US 20170153322A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2017/0153322 A1
HAYASHI (43) Pub. Date: Jun. 1, 2017

(54) ULTRASONIC IMAGING DEVICE AND METHOD OF GENERATING ULTRASONIC IMAGE

(71) Applicant: SEIKO EPSON CORPORATION, Tokyo (JP)

(72) Inventor: Masaki HAYASHI, Matsumoto-shi (JP)

(73) Assignee: SEIKO EPSON CORPORATION, Tokyo (JP)

(21) Appl. No.: 15/360,828

(22) Filed: Nov. 23, 2016

(30) Foreign Application Priority Data

Nov. 26, 2015 (JP) 2015-230321

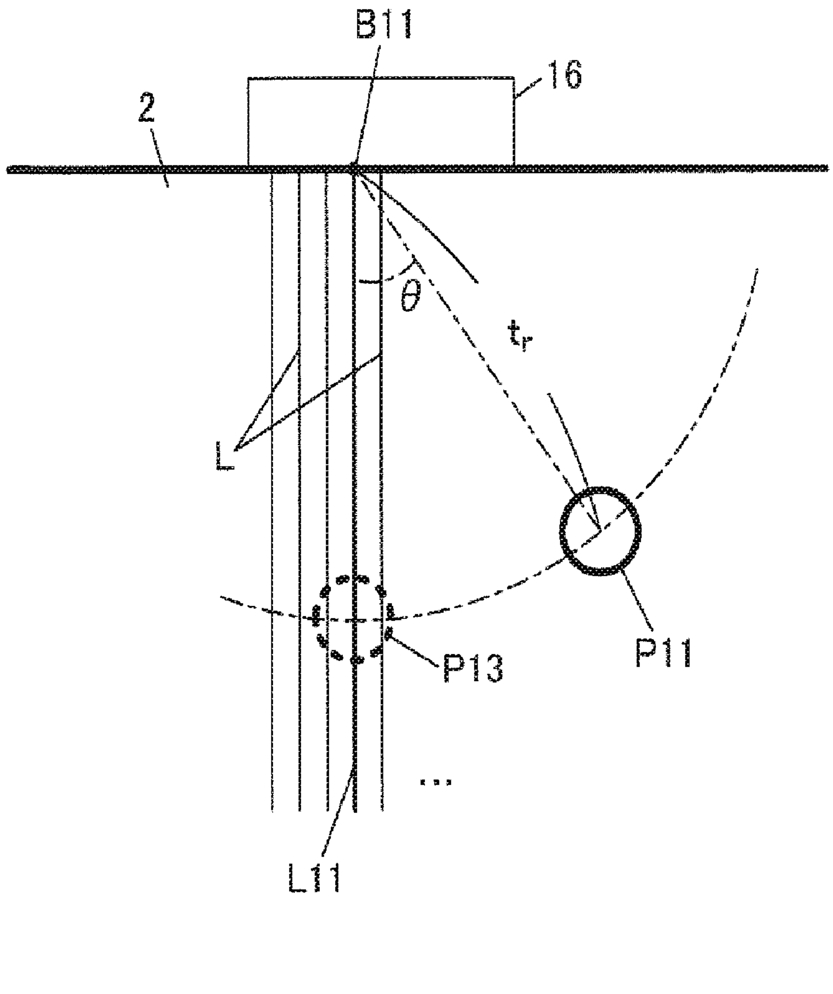
Publication Classification

(51) Int. Cl.
G01S 7/52 (2006.01)
A61B 8/14 (2006.01)
A61B 8/08 (2006.01)
A61B 8/00 (2006.01)
G01S 15/02 (2006.01)
G01S 15/89 (2006.01)

(52) U.S. Cl.
CPC *G01S 7/52047* (2013.01); *G01S 15/02* (2013.01); *G01S 7/5205* (2013.01); *G01S 15/89* (2013.01); *A61B 8/5269* (2013.01); *A61B 8/54* (2013.01); *A61B 8/14* (2013.01); *A61B 8/5207* (2013.01)

(57) ABSTRACT

An ultrasonic measurement control unit of a processing unit of an ultrasonic imaging device forms an ultrasonic measurement unit, which performs ultrasonic measurement, together with an ultrasonic wave transmitting and receiving unit. A desired sensitivity attenuation position setting unit sets a desired sensitivity attenuation position in a generated ultrasonic image. An image generation unit generates an ultrasonic image by performing a beam forming process in which received signals of elements input from the ultrasonic measurement control unit are added. In the beam forming process, a beam forming processing unit performs attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.



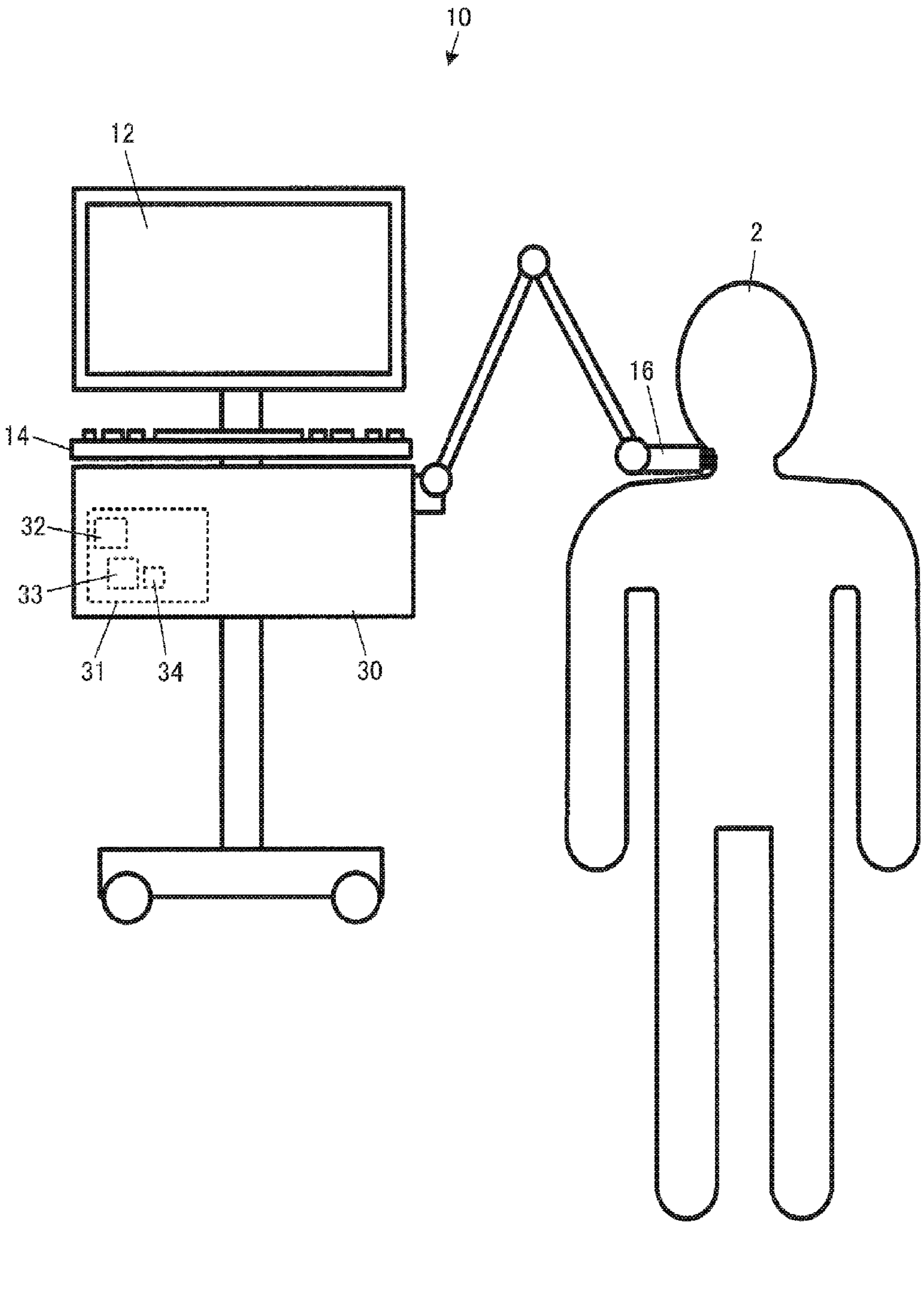


FIG. 1

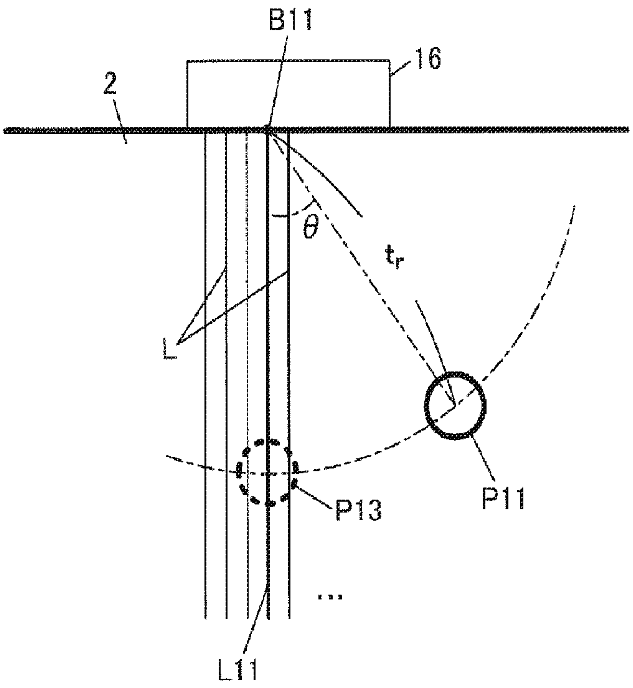

B11
16
2
θ
t_r
L
P11
P13
...
L11

FIG. 2

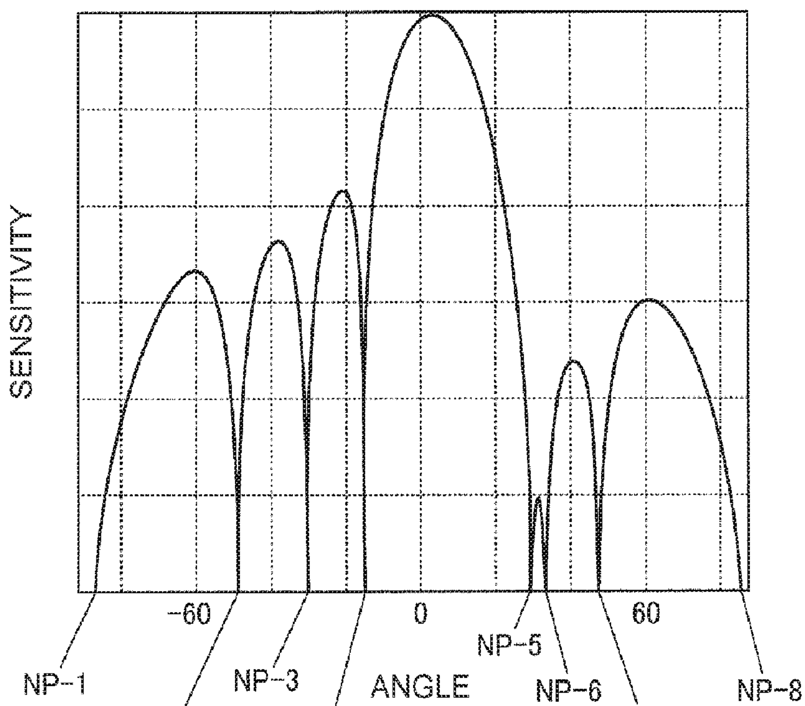

SENSITIVITY
-60
0
60
ANGLE
NP-1
NP-2
NP-3
NP-4
NP-5
NP-6
NP-7
NP-8

FIG. 3

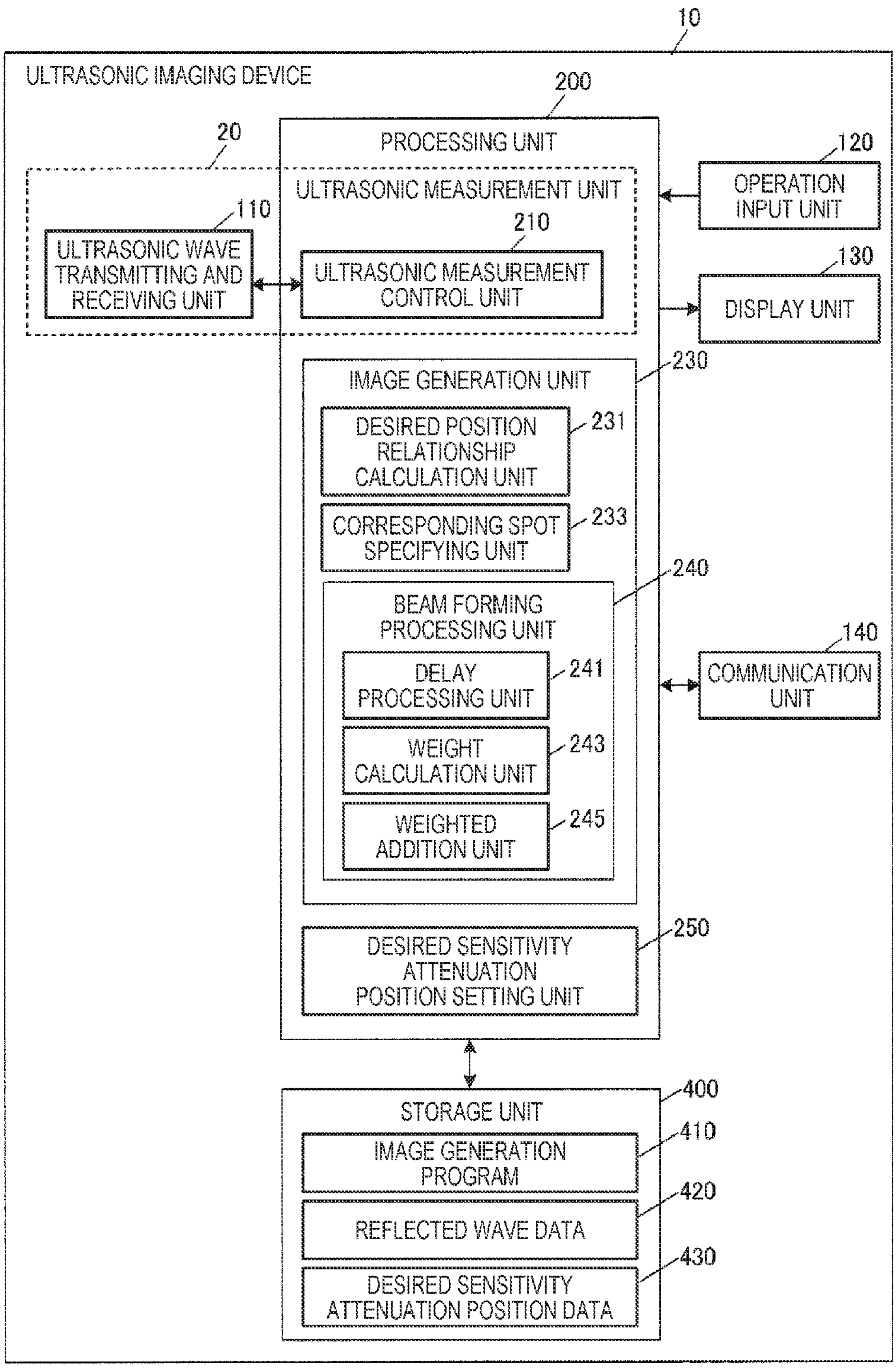

10
ULTRASONIC IMAGING DEVICE
200
PROCESSING UNIT
20
ULTRASONIC MEASUREMENT UNIT
110
ULTRASONIC WAVE TRANSMITTING AND RECEIVING UNIT
210
ULTRASONIC MEASUREMENT CONTROL UNIT
120
OPERATION INPUT UNIT
130
DISPLAY UNIT
230
IMAGE GENERATION UNIT
231
DESIRED POSITION RELATIONSHIP CALCULATION UNIT
233
CORRESPONDING SPOT SPECIFYING UNIT
240
BEAM FORMING PROCESSING UNIT
241
DELAY PROCESSING UNIT
243
WEIGHT CALCULATION UNIT
245
WEIGHTED ADDITION UNIT
140
COMMUNICATION UNIT
250
DESIRED SENSITIVITY ATTENUATION POSITION SETTING UNIT
400
STORAGE UNIT
410
IMAGE GENERATION PROGRAM
420
REFLECTED WAVE DATA
430
DESIRED SENSITIVITY ATTENUATION POSITION DATA

FIG. 4

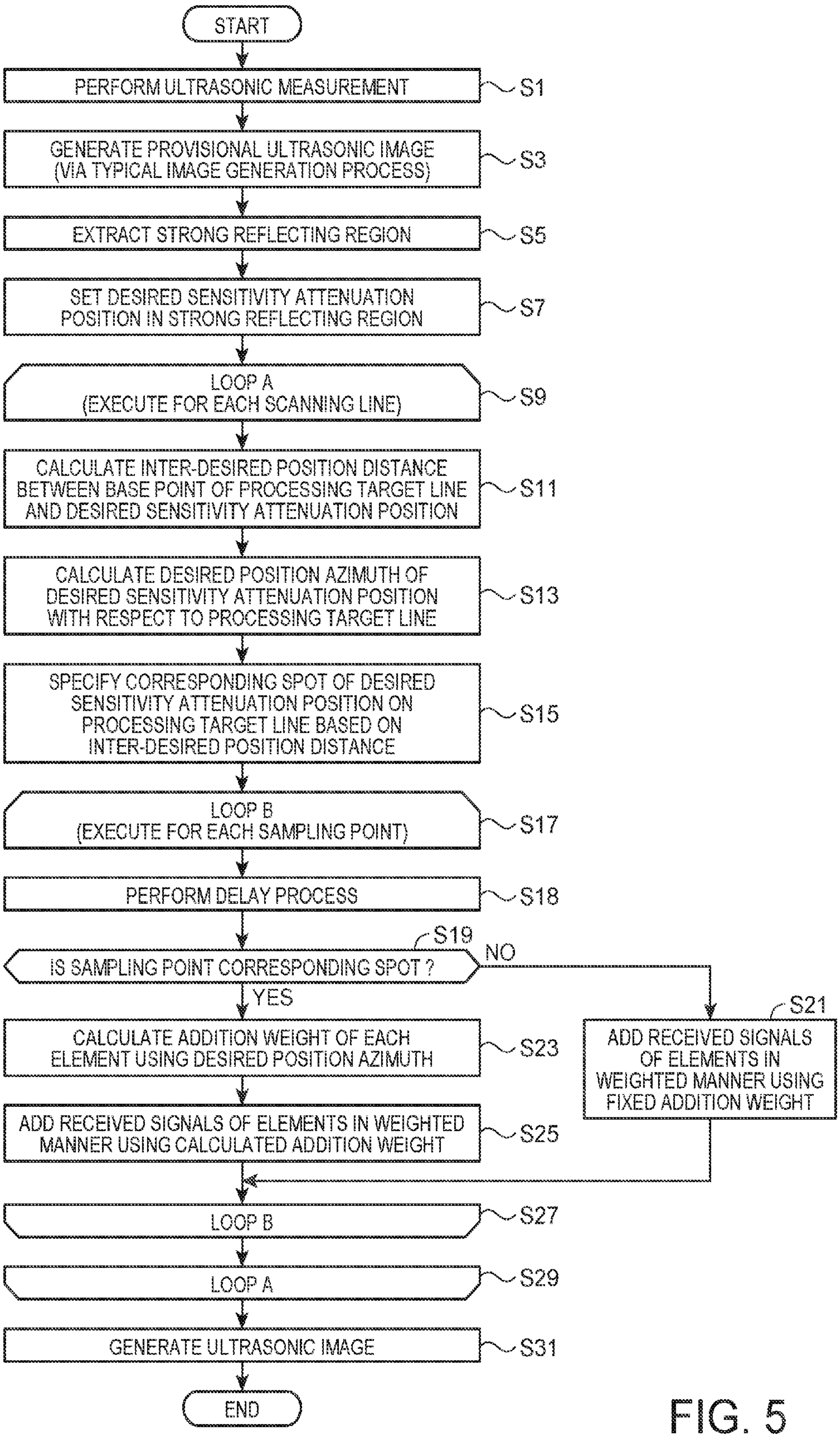

START
PERFORM ULTRASONIC MEASUREMENT
S1
GENERATE PROVISIONAL ULTRASONIC IMAGE (VIA TYPICAL IMAGE GENERATION PROCESS)
S3
EXTRACT STRONG REFLECTING REGION
S5
SET DESIRED SENSITIVITY ATTENUATION POSITION IN STRONG REFLECTING REGION
S7
LOOP A (EXECUTE FOR EACH SCANNING LINE)
S9
CALCULATE INTER-DESIRED POSITION DISTANCE BETWEEN BASE POINT OF PROCESSING TARGET LINE AND DESIRED SENSITIVITY ATTENUATION POSITION
S11
CALCULATE DESIRED POSITION AZIMUTH OF DESIRED SENSITIVITY ATTENUATION POSITION WITH RESPECT TO PROCESSING TARGET LINE
S13
SPECIFY CORRESPONDING SPOT OF DESIRED SENSITIVITY ATTENUATION POSITION ON PROCESSING TARGET LINE BASED ON INTER-DESIRED POSITION DISTANCE
S15
LOOP B (EXECUTE FOR EACH SAMPLING POINT)
S17
PERFORM DELAY PROCESS
S18
S19
IS SAMPLING POINT CORRESPONDING SPOT ?
NO
YES
S21
ADD RECEIVED SIGNALS OF ELEMENTS IN WEIGHTED MANNER USING FIXED ADDITION WEIGHT
CALCULATE ADDITION WEIGHT OF EACH ELEMENT USING DESIRED POSITION AZIMUTH
S23
ADD RECEIVED SIGNALS OF ELEMENTS IN WEIGHTED MANNER USING CALCULATED ADDITION WEIGHT
S25
LOOP B
S27
LOOP A
S29
GENERATE ULTRASONIC IMAGE
S31
END

FIG. 5

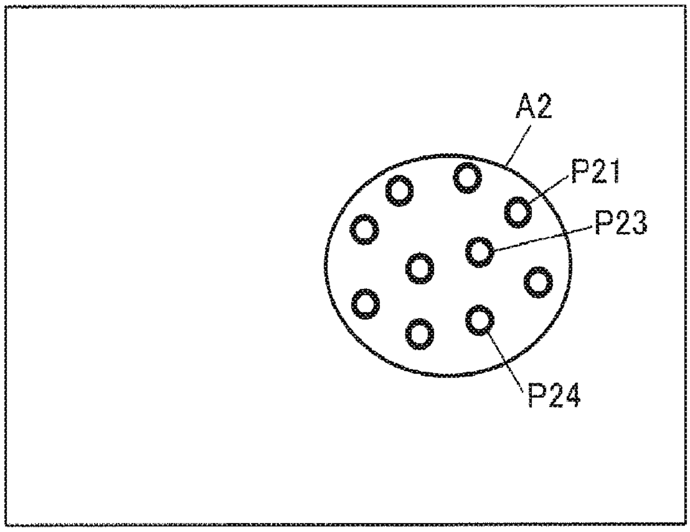


FIG. 6

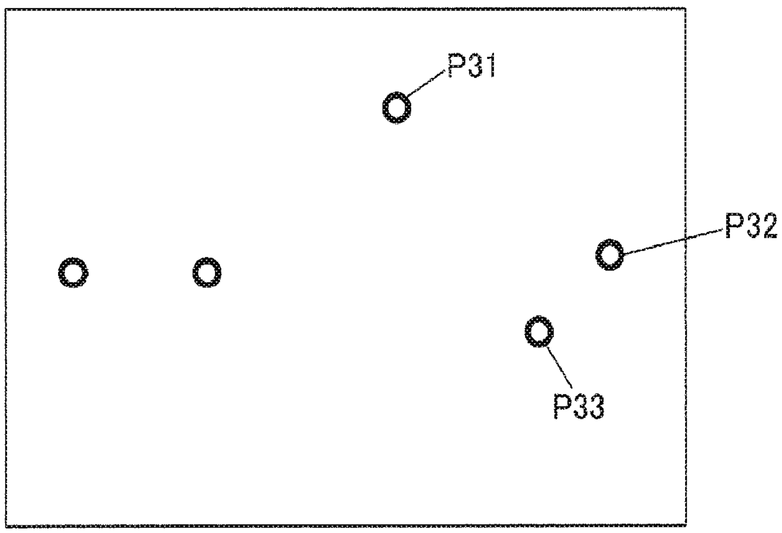


FIG. 7

ULTRASONIC IMAGING DEVICE AND METHOD OF GENERATING ULTRASONIC IMAGE

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention relates to an ultrasonic imaging device generating an ultrasonic image.

[0003] 2. Related Art

[0004] The related art discloses an ultrasonic imaging device that scans with ultrasonic beams via a probe in which multiple ultrasonic elements (oscillators) are arrayed, and images the pattern of the inside of a living body. In an imaging process, ultrasonic waves are transmitted from a body surface of a subject toward the inside of a living body, and a beam forming process, in which received signals (received ultrasonic signals) of the elements for reflected waves are phase added, is performed.

[0005] An artifact (virtual image) which is a problems in generating an ultrasonic image is caused by a side lobe. If a strong reflecting object is present in the direction of the side lobe, reflected waves from the reflecting object are received as undesired waves, thereby causing deterioration in image quality. JP-A-2015-71028 discloses a beam forming process, by which direction constraint is applied and an ultrasonic image does not have sensitivity to undesired waves from directions other than a desired direction, as technology for solving such a problem.

[0006] According to the technology disclosed in JP-A-2015-71028, a weight used to add received signals is determined such that the sensitivities of the undesired waves from the direction other than the desired direction are minimized, and a normal process is performed in the directions other than the desired direction. For this reason, in a case where an artifact occurs due to a side lobe, a process to focus on the artifact part is not performed.

SUMMARY

[0007] An advantage of some aspects of the invention is that an artifact caused by a side lobe is effectively reduced, and deterioration of the quality of an ultrasonic image is prevented.

[0008] A first aspect of the invention is directed to an ultrasonic imaging device that generates an ultrasonic image by performing a beam forming process in which received ultrasonic signals are added, the device including: a position setting unit that sets a desired sensitivity attenuation position in a generated ultrasonic image; and a computational processing unit that executes the beam forming process while performing attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.

[0009] Another aspect of the invention is directed to a method of generating an ultrasonic image in which an ultrasonic image is generated by performing a beam forming process in which received ultrasonic signals are added, the method including: setting a desired sensitivity attenuation position in a generated ultrasonic image; and executing the beam forming process while performing attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.

[0010] According to the first aspect and the like, in the beam forming process in which received ultrasonic signals are added, it is possible to perform attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to a desired sensitivity attenuation position. Accordingly, it is possible to perform the beam forming process while attenuating the signal strength of a received ultrasonic signal arrived from a position inside a living body which is represented by the desired sensitivity attenuation position. As a result, it is possible to effectively reduce an artifact caused by a side lobe, and to prevent deterioration of the quality of an ultrasonic image.

[0011] As a second aspect, the ultrasonic imaging device of the first aspect may be configured such that the beam forming process is performed for each scanning line of ultrasonic waves, and the computational processing unit specifies a corresponding spot of the desired sensitivity attenuation position on a processing target scanning line, and performs the attenuation control when the beam forming process is performed for the corresponding spot.

[0012] According to the second aspect, it is possible to specify a corresponding spot of a desired sensitivity attenuation position on a processing target scanning line. When a beam forming process is performed for the specified corresponding spot, it is possible to perform attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.

[0013] As a third aspect, the ultrasonic imaging device of the second aspect may be configured such that the computational processing unit detects a distance between a base point of the processing target scanning line and the desired sensitivity attenuation position, and specifies the corresponding spot on the processing target scanning line based on the distance.

[0014] According to the third aspect, it is possible to specify a corresponding spot of a desired sensitivity attenuation position on a processing target scanning line based on the distance from a base point of a processing target scanning line to the desired sensitivity attenuation position.

[0015] As a fourth aspect, the ultrasonic imaging device of the second or third aspect may be configured such that the computational processing unit detects the direction of the desired sensitivity attenuation position with respect to the processing target scanning line, calculates an addition weight such that a null point of the receive sensitivity of the received ultrasonic signal faces the direction of the desired sensitivity attenuation position, and adds received ultrasonic signals in a weighted manner using the calculated addition weight.

[0016] According to the fourth aspect, when a beam forming process is performed for a corresponding spot of a desired sensitivity attenuation position on a processing target scanning line, it is possible to calculate an addition weight such that a null point of the receive strength of a received ultrasonic signal faces the direction of the desired sensitivity attenuation position with respect to the processing target scanning line. It is possible to add received ultrasonic signals in a weighted manner using the calculated addition weight.

[0017] As a fifth aspect, the ultrasonic imaging device of the first to fourth aspects may be configured such that the position setting unit sets multiple desired sensitivity attenuation positions in a predetermined region inside the generated ultrasonic image.

[0018] According to the fifth aspect, it is possible to set multiple desired sensitivity attenuation positions in a predetermined region inside a generated ultrasonic image.

[0019] As a sixth aspect, the ultrasonic imaging device of the first to fifth aspects may be configured such that the ultrasonic imaging device further includes a provisional image generation unit that generates a provisional ultrasonic image based on the received ultrasonic signals, and the position setting unit extracts a strong reflecting region from the provisional ultrasonic image, and sets the desired sensitivity attenuation position in the strong reflecting region.

[0020] According to the sixth aspect, it is possible to generate a provisional ultrasonic image, and to set a desired sensitivity attenuation position in a strong reflecting region inside the generated provisional ultrasonic image. Accordingly, it is possible to perform a beam forming process while attenuating the signal strength of received ultrasonic signals reflected by a strong reflecting object in a living body.

[0021] As a seventh aspect, the ultrasonic imaging device of the first to sixth aspects may be configured such that the ultrasonic imaging device further includes a provisional image generation unit that generates a provisional ultrasonic image based on the received ultrasonic signals, and the position setting unit receives an operation input indicating a position in the provisional ultrasonic image, and sets the desired sensitivity attenuation position.

[0022] According to the seventh aspect, it is possible to generate a provisional ultrasonic image, and to set a position in the generated provisional ultrasonic image, which is indicated by an operation input, as a desired sensitivity attenuation position.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

[0024] FIG. **1** is a view illustrating an example of a system configuration of an ultrasonic imaging device.

[0025] FIG. **2** is a view illustrating the principle of a beam forming process of an embodiment.

[0026] FIG. **3** is a graph illustrating the sensitivities of ultrasonic beams.

[0027] FIG. **4** is a block diagram illustrating an example of a functional configuration of an ultrasonic imaging device.

[0028] FIG. **5** is a flowchart illustrating the flow of a process of generating an ultrasonic image.

[0029] FIG. **6** is a view illustrating a setting example in which multiple desired sensitivity attenuation positions are set.

[0030] FIG. **7** is a view illustrating another setting example in which multiple desired sensitivity attenuation positions are set.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0031] FIG. **1** is a view illustrating an example of a system configuration of an ultrasonic imaging device **10** of an embodiment. The ultrasonic imaging device **10** is a device that acquires biological information regarding a subject **2** using ultrasonic waves. The ultrasonic imaging device **10** includes a touch panel **12** that serves as both a unit for displaying measurement results or operation information as images and a unit through which operations are input; a keyboard **14** through which operations are input; an ultrasonic probe **16**; and a processing device **30**.

[0032] A control substrate **31** is mounted in the processing device **30**. The processing device **30** is connected to parts of the device such as the touch panel **12**, the keyboard **14**, and the ultrasonic probe **16** in such a way as to be capable of transmitting to and receiving signals therefrom. The following components are mounted on the control substrate **31**: various integrated circuits such as a central processing unit (CPU) **32**, an application specific integrated circuit (ASIC), and a field programmable gate array (FPGA); a storage medium **33** such as an IC memory or a hard disk; and a communication IC **34** that realizes data communication with external devices. The processing device **30** performs processes including ultrasonic measurement required to acquire biological information by causing the CPU **32** to execute a program stored in the storage medium **33**.

[0033] Specifically, the ultrasonic imaging device **10** performs ultrasonic measurement by transmitting ultrasonic beams to the subject **2** from the ultrasonic probe **16**, and receiving reflected waves via control performed by the processing device **30**. Reflected wave data such as positional information regarding or a change over time in an in vivo structure of the subject **2** by amplifying and processing received signals of the reflected waves. The ultrasonic measurement is repeatedly performed at predetermined intervals. A measurement unit is referred to as a "frame".

[0034] The reflected wave data contains images in modes such as so-called A mode, B mode, M mode, and color Doppler mode. The A mode is a mode of displaying the amplitudes (A mode image) of reflected waves in which a row of sampling points for received signals along a scanning line direction of an ultrasonic beam is represented on a first axis and the received signal strength of a reflected wave at each sampling point is represented on a second axis. The B mode is a mode of displaying a two-dimensional ultrasonic image (B mode image) of an in vivo structure which is visualized by converting the amplitudes (A mode image) of reflected waves, which are obtained by scanning with ultrasonic beams a predetermined probe scanning range, into luminance values.

Principle

[0035] FIG. **2** is a view illustrating the principle of abeam forming process which is performed to generate an ultrasonic image in the embodiment. FIG. **2** schematically illustrates a state in which the ultrasonic probe **16** is brought into contact with a body surface of the subject **2**, and ultrasonic measurement is performed. Multiple ultrasonic elements (not illustrated) are built into the ultrasonic probe **16**. The ultrasonic measurement is performed via a so-called linear scanning method in which ultrasonic beams are transmitted and received along multiple parallel scanning lines L while shifting the position of incidence of an ultrasonic beam in a longitudinal direction of the ultrasonic probe **16** in which the ultrasonic elements are arrayed.

[0036] A main emitted ultrasonic beam represents a main lobe that is emitted along the scanning line L and has a high sound pressure. Due to characteristics of ultrasonic waves, in addition to the main lobe, an ultrasonic beam (side lobe) having a low sensitivity is generated in a direction deviating obliquely from the direction of the scanning line L. If a strong reflecting object is present in the direction of the side lobe, there is a problem in that a virtual image of the strong reflecting object appears in an ultrasonic image. An example of the strong reflecting object is a bone.

[0037] Multiple null points are present in the sensitivities of ultrasonic beams (more specifically, the sensitivities of received reflected waves of ultrasonic waves, but, for the sake of easy understanding, will be described as the sensitivities of ultrasonic beams) in the directions deviating from the scanning lines L. FIG. **3** is a graph illustrating the sensitivity of an ultrasonic beam in each direction with the direction of the scanning line L set to 0 degrees. Points NP (NP-**1** to NP-**8**) where the sensitivity illustrated in FIG. **3** falls rapidly and becomes the minimum represent null points. Accordingly, if the null point NP faces the direction of the strong reflecting object, that is, a side lobe is not emitted in the direction of the strong reflecting object, it is possible to prevent the reception of reflected waves from the strong object.

[0038] In the embodiment, after ultrasonic measurement is performed, first, the position of a strong reflecting object present inside a living body, that is, the position of the strong reflecting object in a generated ultrasonic image is set as a desired sensitivity attenuation position. According to a procedure, for example, a typical image generation process is executed based on the result of the ultrasonic measurement, and a provisional ultrasonic image is generated. Subsequently, a strong reflecting region is extracted from the generated provisional ultrasonic image. The extraction of the strong reflecting region can be performed via a well-known technique. A high luminance region may be extracted from the provisional ultrasonic image, and set as a strong reflecting region. Alternatively, a strong reflecting region may be extracted based on the signal strength of received signals obtained in the ultrasonic measurement. A point in the strong reflecting region is set as a desired sensitivity attenuation position. The method of determining the desired sensitivity attenuation position is not limited to a specific method. One point may be randomly selected from the strong reflecting region, or a central position in the strong reflecting region may be set as the desired sensitivity attenuation position.

[0039] If the desired sensitivity attenuation position has been set, attenuation control for attenuating the signal strength of a received signal corresponding to the desired sensitivity attenuation position is performed, and a beam forming process is executed. Specifically, the beam forming process has all scanning lines as sequential processing targets, and is a process of adding received signals of the elements for each sampling point on a scanning line which is a processing target (hereinafter, referred to as a "processing target line"). In the adding process, apart from a corresponding spot specified on the processing target line which is a spot corresponding to the desired sensitivity attenuation position, received signals of the elements for sampling points are added in a weighted manner using a predetermined fixed addition weight. In contrast, in order for the null point NP to face the direction of the desired sensitivity attenuation position (direction of the strong reflecting object inside the living body which is represented by the desired sensitivity attenuation position), the addition weight used in adding the received signals is dynamically changed, and addition is performed for a sampling point, which is the corresponding spot, in a weighted manner using the changed addition weight. So-called adaptive beam forming is performed.

[0040] The corresponding spot of the desired sensitivity attenuation position on the processing target line represents a sampling point on the processing target line which is affected by reflected waves from the strong reflecting object represented by the desired sensitivity attenuation position, that is, a sampling point among the sampling points on the processing target line at which an arrival time of a reflected wave is the same as that of a reflected wave from the desired sensitivity attenuation position. Specifically, the distance (inter-desired position distance) between a base point of the processing target line which is the position of incidence of an ultrasonic wave and the desired sensitivity attenuation position is calculated. A sampling point on the processing target line, the distance of which from the base point is the inter-desired position distance is specified as the corresponding spot.

[0041] For example, a position P**11** illustrated by a solid circle in FIG. **2** is assumed to be a desired sensitivity attenuation position. If a scanning line L**11** is assumed to be a processing target line, an inter-desired position t_r between a base point B**11** of the processing target line L**11** and the desired sensitivity attenuation position P**11** is calculated. A sampling point on the processing target line L**11**, the distance of which from the base point B**11** is the same distance as the inter-desired position distance t_r for the desired sensitivity attenuation position P**11** is assumed to be a corresponding spot P**13**.

[0042] A beam forming process (adaptive beam forming) for a corresponding spot will be described in detail later. For this process, the direction (desired position azimuth) of the desired sensitivity attenuation position with respect to the processing target line is calculated along with the inter-desired position distance t_r. That is, as illustrated in FIG. **2**, an angle θ between the processing target line L**11** and the direction of the desired sensitivity attenuation position P**11** is calculated as a desired position azimuth, and is used in a beam forming process for the corresponding spot P**13**.

Functional Configuration

[0043] FIG. **4** is a block diagram illustrating an example of a functional configuration of the ultrasonic imaging device **10**. The ultrasonic imaging device **10** includes an ultrasonic wave transmitting and receiving unit **110**; an operation input unit **120**; a display unit **130**; a communication unit **140**; a processing unit **200**; and a storage unit **400**.

[0044] The ultrasonic wave transmitting and receiving unit **110** transmits ultrasonic waves at a pulse voltage output from an ultrasonic measurement control unit **210** of the processing unit **200**. The ultrasonic wave transmitting and receiving unit **110** receives reflected waves of the transmitted ultrasonic waves, and outputs received signals to the ultrasonic measurement control unit **210**. The ultrasonic wave transmitting and receiving unit **110** includes multiple ultrasonic elements, and in FIG. **1**, the ultrasonic probe **16** corresponds to the ultrasonic wave transmitting and receiving unit **110**.

[0045] The operation input unit **120** receives various operation inputs from a user, and outputs an operation input signal, which corresponds to an operation input, to the processing unit **200**. The operation input unit **120** can be realized by a button switch, a lever switch, a dial switch, a track pad, a mouse, or the like. In FIG. **1**, the touch panel **12** and the keyboard **14** correspond to the operation input unit **120**.

[0046] The display unit **130** is realized by a display device such as a liquid crystal display (LCD), and performs various displays based on a display signal from the processing unit **200**. In FIG. **1**, the touch panel **12** corresponds to the display unit **130**.

[0047] The communication unit **140** is a communication device that transmits to and receives data from external devices under control performed by the processing unit **200**. The communication unit **140** is capable of performing communication in various methods, for example, via wired connection using a cable conforming to predetermined communication standards, via connection using an intermediate device referred to as a cradle or the like which also serves as a charger, or via wireless connection using wireless communication. In FIG. **1**, the communication IC **34** corresponds to the communication unit **140**.

[0048] The processing unit **200** is realized by electronic components, for example, microprocessors such as a CPU and a graphics processing unit (GPU), an ASIC, a FPGA, and an IC memory. The processing unit **200** controls the input and output of data between functional units, and calculates biological information regarding the subject **2** by executing various computational processes based on a predetermined program, data, operation input signals from the operation input unit **120**, a received signal of each element, and the like from the ultrasonic wave transmitting and receiving unit **110**. In FIG. **1**, the processing device **30** and the control substrate **31** correspond to the processing unit **200**.

[0049] The processing unit **200** includes the ultrasonic measurement control unit **210**; an image generation unit **230**; and a desired sensitivity attenuation position setting unit **250**.

[0050] The ultrasonic measurement control unit **210** forms the ultrasonic measurement unit **20** together with the ultrasonic wave transmitting and receiving unit **110**. The ultrasonic measurement unit **20** performs ultrasonic measurement. The ultrasonic measurement control unit **210** controls a transmission timing of an ultrasonic pulse from the ultrasonic wave transmitting and receiving unit **110**, and generates and outputs a pulse voltage to the ultrasonic wave transmitting and receiving unit **110** at the transmission timing. The ultrasonic measurement control unit **210** adjusts an output timing of a pulse voltage to each element by performing a transmission delay process. The ultrasonic measurement control unit **210** amplifies and filters the received signal of each element input from the ultrasonic wave transmitting and receiving unit **110**, and outputs the processed received signal (measurement result) of each element to the image generation unit **230**.

[0051] The image generation unit **230** generates an ultrasonic image based on the received signals of the elements input from the ultrasonic measurement control unit **210**. The image generation unit **230** includes a desired position relationship calculation unit **231**; a corresponding spot specifying unit **233**; and a beam forming processing unit **240**.

[0052] The desired position relationship calculation unit **231** calculates the inter-desired position distance t_r between a base point of a processing target line and a desired sensitivity attenuation position, and calculates a desired position azimuth θ of the desired sensitivity attenuation position with respect to the processing target line.

[0053] The corresponding spot specifying unit **233** specifies a corresponding spot of the desired sensitivity attenuation position on the processing target line based on the inter-desired position distance t_r.

[0054] The beam forming processing unit **240** includes a delay processing unit **241**; a weight calculation unit **243**; and a weighted addition unit **245**. The beam forming processing unit **240** performs a beam forming process for each processing target line.

[0055] The delay processing unit **241** performs a delay process in which the received signal of each element is multiplied by a delay of a predetermined delay time D_m for the element. The received signal of each element after the delay process is output to the beam forming processing unit **240**.

[0056] The weight calculation unit **243** calculates an addition weight used to perform a beam forming process for a corresponding spot, based on the desired position azimuth θ. The beam forming process for a corresponding spot is performed in such a way that the weighted addition unit **245** adds the received signals of the elements after the delay process in a weighted manner using the addition weight calculated by the weight calculation unit **243**.

[0057] The calculation of an addition weight will be described. If an addition weight of each element is assumed to be W_m, an output z [n] of the weighted addition unit **245** is the result of multiplying a received signal x_m [n−D_m [n]] of each element after the delay process, which is input from the delay processing unit **241**, by the addition weight W_m of the element, and adding the resultants. The output z [n] is represented by Expression (1). m represents the number of elements (channels). In the embodiment, an addition weight is calculated per element. If a group of multiple elements form one channel, and transmit and receive ultrasonic waves, the ultrasonic measurement control unit **210** outputs a received signal for each channel. In this case, an addition weight for each channel is calculated, and a received signal of each channel is multiplied by the addition weight. n represents the total number of samplings, and x_m [n] represents a received signal of an m^{th} element for a sampling point n.

$$z[n] = \sum_{m=0}^{M-1} w_m[n] x_m[n - D_m[n]] \tag{1}$$

[0058] If Expression (1) is represented by vectors, Expression (1) is converted into Expressions (2) and (3). H represents a complex conjugate transpose, and * represents a complex conjugate.

$$z[n] = w[n]^H X[n] \tag{2}$$

$$w[n] = \begin{bmatrix} w_0^*[n] \\ w_1^*[n] \\ \vdots \\ w_{M-1}^*[n] \end{bmatrix} \tag{3}$$

[0059] A correlation matrix R [n] is given by Expressions (4) and (5).

$$R[N]E[X[N]X[N]^T] \quad (4)$$

$$E[|Z[N]|^2]=W[N]^H R[N]W[N] \quad (5)$$

[0060] An addition weight used to perform beam forming on a corresponding spot is a value that minimizes a variance of z [n] in Expressions (4) and (5), and is obtained by solving a constrained minimization problem represented by Expressions (6) and (7). If a Lagrange undetermined multiplier method is used, an addition weight of each element is represented by Expression (8).

$$\min_{w[m]} w[n]^H R[n] w[n] \quad (6)$$

$$\text{subject to } w[n]^H a = H \quad (7)$$

$$w[n] = \frac{R[n]^{-1} a}{a^H R[n]^{-1} a} H^* \quad (8)$$

[0061] a presents a steering vector, and H represents a constrained response vector. In the embodiment, phasing is already performed, and thus, the direction of a desired wave (main lobe) is assumed to be 0 degrees. Since the null point NP is at the desired position azimuth θ, the direction of an undesired wave is set at θ, and constrained conditions represented by Expressions (9), (10), and (11) are applied.

$$a = [\, a_0 \quad a_\theta \,] \quad (9)$$

$$a_\theta = (\, 1 \quad e^{-j\pi sin(\theta)} \quad e^{-j2\pi sin(\theta)} \quad \ldots \quad e^{-j(M-1)\pi sin(\theta)} \,) \quad (10)$$

$$H = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad (11)$$

[0062] The description returns to FIG. **4**. The weighted addition unit **245** adds the received signals of the elements for sampling points apart from corresponding spots in a weighted manner using the fixed addition weight, and adds the received signals of the elements for the corresponding spots in a weighted manner using the addition weight calculated by the weight calculation unit **243**.

[0063] The desired sensitivity attenuation position setting unit **250** generates a provisional ultrasonic image, extracts a strong reflecting region, and sets a desired sensitivity attenuation position in the generated ultrasonic image by selecting one point in the strong reflecting region.

[0064] The storage unit **400** is realized by a storage medium such as an IC memory, a hard disk, or an optical disk. The storage unit **400** stores in advance a program that realizes various functions of the ultrasonic imaging device **10** by operating the ultrasonic imaging device **10**, and data used in the execution of the program, or temporarily stores data whenever processed. In FIG. **1**, the storage medium **33** mounted on the control substrate **31** corresponds to the storage unit **400**. Connection between the processing unit **200** and the storage unit **400** is not limited to connection via an internal bus circuit inside the device, and may be realized by a communication line such as a local area network (LAN) or Internet. In this case, the storage unit **400** may be realized by an external storage device separate from the ultrasonic imaging device **10**.

[0065] The storage unit **400** stores an image generation program **410**, reflected wave data **420**, desired sensitivity attenuation position data **430**, and the like.

[0066] The processing unit **200** realizes the functions of the ultrasonic measurement control unit **210**, the image generation unit **230**, the desired sensitivity attenuation position setting unit **250**, and the like by reading and executing the image generation program **410**. If these functional units are realized by hardware such as electronic circuits, it is possible to omit a portion of programs for realizing the functions.

[0067] The reflected wave data **420** stores reflected wave data obtained via ultrasonic measurement repeated for each frame. The reflected wave data **420** contains data of a B mode image for each frame which is an ultrasonic image. The desired sensitivity attenuation position data **430** stores desired sensitivity attenuation positions set by the desired sensitivity attenuation position setting unit **250**.

Flow of Process

[0068] FIG. **5** is a flowchart illustrating the flow of a process of generating an ultrasonic image in the embodiment. If a user brings the ultrasonic probe **16** into contact with a body surface, and inputs a predetermined measurement start operation, the process described herein is started. The processing unit **200** operates each unit of the ultrasonic imaging device **10** by reading the image generation program **410** from the storage unit **400** and executing the image generation program **410**. As a result, the process can be realized.

[0069] First, the ultrasonic measurement unit **20** performs ultrasonic measurement (Step S**1**). The image generation unit **230** generates a provisional ultrasonic image by performing a typical image generation process as a provisional image generation unit (Step S**3**). The typical image generation process is a process in which an ultrasonic image is generated via a technique in the related art. In abeam forming process, a fixed addition weight is used for all sampling points on each scanning line. Specifically, first, the delay processing unit **241** performs a delay process on a received signal of each element obtained from the ultrasonic measurement in Step S**1**. The weighted addition unit **245** uses the fixed addition weight as the addition weight W_m of each element, and adds the received signals of the elements after the delay process in a weighted manner according to Expression (1).

[0070] Subsequently, the desired sensitivity attenuation position setting unit **250** extracts a strong reflecting region from the provisional ultrasonic image (Step S**5**), and sets one desired sensitivity attenuation position in the strong reflecting region (Step S**7**).

[0071] If the desired sensitivity attenuation position is set, the beam forming process is performed by repeating the process of a loop A for each scanning line (Steps S**9** to S**29**).

[0072] In the loop A, first, the desired position relationship calculation unit **231** calculates the inter-desired position distance t_r between a base point of a processing target line and a desired sensitivity attenuation position (Step S**11**), and calculates the desire position azimuth θ of the desired sensitivity attenuation position with respect to the processing target line (Step S**13**). The corresponding spot specifying unit **233** specifies a corresponding spot of the desired sensitivity attenuation position on the processing target line based on the inter-desired position distance t_r calculated in Step S**11** (Step S**15**).

[0073] Subsequently, sampling is performed during a predetermined length of time for the processing target line using the results of the ultrasonic measurement performed in Step S1, and the process of a loop B is performed for each sampling point (Steps S**17** to S**27**).

[0074] In the loop B, first, the delay processing unit **241** performs a delay process in which a received signal of each element is multiplied by a delay of the delay time D_m (Step S**18**). Subsequently, the process diverges according to whether a sampling point is the corresponding spot. If the sampling point is not the corresponding spot (Step S**19**: NO), the weighted addition unit **245** uses a fixed addition weight as the addition weight W_m of each element, and adds the received signals of the elements after the delay process in Step S**18** in a weighted manner according to Expression (1) (Step S**21**). In contrast, if the sampling point is the corresponding spot (Step S**19**: YES), the weight calculation unit **243** calculates an addition weight of each element in the aforementioned manner using the desired position azimuth θ calculated in Step S**13** (Step S**23**). The weighted addition unit **245** adds the received signals of the elements after the delay process in Step S**18** in a weighted manner using the addition weight, which is calculated in Step S**23**, as the addition weight W_m of each element according to Expression (1) (Step S**25**).

[0075] If the process of the loop B is repeated, and the sampling for the processing target line ends, the process of the loop A for the processing target line ends. If the process of the loop A is performed for all the scanning lines which are processing targets, an ultrasonic image is generated by performing a necessary process on the obtained output z [n] of each sampling point (Step S**31**), and the process ends. The generated ultrasonic image is suitably controlled and displayed on the display unit **130**.

[0076] As described above, according to the embodiment, it is possible to generate a provisional ultrasonic image in advance, to extract a strong reflecting region therefrom, and to set a desired sensitivity attenuation position in the strong reflecting region. When a beam forming process is performed for a corresponding spot of a desired sensitivity attenuation position on a processing target line, it is possible to calculate an addition weight for the null point NP to face the direction of the desired sensitivity attenuation position, and to add in a weighted manner a received signal of each element using the calculated addition weight. Accordingly, it is possible to perform the beam forming process while reliably attenuating the signal strength of a received signal arrived from a strong reflecting object inside a living body which is represented by the desired sensitivity attenuation position. As a result, it is possible to effectively reduce an artifact caused by a side lobe, and to prevent deterioration of the quality of an ultrasonic image.

[0077] The invention is not limited to the configuration of the embodiment in which a desired sensitivity attenuation position is automatically set in a strong reflecting region extracted from a provisional ultrasonic image. Alternatively, a desired sensitivity attenuation position may be manually set according to an operation input performed by a user. For example, the setting of a desired sensitivity attenuation position may be realized by performing control to display a provisional ultrasonic image, which is generated in Step S**3** illustrated in FIG. **5**, on the display unit **130**, and receiving an operation of designating one point in the provisional ultrasonic image via the operation input unit **110**. Alternatively, instead of a process of extracting a strong reflecting region, a user may manually designate the range of a strong reflecting region in a provisional ultrasonic image. A strong reflecting region may be extracted from a captured image of the same site obtained via a computed tomography (CT) scan, magnetic resonance imaging (MRI), or the like, and a desired sensitivity attenuation position may be set therein.

[0078] The number of desired sensitivity attenuation positions is not limited to one. Alternatively, multiple desired sensitivity attenuation positions may be set. FIGS. **6** and **7** are views illustrating setting examples in which multiple desired sensitivity attenuation positions are set. FIG. **6** illustrates a mode in which multiple desired sensitivity attenuation positions P**21**, P**22**, P**23**, . . . are set in a strong reflecting region A**2**. A predetermined number of multiple desired sensitivity attenuation positions P**21**, P**22**, P**23**, . . . may be automatically set, or may be manually designated and set by a user.

[0079] In contrast, as illustrated in FIG. **7**, multiple desired sensitivity attenuation positions P**31**, P**32**, P**33**, . . . may be discretely set in a generated ultrasonic image. Also, in this case, the desired sensitivity attenuation positions P**31**, P**32**, P**33**, . . . may be manually designated and set by a user. Alternatively, in a case where multiple strong reflecting regions are extracted from a provisional ultrasonic image, one or a predetermined number of desired sensitivity attenuation positions may be automatically set in each of the strong reflecting regions.

[0080] In a case where multiple desired sensitivity attenuation positions are set, an addition weight is calculated such that the null point NP faces the direction of each of the desired sensitivity attenuation positions. As illustrated in FIG. **3**, multiple null points NP are present. In the modification example, an addition weight is calculated such that each desired sensitivity attenuation position faces a separate null point NP. Specifically, when calculating an addition weight according to Expression (8), the weight calculation unit **243** applies constrained conditions represented by Expressions (12), (13), and (14) in which the direction of an undesired wave is set at θ_k, instead of the constrained conditions represented by Expressions (9), (10), and (11). k represents the number of desired sensitivity attenuation positions.

$$a = [\, a_0 \;\; a_{\theta 1} \;\; a_{\theta 2} \;\; \ldots \;\; a_{\theta k} \,] \tag{12}$$

$$a_{\theta k} = (\, 1 \;\; e^{-j\pi sin(\theta k)} \;\; e^{-j2\pi sin(\theta k)} \;\; \ldots \;\; e^{-j(M-1)\pi sin(\theta k)} \,) \tag{13}$$

$$H = \begin{bmatrix} 1 \\ H_1 \\ H_2 \\ \vdots \\ H_k \end{bmatrix} \tag{14}$$

where $H_1 = 1,\ H_i = 0 (1 < i \leqq k)$

[0081] According to the modification example, when a beam forming process is performed for a corresponding spot of each desired sensitivity attenuation position on a processing target line, it is possible to calculate an addition weight for the null points NP to respectively face the directions of the desired sensitivity attenuation positions, and to add a received signal of each element in a weighted manner using the calculated addition weight. Accordingly, it is possible to perform the beam forming process while reliably attenuating the signal strength of the received signal corresponding to each desired sensitivity attenuation position, and to obtain the same effects as those in the embodiment. As illustrated in FIG. **6**, in a case where multiple desired sensitivity attenuation positions are set in a strong reflecting region inside a generated ultrasonic image, it is possible to concentrate the null points NP in the strong reflecting region, and thus, it is possible to effectively reduce the effects of reflected waves from the corresponding reflecting object, and to prevent the occurrence of a virtual image.

[0082] In the embodiment, adaptive beam forming is exemplified as a technique by which the null point NP faces the direction of a desired sensitivity attenuation position; however, the invention is not limited to the adaptive beam forming. For example, it is possible to calculate an addition weight using Schelkunoff array polynomial for the null point NP to face the direction of a desired sensitivity attenuation position.

[0083] In the embodiment, ultrasonic measurement is performed via a linear scanning method. Alternatively, the invention can be also applied similarly in a case in which scanning is performed via other methods such as sector scanning and offset sector scanning.

[0084] The entire disclosure of Japanese Patent Application No. 2015-230321 filed on Nov. 26, 2015 is expressly incorporated by reference herein.

What is claimed is:

1. An ultrasonic imaging device that generates an ultrasonic image by performing abeam forming process in which received ultrasonic signals are added, the device comprising:

a position setting unit that sets a desired sensitivity attenuation position in a generated ultrasonic image; and

a computational processing unit that executes the beam forming process while performing attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.

2. The ultrasonic imaging device according to claim **1**,

wherein the beam forming process is performed for each scanning line of ultrasonic waves, and

wherein the computational processing unit specifies a corresponding spot of the desired sensitivity attenuation position on a processing target scanning line, and performs the attenuation control when the beam forming process is performed for the corresponding spot.

3. The ultrasonic imaging device according to claim **2**,

wherein the computational processing unit detects a distance between a base point of the processing target scanning line and the desired sensitivity attenuation position, and specifies the corresponding spot on the processing target scanning line based on the distance.

4. The ultrasonic imaging device according to claim **2**,

wherein the computational processing unit detects the direction of the desired sensitivity attenuation position with respect to the processing target scanning line, calculates an addition weight such that a null point of the receive sensitivity of the received ultrasonic signal faces the direction of the desired sensitivity attenuation position, and adds received ultrasonic signals in a weighted manner using the calculated addition weight.

5. The ultrasonic imaging device according to claim **1**,

wherein the position setting unit sets multiple desired sensitivity attenuation positions in a predetermined region inside the generated ultrasonic image.

6. The ultrasonic imaging device according to claim **1**, further comprising:

a provisional image generation unit that generates a provisional ultrasonic image based on the received ultrasonic signals,

wherein the position setting unit extracts a strong reflecting region from the provisional ultrasonic image, and sets the desired sensitivity attenuation position in the strong reflecting region.

7. The ultrasonic imaging device according to claim **1**, further comprising:

a provisional image generation unit that generates a provisional ultrasonic image based on the received ultrasonic signals,

wherein the position setting unit receives an operation input indicating a position in the provisional ultrasonic image, and sets the desired sensitivity attenuation position.

8. A method of generating an ultrasonic image in which an ultrasonic image is generated by performing a beam forming process in which received ultrasonic signals are added, the method comprising:

setting a desired sensitivity attenuation position in a generated ultrasonic image; and

executing the beam forming process while performing attenuation control to attenuate the signal strength of a received ultrasonic signal corresponding to the desired sensitivity attenuation position.

* * * * *

专利名称(译)	超声成像装置和产生超声图像的方法		
公开(公告)号	US20170153322A1	公开(公告)日	2017-06-01
申请号	US15/360828	申请日	2016-11-23
[标]申请(专利权)人(译)	精工爱普生株式会社		
申请(专利权)人(译)	SEIKO EPSON CORPORATION		
当前申请(专利权)人(译)	SEIKO EPSON CORPORATION		
[标]发明人	HAYASHI MASAKI		
发明人	HAYASHI, MASAKI		
IPC分类号	G01S7/52 A61B8/14 A61B8/08 A61B8/00 G01S15/02 G01S15/89		
CPC分类号	G01S7/52047 G01S15/02 G01S7/5205 A61B8/5207 A61B8/5269 A61B8/54 A61B8/14 G01S15/89 G01S7/52033 G01S15/8915		
优先权	2015230321 2015-11-26 JP		
外部链接	Espacenet USPTO		

摘要(译)

超声波成像装置的处理单元的超声波测量控制单元与超声波发送和接收单元一起形成超声波测量单元，其执行超声波测量。期望的灵敏度衰减位置设置单元在所生成的超声图像中设置期望的灵敏度衰减位置。图像生成单元通过执行波束形成处理来生成超声波图像，在波束形成处理中添加从超声波测量控制单元输入的元素的接收信号。在波束形成过程中，波束形成处理单元执行衰减控制以衰减对应于所需灵敏度衰减位置的接收超声信号的信号强度。