_{nk}[s] = \sum_{n=0}^{N-1} \alpha_n \cdot x_{nf}[s] \cdot \delta[s - N_k]$$

α_n : Weighting Factor

[0035] Herein, $1 \leq n \leq K$. M is the number of all elements in rows and columns on a virtual plane coordinate.

[0036] Next, the beam power level calculating step (S60) for calculating the beam power levels z of the generated sound source values r_{nk} is performed.

$$z_k = \frac{1}{N} \sum_{s=0}^{S-1} r_{nk}^2 [s]$$

[0037] In the visual display step (S70), the beam power levels z calculated in step S50 are overlaid and displayed on the display device 70 together with an optical image in the direction which the sensor array 10 faces.

Apparatus

[0038] An apparatus that performs the method of the present invention will be described in detail. The apparatus for performing the method of the present invention includes an ultrasonic sensor array 10, a data acquisition board (DAQ board) 20, a main board 30, a data storage medium 40, a battery 50, a plastic body case 60, and a display device 70.

[0039] As illustrated in FIG. 2, the ultrasonic sensor array 10 is constituted by a plurality N of ultrasonic sensors 11 and senses ultrasonic signals radiated from a facility while orienting the radiation sound source. The ultrasonic sensor array 10 may have a structure in which a plurality of MEMS microphones, ultrasonic transducers or ultrasonic wave sensors are mounted on a printed circuit board (PCB) on a planar surface or a flexible PCB on a curved (three-dimensional) surface, a sphere, a substantially ball-shaped polyhedron, a hemisphere, and a rear-opened convex curved surface.

[0040] An electronic circuit for acquiring the ultrasonic signals x_n using ultrasonic signals sensed from the ultrasonic sensor array 10 as a sampling frequency f_s is mounted on the substrate of the DAQ board 20. The DAQ board 20 performs sampling and may include a signal amplification circuit.

[0041] In the main board 30, an operation processing device 31 that processes digital (alternatively, analog) ultrasonic signals received from the DAQ board 20 is mounted on the substrate and transmits the processed ultrasonic sound source information to the display device 70. The data storage medium 40 stores data processed in the operation processing device 31 of the main board 30.

[0042] The apparatus includes an optical camera 80 for picking up an image of a direction in which the ultrasonic sensor array 10 is directed and transmitting the image to the main board 30. The display device 70 visually displays the data processed by the operation processing unit 31 of the main board 30 and is integrally installed in the plastic body case 60. Alternatively, the display device 70 is integrally fixed to the plastic body case 60 so as to be exposed to the outside of the plastic body case 60.

[0043] The battery 50 supplies electric power to the data acquisition board 20, the main board 30 and the display device 70, and it is preferable that the battery 50 is installed in a detachable and rechargeable state inside the plastic body case 60. However, the battery may be a separate portable rechargeable battery which is located outside the plastic body case 60 and supplies electric power to the data acquisition board 20 and the main board 30 by electric wires. Alternatively, both an internal battery and an external auxiliary battery may be provided and used.

[0044] The plastic body case 60 is formed of a hard material for fixing the ultrasonic sensor array 10, the data acquisition board 20, the main board 30 and the data storage medium 40. The plastic body case 60 supports the array 10 constituted by the plurality of ultrasonic sensors 11 electri-

cally connected to each other, or supports the ultrasonic sensor array **10** by supporting and fixing an ultrasonic sensor array PCB mounted on a flat or curved plate on which the ultrasonic sensors **11** are mounted. The inside of the plastic body case **60** has a hollow chamber, and the data acquisition board **20** and the main board **30** having an operation processing capability are fixedly installed in the hollow chamber.

[0045] The display device **70** visually displays the data processed by the operation processing unit **31** of the main board **30** and is integrally installed in the plastic body case **60**. Alternatively, the display device **70** is integrally fixed to the plastic body case **60** so as to be exposed to the outside of the plastic body case **60**.

[0046] The present invention includes an electronic recording medium on which a program is recorded for the radiation ultrasound visualization method, wherein the electronic recording medium is an electronic device including a CPU for executing a program, a hard disk on which a program is stored, a stationary memory, a removable memory and the like.

[0047] The present invention has been described in association with the above-mentioned preferred embodiment, but the scope of the present invention is not limited to the embodiment and the scope of the present invention is determined by the appended claims, and thereafter, the scope of the present invention will include various modifications and transformations included in an equivalent range to the present invention.

[0048] Reference numerals disclosed in the appended claims are just used to assist appreciation of the present invention and it is revealed that the reference numerals do not influence analysis of the claims and it should not be narrowly analyzed by the disclosed reference numerals.

What is claimed is:

1. A radiation ultrasonic wave visualization method in which an ultrasonic wave radiated by a sound source is visualized, comprising:

heterodyne-converting ultrasonic signals ($S1_n$) in a band of at least 20 KHz or more, which are acquired by an ultrasonic sensor array (**10**) constituted by a plurality of (N) ultrasonic sensors (**11**) and converting the ultrasonic signals $S1_n$ into a low-frequency signal ($S2_n$) and thereafter;

beamforming the converted low-frequency signals or beamforming the converted low-frequency signals based on resampling signals (x_n); and

thereby handling the low-frequency signals without distorting ultrasonic sound location information to reduce a data handling amount in the beamforming step.

2. A radiation ultrasonic wave visualization method, comprising:

an ultrasonic wave sensing step (S110), in which an ultrasonic sensor array (**10**) constituted by a plurality (N) of ultrasonic sensors (**11**) senses ultrasonic wave signals;

a first data acquiring step (S120), in which a data acquiring board (DAQ board) acquires ultrasonic signals ($S1_n$) in an ultrasonic frequency band of 20 KHz to 200 KHz by using ultrasonic signals sensed by the ultrasonic sensor array as a first sampling frequency (f_{s1});

a low-frequency conversion signal generating step (S130), in which a main board (**30**) heterodyne-con-

verts the ultrasonic signals $S1_n$ acquired in the first data acquiring step (S120), and generates low-frequency conversion signals ($S2_n$) in a sound wave band (20 Hz to 20 KHz) based on the ultrasonic signals ($S1_n$);

a second data acquiring step (S140), in which the main board (**30**) re-samples the low-frequency conversion signals ($S2_n$) generated in the low-frequency conversion signal generating step (S130) as a second sampling frequency (f_{s2}), which is smaller than the first sampling frequency (f_{s1}) to acquire a low-frequency re-sampling signal (x_n); and

a sound field visualizing step (S200), in which the main operation board (**30**) beam-forms the low-frequency re-sampling signals (x_n) and a display device (**70**) performs the sound field visualization,

wherein the ultrasonic sound source is visualized by converting an ultrasonic signal in a band of 20 KHz or more into a sound wave band signal without distorting sound source location information of the sound source of the radiation ultrasonic wave and then re-sampling and beam forming the converted ultrasonic signal.

3. The radiation ultrasonic wave visualization method of claim 2, wherein the first sampling frequency (f_{s1}) is in a range of 20 KHz to 200 KHz, the second sampling frequency (f_{s2}) is in a range of 20 Hz to 20 KHz, and the first sampling frequency (f_{s1}) is selected to be at least two times larger than the second sampling frequency (f_{s2}).

4. The radiation ultrasonic wave visualization method of claim 2, wherein

the sound field visualizing step (S200) includes

a sound source calculating step (S50), in which a time delay correction is applied to each of the ultrasonic signals (x_n) using the delay distances calculated above, and sound source values (r_{nk}) of the virtual plane points are calculated by summing up the time delay correction after the main board including an operation processing device calculates distances between the sensors and virtual plane points using sensor coordinates and virtual plane coordinates;

a beam power level calculating step (S60), in which the main board calculates beam power levels (z) of the sound source values (r_{nk}) generated in the second data acquiring step (S140); and

a visual display step (S70), in which the beam power levels (z) calculated in the sound source calculating step (S50) are overlaid and displayed on the display device (**70**) together with an optical image in the direction in which the sensor array (**10**) is directed.

5. The radiation ultrasonic wave visualization method of claim 2, further comprising:

between the second data acquiring step (S140) and the sound field visualizing step (S200),

applying a band pass filter in predetermined frequency bands (f_1 and f_2) to the ultrasonic signals (x_n) acquired in the second data acquiring step (S140).

6. An electronic apparatus performing the radiation ultrasonic wave visualization method of claim 1.

7. An electronic apparatus performing the radiation ultrasonic wave visualization method of claim 2.

* * * * *

专利名称(译)	用于执行辐射超声波可视化方法的辐射超声波可视化方法和电子设备		
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[标]申请(专利权)人(译)	SM仪器株式会社		
申请(专利权)人(译)	SM仪器有限公司.		
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发明人	KIM, YOUNG KI KIM, YOUNGMIN LEE, JEASUN LEE, KWANG HYUN HAN, SEONG JOO LIM, JUNG HYUN		
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外部链接	Espacenet USPTO		

摘要(译)

一种辐射超声波可视化方法，其中由声源辐射的超声波可视化，包括：外差转换至少20KHz或更高频带的超声波信号，其由多个由多个构成的超声波传感器阵列获取。超声波传感器并将超声波信号转换成低频信号，然后，对转换后的低频信号进行波束形成，或者根据重采样信号对转换后的低频信号进行波束形成，从而处理低频信号，而不会将超声波声音位置信息变形为减少波束成形步骤中的数据处理量。

