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(54) ULTRASONIC DIAGNOSTIC APPARATUS AND ULTRASONIC DIAGNOSTIC METHOD

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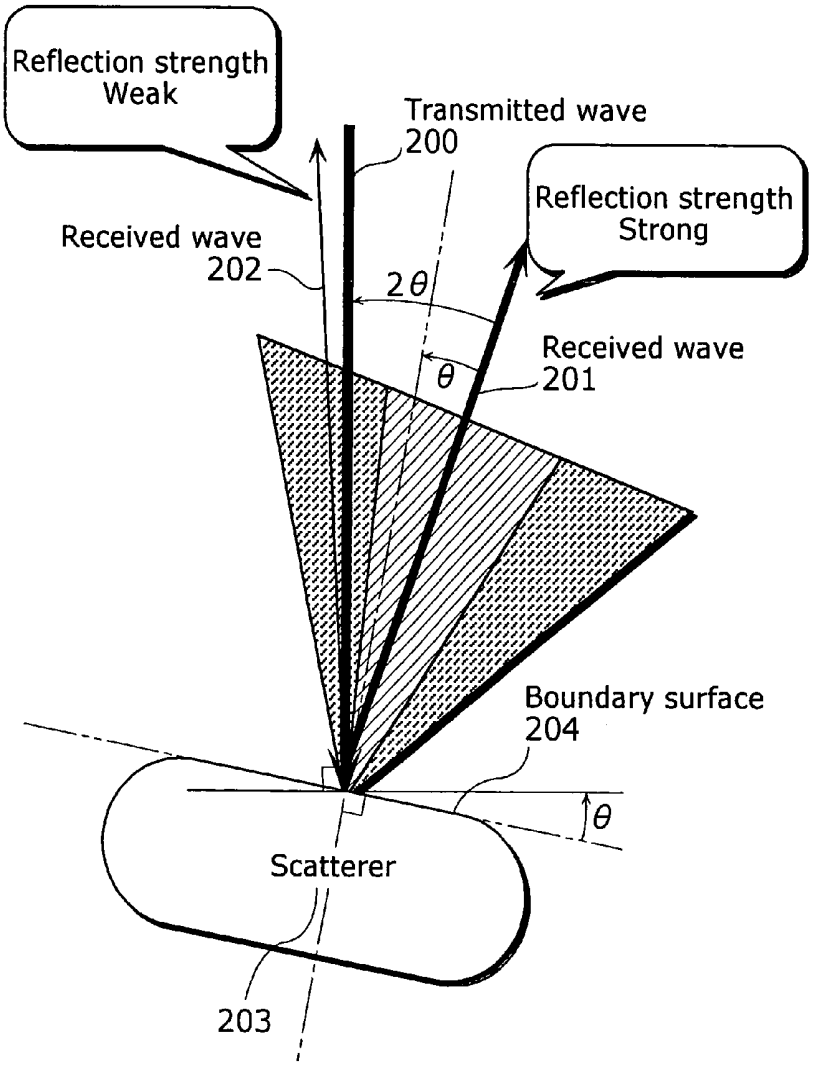
(57) ABSTRACT

In an ultrasonic diagnostic apparatus (**100**) capable of generating an ultrasound image equivalent to one generated by combining images shot from various angles, without causing problems concerning an increased number of hardware pieces and a decreased frame rate, a pulsar (**12**) generates pulse signals for emitting ultrasound based on trigger signals received from a control unit (**11**), and outputs such signals to a group of transducers (**1**) via an amplifier (**13**). The group of transducers (**1**) receives ultrasonic echoes from a scatterer. A buffer (**17**) stores the reflected signals received via a delayer (**14**) and an A/D converter (**16**). A reflection angle detection unit (**18**) specifies a reflection angle and a reflection strength pattern of the reflected signals, and a weighting/addition unit (**15**) performs weighing based on such reflection strength pattern. A detection unit (**19**) performs detection, and a display unit (**20**) displays an ultrasound image and the reflection angle.



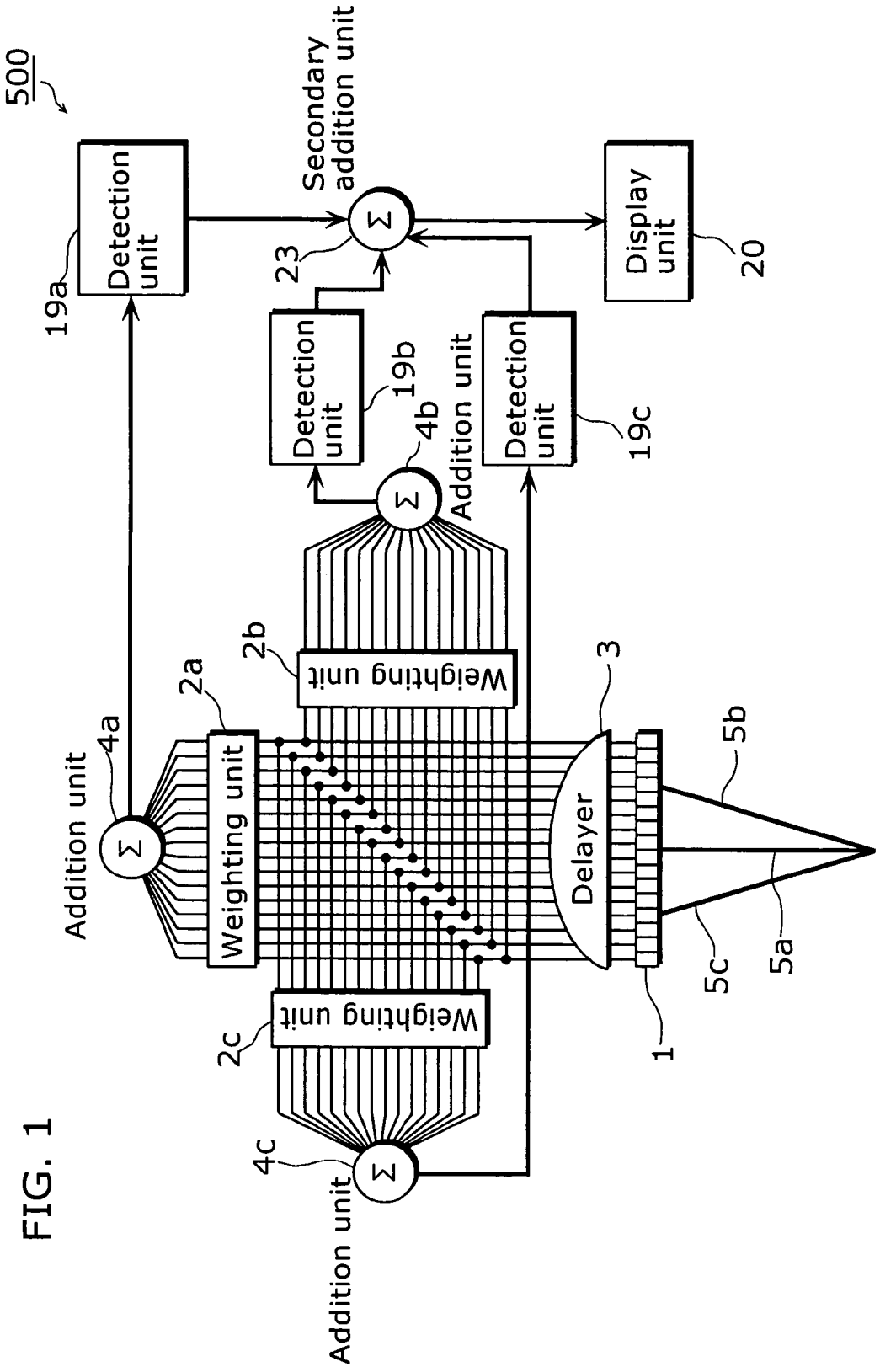

500
Detection unit
19a
Secondary addition unit
23
Σ
Display unit
20
Detection unit
19b
Addition unit
4b
Detection unit
19c
Σ
Weighting unit
2b
2a
3
Addition unit
4a
Σ
Weighting unit
Delayer
5b
5c
5a
1
Weighting unit
2c
4c
Σ
Addition unit

FIG. 1

FIG. 2

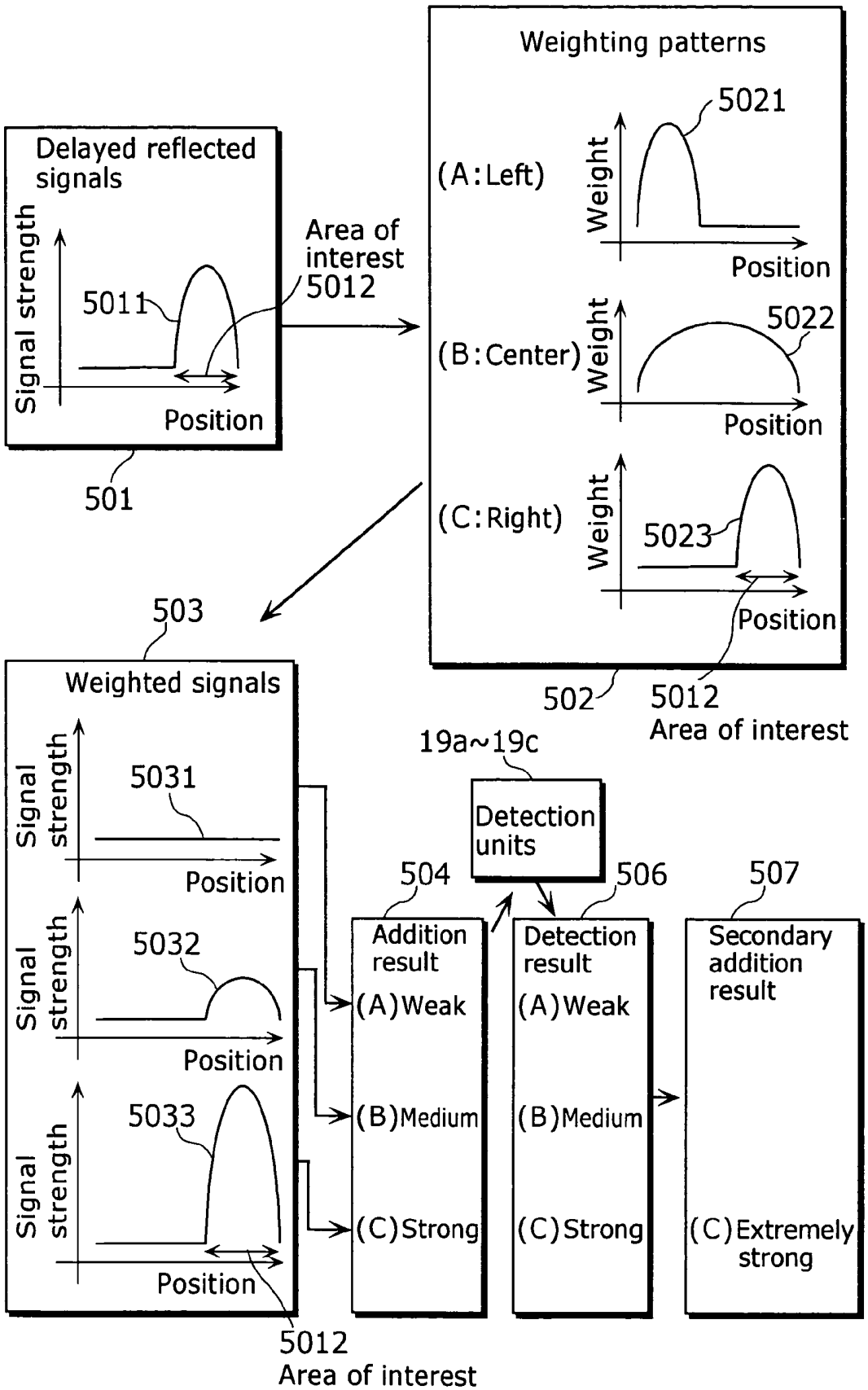

Weighting patterns
5021
(A:Left)
Weight
Position
Delayed reflected signals
Signal strength
5011
Area of interest
5012
Position
(B:Center)
5022
Weight
Position
501
(C:Right)
5023
Weight
Position
503
502
5012
Area of interest
Weighted signals
19a~19c
Signal strength
5031
Position
Detection units
504
506
507
Addition result
Detection result
Secondary addition result
(A)Weak
(A)Weak
5032
Signal strength
Position
(B)Medium
(B)Medium
5033
Signal strength
(C)Strong
(C)Strong
(C)Extremely strong
Position
5012
Area of interest

FIG. 3

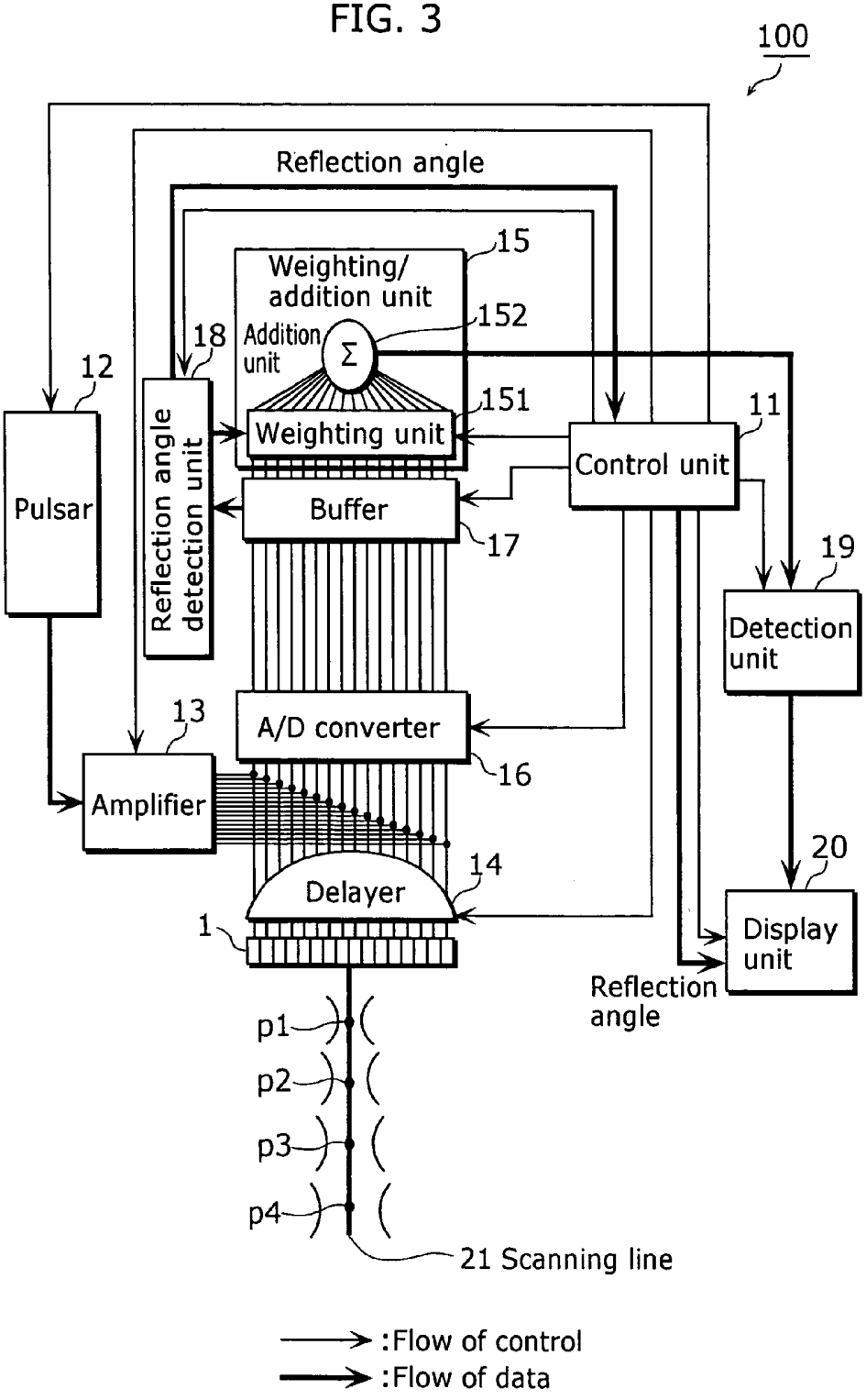

100
Reflection angle
15
Weighting/
addition unit
152
Addition
unit
Σ
18
12
151
11
Pulsar
Reflection angle
detection unit
Weighting unit
Control unit
Buffer
17
19
Detection
unit
13
A/D converter
16
Amplifier
20
14
Delayer
1
Display
unit
Reflection
angle
p1
p2
p3
p4
21 Scanning line
:Flow of control
:Flow of data

FIG. 4

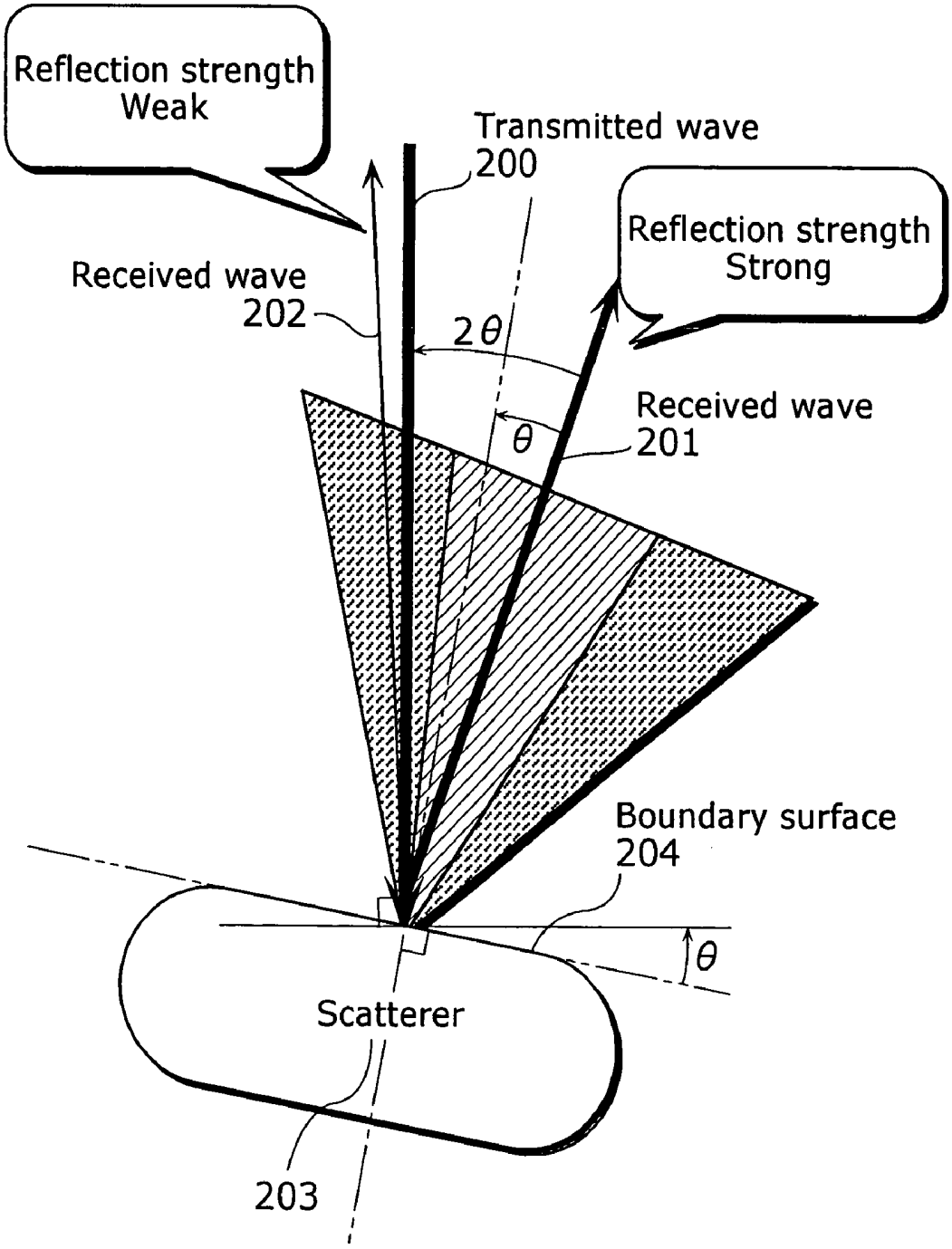

Reflection strength
Weak
Transmitted wave
200
Reflection strength
Strong
Received wave
202
2θ
Received wave
201
θ
Boundary surface
204
θ
Scatterer
203

FIG. 5A

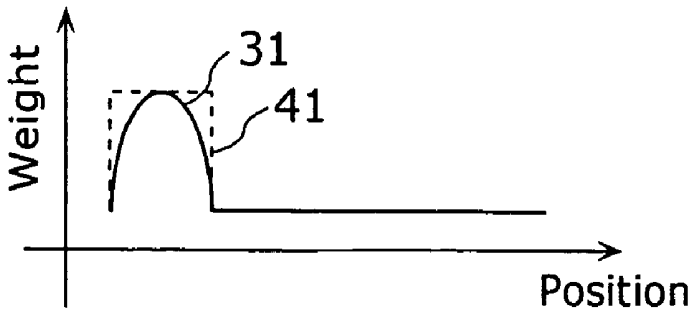


FIG. 5B

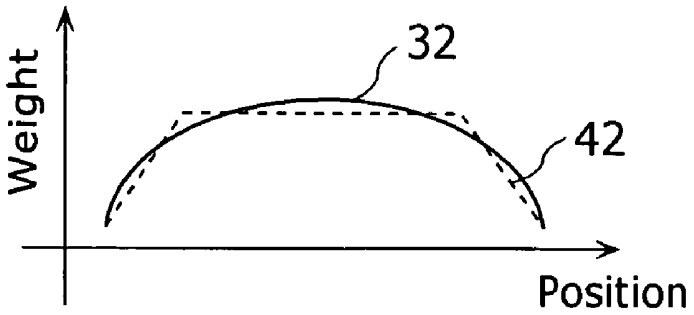


FIG. 5C

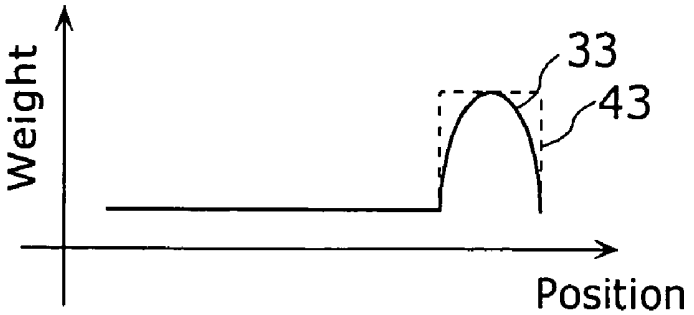


FIG. 6

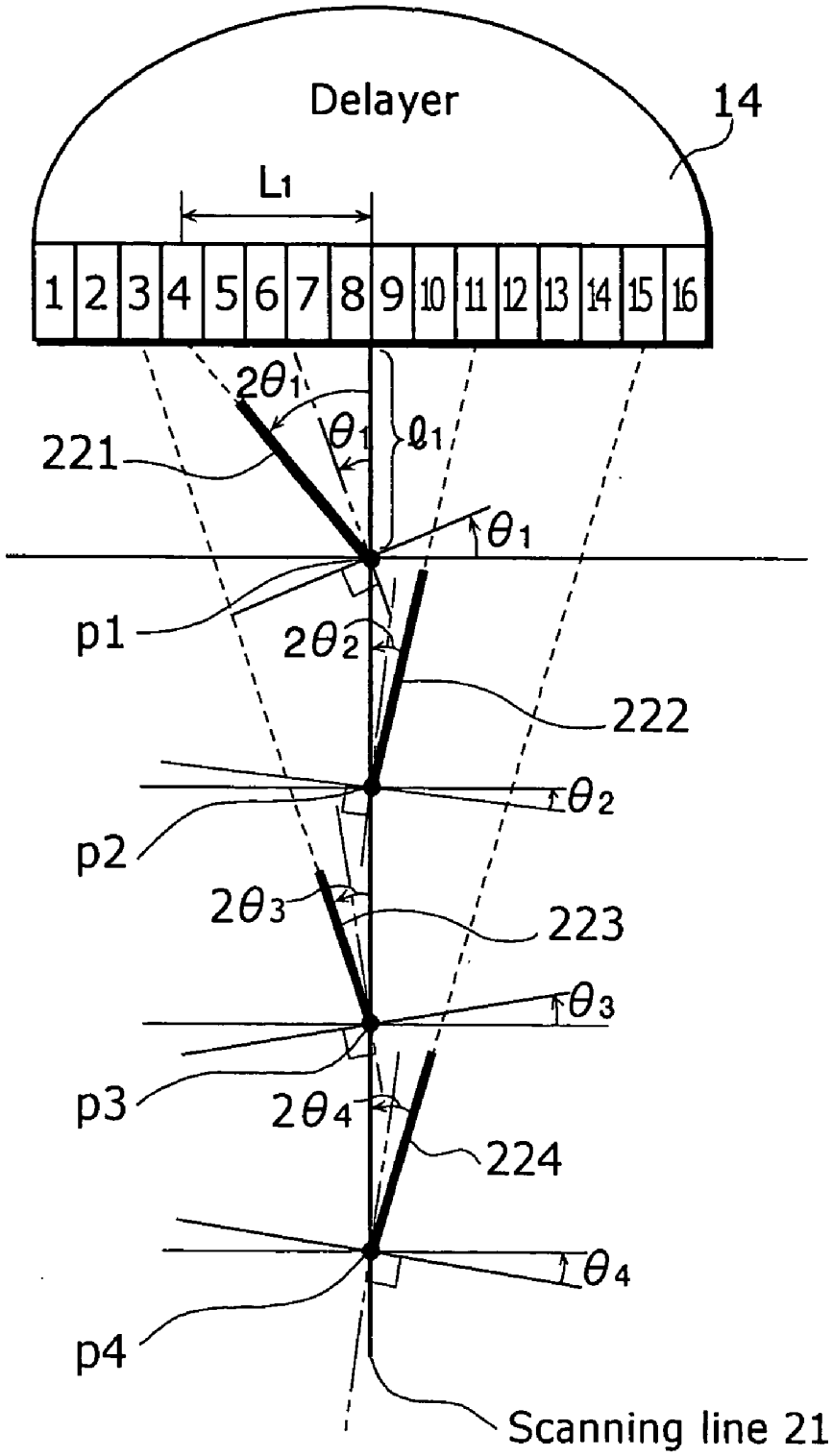

Delayer
14
L1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
2θ1
θ1
ℓ1
221
θ1
p1
2θ2
222
θ2
p2
2θ3
223
θ3
p3
2θ4
224
θ4
p4
Scanning line 21

FIG. 7

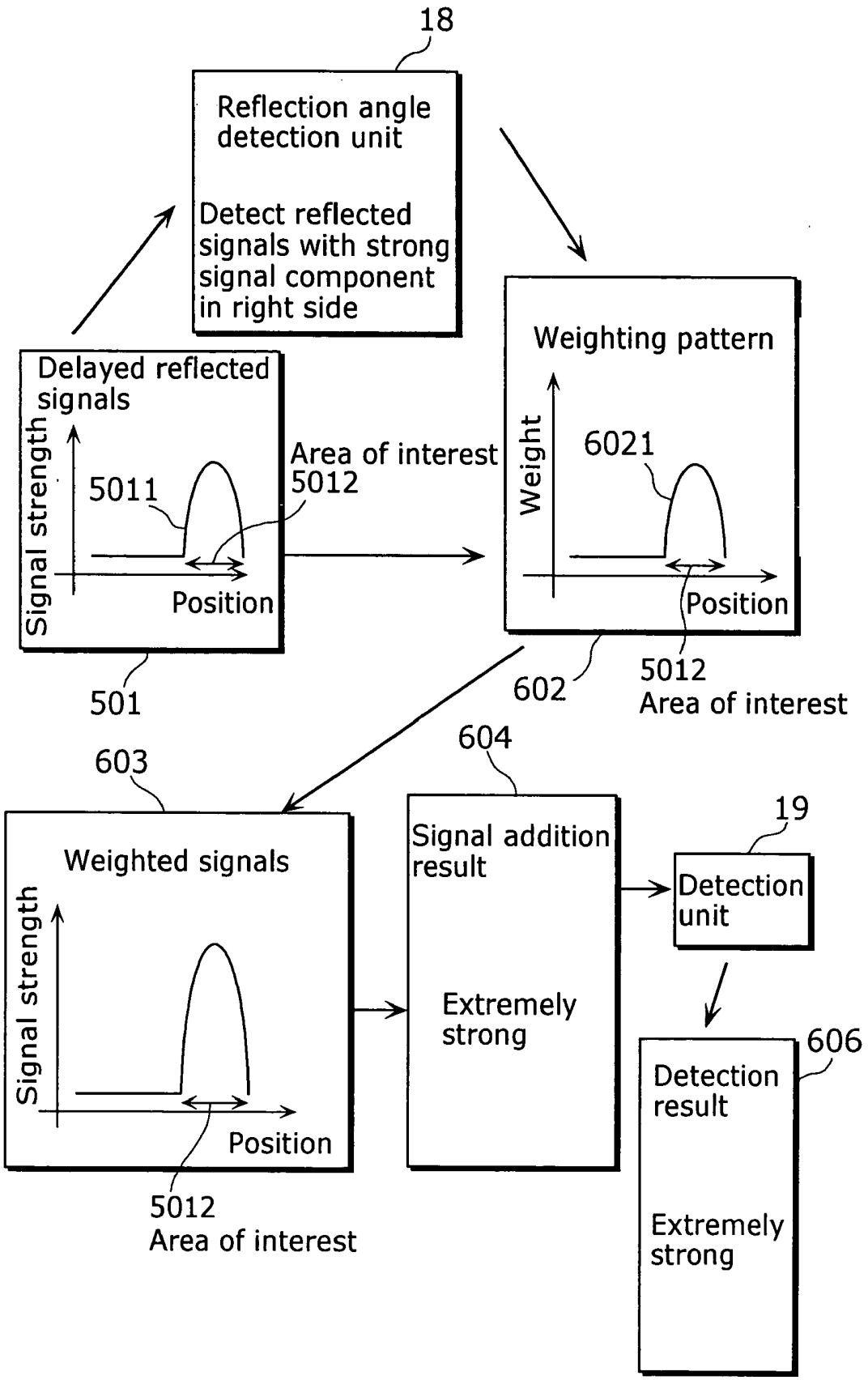

18
Reflection angle detection unit
Detect reflected signals with strong signal component in right side
Delayed reflected signals
Signal strength
5011
Area of interest
5012
Position
501
Weighting pattern
Weight
6021
Position
602
5012
Area of interest
603
Weighted signals
Signal strength
Position
5012
Area of interest
604
Signal addition result
Extremely strong
19
Detection unit
606
Detection result
Extremely strong

FIG. 8

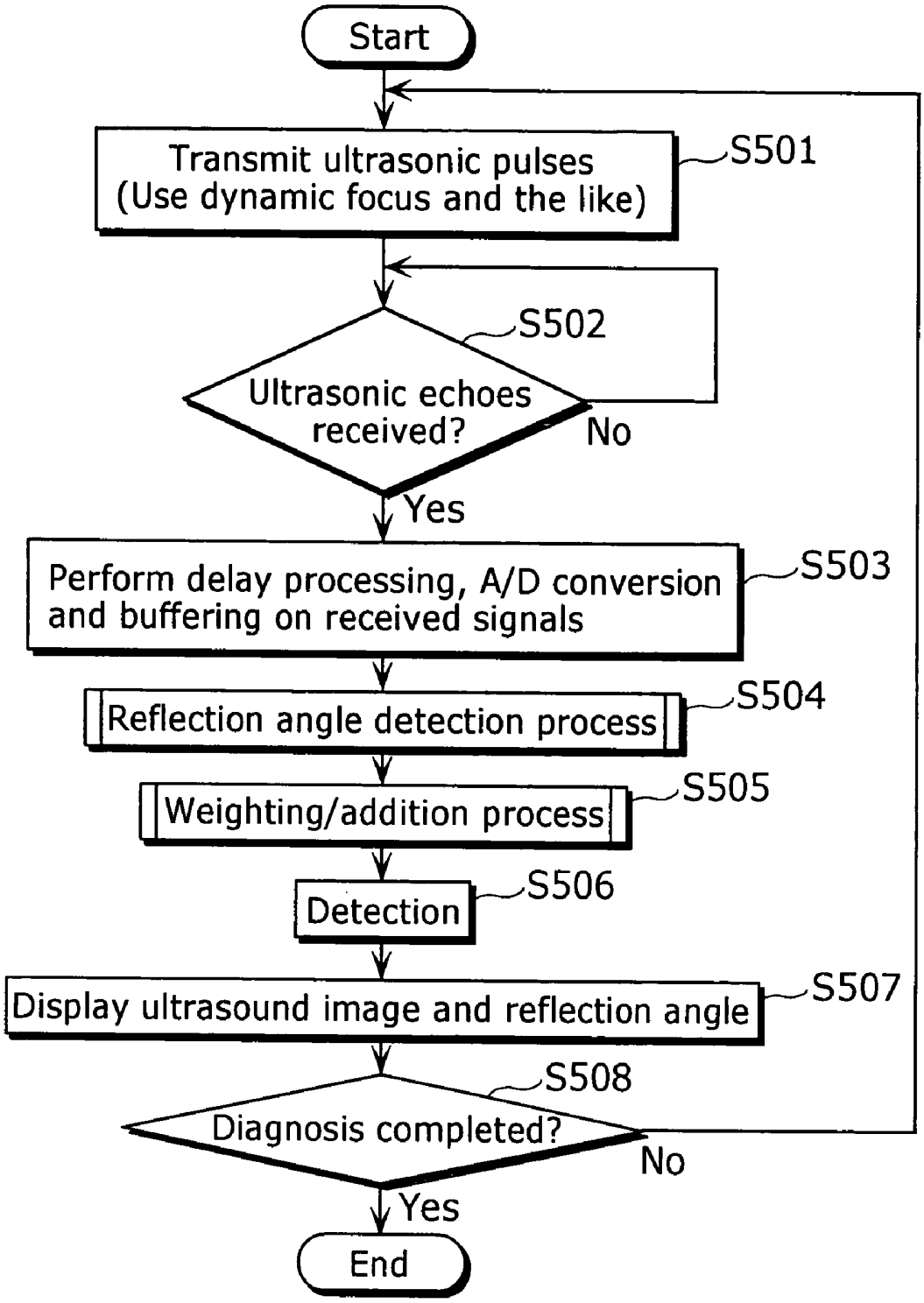

Start
Transmit ultrasonic pulses (Use dynamic focus and the like)
S501
S502
Ultrasonic echoes received?
No
Yes
Perform delay processing, A/D conversion and buffering on received signals
S503
Reflection angle detection process
S504
Weighting/addition process
S505
Detection
S506
Display ultrasound image and reflection angle
S507
S508
Diagnosis completed?
No
Yes
End

FIG. 9

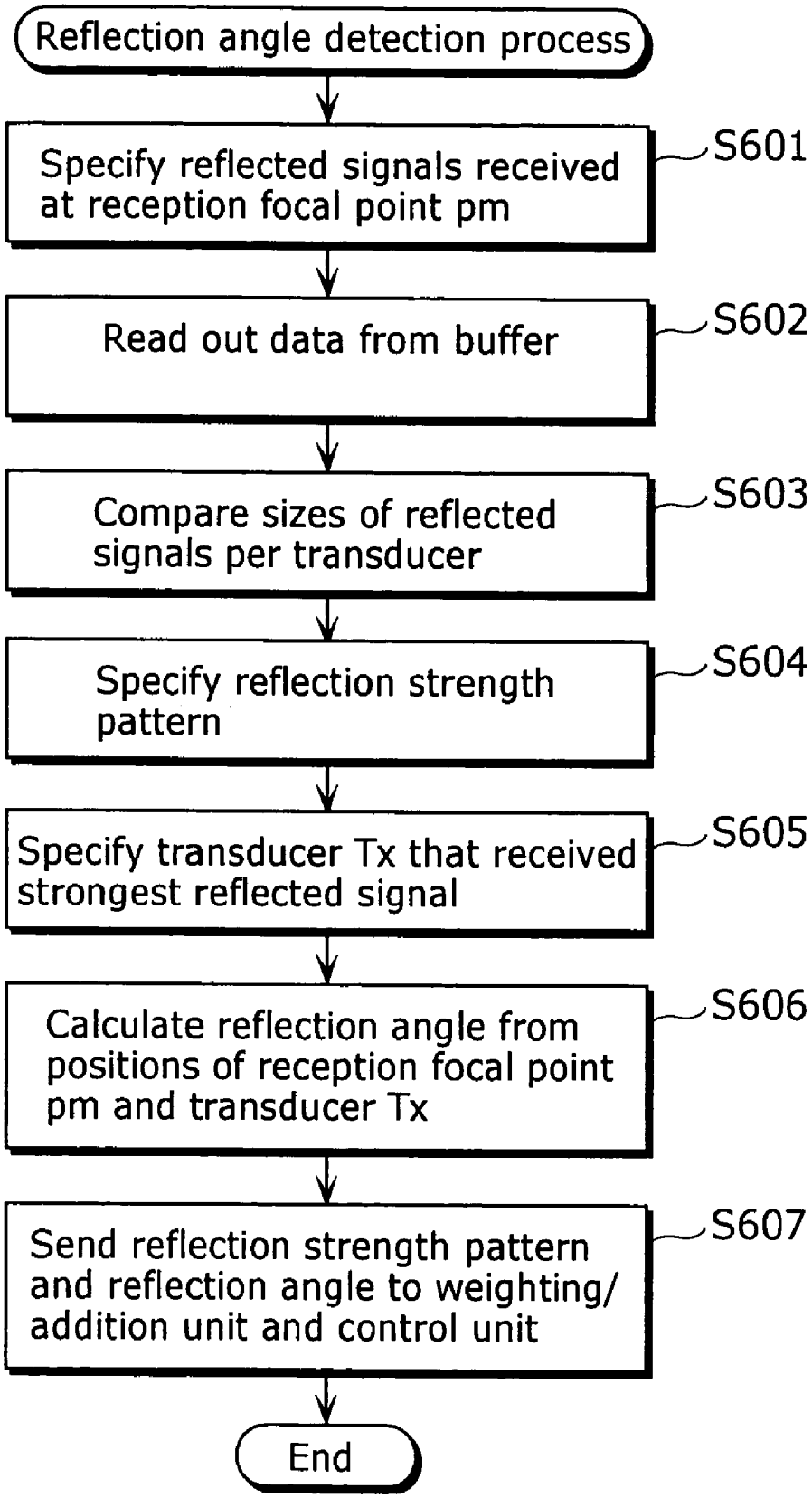
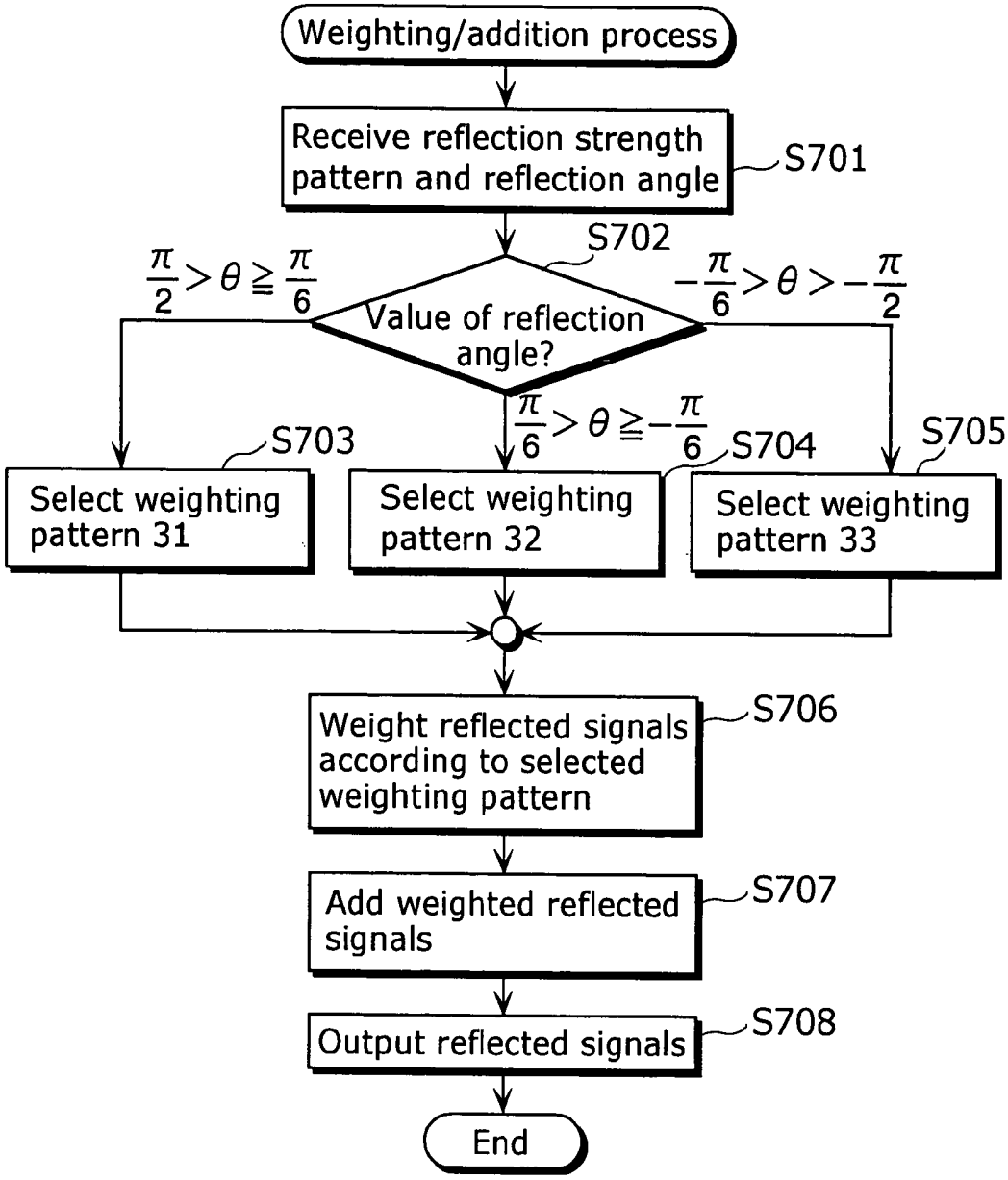

Reflection angle detection process
Specify reflected signals received at reception focal point pm
S601
Read out data from buffer
S602
Compare sizes of reflected signals per transducer
S603
Specify reflection strength pattern
S604
Specify transducer Tx that received strongest reflected signal
S605
Calculate reflection angle from positions of reception focal point pm and transducer Tx
S606
Send reflection strength pattern and reflection angle to weighting/addition unit and control unit
S607
End

FIG. 10


Weighting/addition process
Receive reflection strength pattern and reflection angle
S701
S702
Value of reflection angle?
$\frac{\pi}{2} > \theta \geqq \frac{\pi}{6}$
$-\frac{\pi}{6} > \theta > -\frac{\pi}{2}$
$\frac{\pi}{6} > \theta \geqq -\frac{\pi}{6}$
S703
Select weighting pattern 31
S704
Select weighting pattern 32
S705
Select weighting pattern 33
Weight reflected signals according to selected weighting pattern
S706
Add weighted reflected signals
S707
Output reflected signals
S708
End

ULTRASONIC DIAGNOSTIC APPARATUS AND ULTRASONIC DIAGNOSTIC METHOD

BACKGROUND OF THE INVENTION

[0001] (1) Field of the Invention

[0002] The present invention relates to an ultrasonic diagnostic apparatus that displays an ultrasound image on the basis of an echo signal obtained by transmitting and receiving ultrasound.

[0003] (2) Description of the Related Art

[0004] Ultrasonic diagnostic apparatuses have been widely used as indispensable apparatuses in such a field as clinical medicine, since they are capable of obtaining a two-dimensional (2D) image of soft tissues of a living body without invasion as well as offering a high level of safety to such living body to be examined.

[0005] In recent years, ultrasonic diagnostic apparatuses have been required to be capable of quantitatively calculating the size and cross section of a lesion and the like, since changes in their values are used to evaluate the progression and treatment process of the lesion. Therefore, it is also imperative for ultrasonic diagnostic apparatuses to be capable of extracting the contour and boundary of the lesion which are used to calculate its size and cross section.

[0006] The clearer an image is, the more precisely a contour and a boundary are extracted. An ultrasonic diagnostic apparatus receives ultrasonic echoes reflected back from the boundary surface of a scatterer, and generates an ultrasound image based on such reflected echoes. Therefore, if the boundary surface of such scatterer is inclined, the strength of ultrasonic echoes to be received at the points from which the ultrasound was transmitted is reduced. Because of this reason, it is impossible for the existing ultrasonic diagnostic apparatus to reproduce the distribution of actual signal strengths, and therefore to generate a desirable ultrasound image. In order to solve this problem, an existing ultrasonic diagnostic apparatus combines images shot from various angles, so as to generate one ultrasound image.

[0007] **FIG. 1** is a block diagram showing a functional configuration of an existing ultrasonic diagnostic apparatus **500** that combines ultrasound images shot from various angles (Refer to Japanese Laid-Open Patent application No. 5-115479 for example).

[0008] In this ultrasonic diagnostic apparatus **500**, a group of transducers **1** where plural transducers are arranged receives ultrasonic echoes, and converts them into electric signals, which are then delayed by a delayer **3**. Then, such delayed signals are weighted by weighting units **2***a*, **2***b*, and **2***c* in respective systems (three systems are shown in **FIG. 1**), and the weighted electric signals are added by addition units **4***a*, **4***b* and **4***c* in the respective systems. Accordingly, processing is performed based on three received beams **5***a*, **5***b*, and **5***c*, in appearance, so as to generate an ultrasound image. After this, the electric signals are detected by detection units **19***a*, **19***b*, and **19***c* in the respective systems, and these detected electric signals are combined in a secondary addition unit **23**. Finally, a display unit **20** generates and displays an ultrasound image based on such combined signals.

[0009] **FIG. 2** is a block diagram showing an outline of the processing performed by the existing ultrasonic diagnostic apparatus **500**. First, when the group of transducers **1** receives a group of reflected signals, the delayer **3** delays such received reflected signals. The strength of the resulting reflected signals **501** is strong in the right side. Subsequently, the weighting units **2***a*, **2***b*, and **2***c* weight the reflected signals **501** according to a weighting pattern **502** (a leftward weighting pattern **5021**, a center weighting pattern **5022**, and a rightward weighting pattern **5023**). The weighting according to these three patterns corresponds to the reception of the received beams **5***c*, **5***a*, and **5***b* in **FIG. 1**. By weighting the reflected signals **501** according to the respective weighting patterns, a group of weighted electric signals **503** is obtained.

[0010] As **FIG. 2** shows, a group of signals which has been weighted according to the leftward weighting pattern **5021** includes no signal components as a group of signals **5031**. A group of signals which has been weighted according to the center weighting pattern **5022** is weak in signal strength as a group of signals **5032**. And a group of signals which has been weighted according to the rightward weighting pattern **5023** is enhanced in signal strength as a group of signals **5033**. When the addition units **4***a*, **4***b*, and **4***c* add these signals, an addition result **504** indicates signal components which are strong rightward. Furthermore, when the detection units **19***a*~**19***c* detect the resulting signals, signals to be obtained are ones whose rightward signal components are strong. Then, the secondary addition unit **23** adds a detection result **506**, and signals whose rightward signal components are further stronger are obtained as a secondary addition result **507**.

[0011] As described above, even when most of the ultrasonic echoes are strongly reflected back from a rightward direction, the existing ultrasonic diagnostic apparatus is capable of reliably receiving such reflected ultrasound echoes and generating an ultrasound image.

[0012] However, in order to generate an ultrasound image based on ultrasonic echoes from various directions, either of the following two methods is required: combining plural images which are shot by changing angles at which ultrasonic echoes should be received; and combining plural images which are simultaneously shot from various angles. However, the former method has the problem that a frame rate decreases because of an increased number of times images are shot, whereas the latter method has the problem that more pieces of hardware are required in order to receive reflected signals from various directions all at once.

[0013] The existing ultrasonic diagnostic apparatus **500** solves the former problem about a decreased frame rate, but cannot solve the latter problem about an increased number of required hardware pieces.

SUMMARY OF THE INVENTION

[0014] The present invention has been conceived in view of the above problems, and it is an object of the present invention to provide an ultrasonic diagnostic apparatus capable of generating an ultrasound image which is equivalent in quality to an ultrasound image generated by combining plural images shot from various angles, without causing the above problems about an increased number of hardware pieces and a decreased frame rate.

[0015] In order to achieve the above object, the ultrasonic diagnostic apparatus according to the present invention may be an ultrasonic diagnostic apparatus, comprising: an ultrasound transmitting/receiving unit in which a plurality of transducers are arranged, each of the transducers transmitting ultrasound into an object to be examined, receiving the ultrasound reflected back from inside said object, and converting the reflected ultrasound into an electric signal; a feature detection unit operable to detect a feature of the reflected ultrasound based on the electric signal converted by each of the transducers; a weighting unit operable to weight the electric signal of each of the transducers in a specified manner, depending on the detected feature; and an image generation unit operable to generate an ultrasound image based on the weighted electric signal of each of the transducers. Moreover, in order to achieve the above object, in the above ultrasonic diagnostic apparatus, the feature detection unit may compare signal strengths of the respective electric signals of the transducers, and determine a reflection angle as the feature of the ultrasound, based on a position of one of the transducers specified by said comparison and on a position of a predetermined reception focal point.

[0016] The above configuration enables reflected signals to be weighted by hardware in a single system based on the reflection strength of ultrasonic echoes. Accordingly, it becomes possible to perform weighting with a simpler hardware configuration for performing weighting as well as to circumvent the problem about a decreased frame rate.

[0017] Note that, in order to achieve the above object, it is possible for the present invention to be embodied as an ultrasonic diagnostic method which includes, as its steps, the characteristic constitute elements of the above ultrasonic diagnostic apparatus, and as a program which includes all of such steps. Also, such program can not only be stored in a ROM and the like equipped to the ultrasonic diagnostic apparatus, but also be distributed via recording media such as CD-ROM, and transmission media such as a communication network.

[0018] As described above, since the ultrasonic diagnostic apparatus according to the present invention assigns weights to reflected signals in an appropriate manner according to a reflection angle of ultrasonic echoes. Accordingly, it is not necessary to combine images even when ultrasonic echoes are strongly reflected in a slanting direction, and therefore it becomes possible to simplify an existing hardware configuration required to perform weighting and secondary addition for a plural number of times. Therefore, the present invention is significantly effective at reducing the number of hardware pieces related to transducers which are arranged in a three-dimensional manner. Moreover, the present invention makes it possible for a reflection angle to be visualized as information about tissues of an examined object in the direction of the scatterer.

[0019] Furthermore, the present invention is capable of obtaining, from a single received beam, an image in accordance with the strength of reflected signals, without needing to generate an ultrasound image from plural received beams passing through the same point as required in an existing technique. Accordingly, it is possible to circumvent the problem about a decreased frame rate attributable to receiving beams for a number of times and the problem about an increased number of hardware pieces attributable to receiving beams from a number of angles.

[0020] For further information about the technical background to this application, Japanese Paten application No. 2003-008749 filed on Jan. 16, 2003 is incorporated herein by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings that illustrate a specific embodiment of the invention. In the Drawings:

[0022] **FIG. 1** is a block diagram showing a functional configuration of an existing ultrasonic diagnostic apparatus that combines ultrasound images shot from various angles;

[0023] **FIG. 2** is a block diagram showing an outline of processing performed by the existing ultrasonic diagnostic apparatus;

[0024] **FIG. 3** is a block diagram showing a functional configuration of an ultrasonic diagnostic apparatus according to the present invention;

[0025] **FIG. 4** is a diagram showing an example distribution of strengths of ultrasonic echoes reflected back from a scatterer;

[0026] FIGS. **5**A~**5**C are diagrams showing examples of weighting patterns to be specified by a weighting unit;

[0027] **FIG. 6** is a diagram showing an example method of detecting reflection angles in a reflection angle detection unit;

[0028] **FIG. 7** is a block diagram showing an outline of processing performed in the ultrasonic diagnostic apparatus according to the present invention;

[0029] **FIG. 8** is a flowchart showing a flow of entire processing performed in the ultrasonic diagnostic apparatus according to the present invention;

[0030] **FIG. 9** is a flowchart showing, in detail, an example of the reflection angle detection processing in **FIG. 8**; and

[0031] **FIG. 10** is a flowchart showing, in detail, an example of the weighting/addition processing in **FIG. 8**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0032] The following explains the preferred embodiment according to the present invention with reference to the figures.

[0033] **FIG. 3** is a block diagram showing a functional configuration of an ultrasonic diagnostic apparatus **100** according to the present embodiment. As **FIG. 3** shows, the ultrasonic diagnostic apparatus **100** is an apparatus that generates an ultrasound image by taking into account angles at which ultrasonic echoes are reflected back from a tissue and the like of an object to be examined (to be also referred to as "scatterer" hereinafter). Such ultrasonic diagnostic apparatus **100** is comprised of a control unit **11**, a pulsar **12**, an amplifier **13**, the group of transducers **1**, a delayer **14**, an

A/D converter **16**, a buffer **17**, a weighting/addition unit **15**, a reflection angle detection unit **18**, a detection unit **19**, and a display unit **20**.

[**0034**] The control unit **11**, which is intended for exercising an overall control of the ultrasonic diagnostic apparatus **100**, is equipped with a CPU, a ROM, a RAM, and the like. In particular, the control unit **11** controls timings (e.g. synchronization) at which each unit in the ultrasonic diagnostic apparatus **100** performs processing. Moreover, the control unit **11** outputs trigger signals for controlling timings at which pulse signals generated by the pulsar **12** are outputted. Also, the control unit **11** receives a reflection angle detected by the reflection angle detection unit **18**, and notifies the display unit **20** of the received reflection angle. Furthermore, the control unit **11** outputs, to the delayer **14**, delay control signals used for performing focus processing.

[**0035**] The pulsar **12** generates pulse signals according to the trigger signals outputted from the control unit **11**, and outputs such pulse signals to the amplifier **13**. In this case, taking into account that the number of transducers is "T" ("T" is an arbitrary natural number, which is generally 32, 64, and 128), the control unit **11** outputs, to the delayer **14**, delay control signals that allow ultrasonic echoes to be focused on at least one focal point which is located at a certain depth inside an object to be examined and to which ultrasound shall be transmitted (to be referred to as "transmission focal points" hereinafter). Then the control unit **11** determines timings of outputting the trigger signals.

[**0036**] The amplifier **13** amplifies the pulse signals generated by the pulsar **12**, and the resultant is inputted to the group of transducers **1**. The first "T"th transducers in the group of transducers **1** emit ultrasound focusing on a predetermined focal point (e.g. one of or some of the positions indicated by p**1**~p**4** in **FIG. 3**). Here, transmission beams shall be formed in a horizontal direction with respect to a scanning line **21** which runs vertically to the direction in which the group of transducers **1** is laid out.

[**0037**] Note that ultrasound transmitted into the examined object is reflected at positions "pm"s at the depth of "m" ("m"=1, 2, . . .) one by one. The group of transducers **1** receives such reflected ultrasonic echoes, and converts them into electric signals. The converted electric signals (to be referred to as "reflected signals" hereinafter) are inputted to the delayer **14** which corresponds to each transducer in the group of transducers **1**.

[**0038**] The delayer **14** delays the reflected signals so that the focal point at which the reflected signals should be received (to be referred to as "reception focal point(s)" hereinafter) shifts to p**1**→p**2**→. . . →p**4** sequentially with the elapse of time (processing so-called "dynamic focus"), according to an instruction from the control unit **11**. Then, the delayer **14** transmits the delayed signals to the A/D converter **16**.

[**0039**] The A/D converter **16** performs A/D conversion on the reflected signals sent by the delayer **14**, and outputs the resulting signals one by one to the buffer **17** and the reflection angle detection unit **18**. Here, the buffer **17** is a storage device made up of a RAM and the like for storing data indicating reflected signals corresponding to all pixels on the display unit **20**.

[**0040**] The weighting/addition unit **15** is intended for weighting and adding the reflected signals stored in the buffer **17**, and is made up of a weighting unit **151** and an addition unit **152**.

[**0041**] Referring to **FIG. 4**, an explanation is given here of the concept of weighting performed by the weighting/addition unit **15**.

[**0042**] **FIG. 4** is a diagram showing an example distribution of strengths of ultrasonic echoes reflected back from the scatterer (to be referred to as "reflection strengths" hereinafter). Generally, ultrasound is reflected at a boundary surface **204** of a scatterer **203** (e.g. a tissue in the examine object). However, when the boundary surface **204** is inclined at an angle of θ, meaning that the boundary surface **204** is not positioned vertically to the direction in which the ultrasound is transmitted, such ultrasound is strongly reflected toward a direction different from the one in which it was transmitted (in **FIG. 4**, such direction is one reached by inclining the boundary surface **204** by −2θ anticlockwise). Thus, when ultrasound is strongly reflected toward a direction different from the one in which it was transmitted, the weighting unit **151** performs weighting in a predetermined manner, depending on the strength of such reflected ultrasound. By performing weighting in the above manner, it is possible to generate a sharper ultrasound image.

[**0043**] The weighting unit **151** is capable of reading out, from the buffer **17**, the data indicating the reflected signals, so as to perform weighting on the read-out data according to an instruction from the reflection angle detection unit **18**. For example, the weighting unit **151** selects one of the preregistered weighting patterns based on the signal strength pattern of a group of reflected signals specified by the reflection angle detection unit **18** to be explained later, and performs weighting according to such selected weighting pattern. This weighting unit **151** is made up of a plurality of amplifiers (not illustrated in the diagram), which perform gain control on each data under the instructions from the reflection angle detection unit **18** and the control unit **11**.

[**0044**] Note that the above method is not an exclusive method of weighting reflected signals, and therefore that weighting may also be performed according to an equation.

[**0045**] Here, an explanation is given of an example method of performing weighting according to an equation. Letting that "h(t)" is the strength of a signal to be inputted from a transducer t (t:1≦t≦T, T: tonal number of transducers) to the reflection angle detection unit **18**, the weight "w(t)" that the weighting unit **151** assigns to an electric signal corresponding to the transducer t can be represented by the use of the following equation (1):

$$w(t) = \frac{s(t)}{\sum_{k=1}^{T} s(k)} \quad \text{where, } s(t) = \frac{h(t) - \min_{1 \le j \le T} (h(j))}{\max_{1 \le i \le T} (h(i)) - \min_{1 \le j \le T} (h(j))} \tag{1}$$

[**0046**] In the above equation (1), the weight w(t) of each transducer is represented as a value which is obtained by determining a ratio (s(t)) of the difference between the reflection strength of each transducer t and the minimum reflection strength value with respect to the variations of the

reflection strengths (i.e. the difference between the maximum and minimum reflection strength values) and by further normalizing each s(t). In the above equation (1), "max" and "min" are functions which respectively indicate the maximum value and the minimum value of the reflection strengths when i, j, or k changes, where 1≦i, j or k≦T.

[0047] Such weighting unit **151** is capable of dynamically changing weighting patterns. Accordingly, even when ultrasonic echoes are reflected in various directions from each position on the scanning line, it is possible for the weighting unit **151** to perform weighting according to a weighting pattern appropriate to the respective directions. Subsequently, the addition unit **152** performs addition on each weighted reflected signal outputted by the weighting unit **151** on a pixel-by-pixel basis in the display unit **20**.

[0048] FIGS. **5**A~**5**C are diagrams showing examples of the weighting patterns to be specified by the weighting unit **151**. **FIG. 5A** shows the weighting pattern **31** to be used when a group of signals with strong signal strength appears in the left side of the group of transducers **1**. **FIG. 5B** shows the weighting pattern **32** to be used when a group of signals with strong signal strength appears in the center of the group of transducers **1**. **FIG. 5C** shows the weighting pattern **33** to be used when a group of signals with strong signal strength appears in the right side of the group of transducers **1**.

[0049] Note that, as indicated by broken lines in FIGS. **5**A~**5**C, more simplified weighting patterns **41**~**43** may also be used in the respective cases.

[0050] The reflection angle detection unit **18** determines a reflection angle of the ultrasonic echoes based on the values of the respective reflected signals which are outputted from the A/D converter **16** and which are obtained from the respective transducers **1**~T. Furthermore, the reflection angle detection unit **18** specifies a signal strength pattern of the reflected signals, and sends the specified signal strength pattern to the weighting unit **151**. For example, the reflection angle detection unit **18** detects, from among the reflected signals obtained via the group of transducers **1**, a group of signals with strong signal strength, and specifies a signal strength pattern of such signals. Moreover, the reflection angle detection unit **18** determines a reflection angle on the basis of the position of a transducer that corresponds to the reflected signal with the strongest signal strength out of the group of reflected signals (A detailed explanation is given later of a method of detecting a "reflection angle").

[0051] Note that the present invention is not limited to the above-explained weighting pattern specification method, and therefore that another method may also be used. An example is pattern matching utilizing a neural network and a method that simply limits a section in which weighting should be performed.

[0052] The detection unit **19** detects the reflected signals obtained in the weighting/addition unit **15**, and outputs the resultant to the display unit **20**. The display unit **20** generates an ultrasound image on the basis of the reflected signals outputted from the detection unit **19**, and displays the image on the CRT or the like. Furthermore, the display unit **20** displays, as the inclination of the boundary surface **204**, the value of the reflection angle itself sent by the control unit **11** or such reflection angle. Accordingly, the user of the ultrasonic diagnostic apparatus **100** can know the inclination of the examined object. Note that possible methods of representing or presenting such inclination include a method of representing the inclination as color information and a method of presenting the inclination as a numeric value, but the present invention is not limited to these methods.

[0053] Also note that an ultrasonic diagnostic apparatus is normally required to take into account an anti-noise measure and signal dampening attributable to propagated distance. However, such details are not directly related to the features of the present invention, and therefore an explanation of them is omitted here.

[0054] **FIG. 6** is a diagram showing an example method of detecting reflection angles in the reflection angle detection unit **18**. As **FIG. 6** shows, the direction on the scanning line in which the ultrasonic echo with the strongest signal reception strength shifts to a direction **221**→a direction **222**→a direction **223**→a direction **224**, along with the shift of the reception focal points to positions p**1**→p**2**→. . . →p**4**.

[0055] Here, let us focus on the reception focal point p**1**, and give an explanation of a method of detecting a reflection angle on the basis of the ultrasonic echo reflected back from such position p**1**. Generally, the following values are known beforehand (i.e. the following values are under the control of the control unit **11**): (i) the timing at which ultrasound is transmitted; (ii) the timing at which ultrasonic echoes are received; and (iii) the transmission speed at which the ultrasound is transmitted inside the examined object. Therefore, based on these values (i)~(iii), it is possible to determine a vertical distance **11** from the bottom of the group of transducers **1** to the position p**1** as well as a distance L1 from the scanning line **21** to the transducer that receives the ultrasonic echo with the strongest reflection strength, and to determine θ1 from |1 and L1. Note that θ2~θ4 at p**2**~p**4** shall also be determined in this manner.

[0056] Next, referring to FIGS. **7**~**10**, an explanation is given of the operation of the ultrasonic diagnostic apparatus **100** with the above configuration.

[0057] **FIG. 7** is a block diagram showing an outline of the processing performed in the ultrasonic diagnostic apparatus **100**.

[0058] First, when the A/D converted reflected signals are stored into the buffer **17** (**501**), the reflection angle detection unit **18** notifies the weighting/addition unit **15** that the reflection strength in the right side of the group of transducers **1** is strong, based on such reflected signals. Then, the reflection angle detection unit **18** detects a reflection angle, and notifies the weighting/addition unit **1** of the detected reflection angle. Here, an area of interest **5012** shall be the right side of the group of transducers **1** indicating a strong reflection strength. In this case, the weighting/addition unit **15** selects a weighting pattern **6021** with which weighting is performed in a specified manner, performs weighting on the area of interest **5012** according to such selected weighting pattern **6021** (**603**), and adds up the reflected signals (**604**). As a result, the result of adding the reflected signals in the area of interest **5012** as well as the detection result in the detection unit **19** will be further enhanced (in **FIG. 7**, such enhanced results are indicated as "Extremely strong").

[0059] **FIG. 8** is a flowchart showing the flow of the entire processing performed in the ultrasonic diagnostic apparatus **100**.

[0060] First, the pulsar **12** receives trigger signals from the control unit **11**, generates pulse signals for emitting ultrasound based on such trigger signals, and outputs the generated pulse signals to the group of transducers **1** via the amplifier **13** (S501). In this case, the delayer **14** generates the pulse signals so that ultrasonic pulses can be focused on at least one transmission focal point located at a certain depth inside the examined object according to delay control signals sent by the control unit **11**.

[0061] Next, when the group of transducers **1** receives ultrasonic echoes reflected back from the scatterer (Yes in S502), the reflected signals are stored in the buffer **17** via the delayer **14** and the A/D converter **16** (S503).

[0062] Subsequently, the reflection angle detection unit **18** specifies a reflection angle and the signal strength pattern of the reflected signals (S504), and the weighting/addition unit **15** performs weighting and addition processing accordingly (S505).

[0063] Then, the detection unit **19** detects the reflected signals (S506), and the display unit **20** displays a generated ultrasound image and the reflection angle (S507). The above steps are repeated until the diagnosis completes (S501~S508).

[0064] **FIG. 9** is a flowchart showing, in detail, an example of the reflection angle detection process (5503) in **FIG. 8**.

[0065] First, the reflection angle detection unit **18** specifies reflected signals received at the reception focal point pm, upon the instruction of the control unit **11** (S601), and reads out necessary data from the buffer **17** (S602).

[0066] Next, the reflection angle detection unit **18** compares the sizes of such received reflected signals on a transducer-by-transducer basis (S603), and specifies a weighting pattern based on the signal strength pattern of the reflected signals (5604). Furthermore, the reflection angle detection unit **18** specifies a transducer Tx that has received the reflected signal with the strongest signal strength (S605).

[0067] Subsequently, the reflection angle detection unit **18** determines a reflection angle from the position of the reception focal point pm and the position of the transducer Tx (S606). Then, the reflection angle detection unit **18** sends the determined reflection angle to the control unit **11** and the weighting/addition unit **15** (S607).

[0068] **FIG. 10** is a flowchart showing, in detail, an example of the weighting/addition process (S504) in **FIG. 8**.

[0069] First, the weighting unit **151** receives the reflection strength pattern and the reflection angle from the reflection angle detection unit **18** (S701). On the basis of such reflection angle (S702), the weighting unit **151** selects one weighting pattern (e.g. one of the weighting patterns **31~33**) (S703~S705).

[0070] Next, the addition unit **152** weights the reflected signals according to the selected weighting pattern (S706), and adds the resulting signals (S707).

[0071] Then, the addition unit **152** outputs the added reflected signals to the detection unit **19** (S708).

[0072] As described above, the ultrasonic diagnostic apparatus according to the present invention specifies a reflection angle on the basis of the strength of ultrasonic echoes and weights reflected signals according to such reflection angle. Accordingly, with a hardware configuration simpler than that of an existing ultrasonic diagnostic apparatus, it becomes possible to generate an ultrasound image which is equivalent in quality to an ultrasound image generated by such existing ultrasonic diagnostic apparatus.

[0073] Note that the above-explained embodiment presents an example in which the weighting unit **151** specifies a weighting pattern, but it is also possible that the reflection angle detection unit **18** specifies a weighting pattern instead.

[0074] Also, the above-explained embodiment presents an example in which a method of selecting a weighting pattern based on the reflection angle and a method using the equation (1) are used as the methods of determining a weighting pattern. However, the present invention is not limited to these methods, and therefore a weighting pattern may also be determined, for example, by using the learning algorithm in the neural network as well as by employing pattern matching.

[0075] Furthermore, the above-explained embodiment presents an example in which transducers are arranged in a one-dimensional array, but the present invention is not limited to such arrangement. Therefore, the present invention is also applicable to a group of transducers in two-dimensional or three-dimensional array.

[0076] Moreover, the ultrasonic diagnostic apparatus may be implemented as any one of an analog circuit, a digital circuit, and software.

What is claimed is:

1. An ultrasonic diagnostic apparatus, comprising:

an ultrasound transmitting/receiving unit in which a plurality of transducers are arranged, each of the transducers transmitting ultrasound into an object to be examined, receiving the ultrasound reflected back from inside said object, and converting the reflected ultrasound into an electric signal;

a feature detection unit operable to detect a feature of the reflected ultrasound based on the electric signal converted by each of the transducers;

a weighting unit operable to weight the electric signal of each of the transducers in a specified manner, depending on the detected feature; and

an image generation unit operable to generate an ultrasound image based on the weighted electric signal of each of the transducers.

2. The ultrasonic diagnostic apparatus according to claim 1,

wherein the weighting unit modifies the weighting and further weights the electric signal of each of the transducers in the modified manner, depending on the detected feature, and

the image generation unit generates the ultrasound image based on the electric signal of each of the transducers which has been weighted in said modified manner.

3. The ultrasonic diagnostic apparatus according to claim 1,

wherein the feature detection unit compares signal strengths of the respective electric signals of the transducers, and determines a reflection angle as the feature of the ultrasound, based on a position of one of the transducers specified by said comparison and on a position of a predetermined reception focal point.

4. The ultrasonic diagnostic apparatus according to claim 3, further comprising a storage unit operable to store a plurality of weighting patterns,

wherein the weighting unit selects one of the weighting patterns stored in the storage unit based on the reflection angle detected by the feature detection unit, and weights the electric signal of each of the transducers according to said selected weighting pattern.

5. The ultrasonic diagnostic apparatus according to claim 3, further comprising a display unit operable to display the reflection angle detected by the feature detection unit.

6. The ultrasonic diagnostic apparatus according to claim 1,

wherein the feature detection unit measures a signal strength of the electric signal of each of the transducers, and uses said signal strength as the feature of the ultrasound.

7. The ultrasonic diagnostic apparatus according to claim 6,

wherein the weighting unit determines a weight w(t) for the electric signal corresponding to an arbitrary "t"th transducer using the following equation, letting that h(t) is the measured signal strength of said "t"th transducer:

$$w(t) = \frac{s(t)}{\sum_{k=1}^{T} s(k)} \text{ where, } s(t) = \frac{h(t) - \min_{1 \leq j \leq T} (h(j))}{\max_{1 \leq i \leq T} (h(i)) - \min_{1 \leq j \leq T} (h(j))}$$

8. An ultrasonic diagnostic method comprising:

an ultrasound transmitting/receiving step of transmitting ultrasound into an object to be examined, receiving the ultrasound reflected back from inside said object, and converting the reflected ultrasound into an electric signal using each of a plurality of transducers which are arranged;

a feature detection step of detecting a feature of the reflected ultrasound based on the electric signal converted by each of the transducers;

a weighting step of weighting the electric signal of each of the transducers in a specified manner, depending on the detected feature; and

an image generation step of generating an ultrasound image based on the weighted electric signal of each of the transducers.

9. The ultrasonic diagnostic method according to claim 8,

wherein in the weighting step, the weighting is modified and the electric signal of each of the transducers is further weighted in the modified manner, depending on the detected feature, and

in the image generation step, the ultrasound image is generated based on the electric signal of each of the transducers which has been weighted in said modified manner.

10. The ultrasonic diagnostic method according to claim 8,

wherein in the feature detection step, signal strengths of the respective electric signals of the transducers are compared, and a reflection angle is determined as the feature of the ultrasound, based on a position of one of the transducers specified by said comparison and on a position of a predetermined reception focal point.

11. A program for an ultrasonic diagnostic apparatus, the program causing a computer to execute the following steps:

an ultrasound transmitting/receiving step of transmitting ultrasound into an object to be examined, receiving the ultrasound reflected back from inside said object, and converting the reflected ultrasound into an electric signal using each of a plurality of transducers which are arranged;

a feature detection step of detecting a feature of the reflected ultrasound based on the electric signal converted by each of the transducers;

a weighting step of weighting the electric signal of each of the transducers in a specified manner, depending on the detected feature; and

an image generation step of generating an ultrasound image based on the weighted electric signal of each of the transducers.

12. The program according to claim 11,

wherein in the weighting step, the weighting is modified and the electric signal of each of the transducers is further weighted in the modified manner, depending on the detected feature, and

in the image generation step, the ultrasound image is generated based on the electric signal of each of the transducers which has been weighted in said modified manner.

13. The program according to claim 11,

wherein in the feature detection step, signal strengths of the respective electric signals of the transducers are compared, and a reflection angle is determined as the feature of the ultrasound, based on a position of one of the transducers specified by said comparison and on a position of a predetermined reception focal point.

* * * * *

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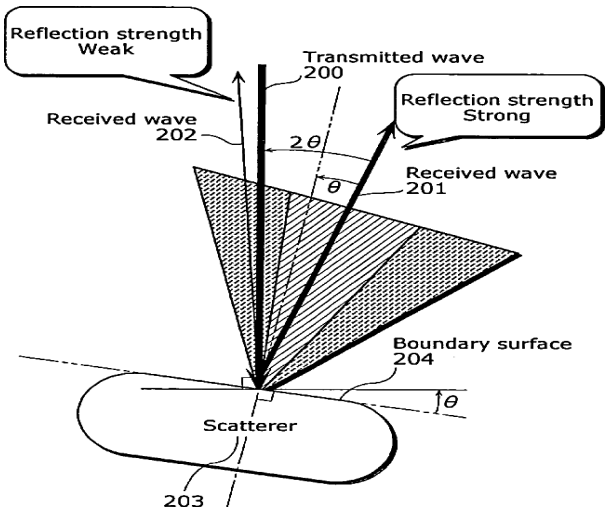
在能够产生等于通过组合从各种角度拍摄的图像而产生的超声图像的超声诊断设备（100）中，不会引起与硬件数量增加和帧速率降低有关的问题，脉冲星（12）产生脉冲信号用于基于从控制单元（11）接收的触发信号发射超声波，并经由放大器（13）将这样的信号输出到一组换能器（1）。该组换能器（1）接收来自散射体的超声回波。缓冲器（17）存储经由延迟器（14）和A / D转换器（16）接收的反射信号。反射角度检测单元（18）指定反射信号的反射角度和反射强度图案，并且加权/加法单元（15）基于这样的反射强度图案执行加权。检测单元（19）执行检测，并且显示单元（20）显示超声图像和反射角。