US 20040102700A1

(19) United States
(12) Patent Application Publication
Asafusa
(10) Pub. No.: US 2004/0102700 A1
(43) Pub. Date: May 27, 2004

(54) ULTRASONIC DIAGNOSTIC APPARATUS

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(21) Appl. No.: **10/275,715**

(22) PCT Filed: **May 9, 2001**

(86) PCT No.: **PCT/JP01/03867**

Publication Classification

(51) **Int. Cl.**^{7} **A61B 8/00**
(52) **U.S. Cl.** **600/437**

(57) **ABSTRACT**

An ultrasonic diagnostic apparatus for obtaining and displaying a three-dimensional image within a short time by performing three-dimensional scanning in an object with ultrasonic beams at rapid speed. A plurality of small transducer blocks is formed through selective connection on a two-dimensional transducer array provided on an ultrasonic probe. Driving pulse signals generated by a pulse generating circuit are modulated by a frequency modulator. These driving pulse signals respectively having different frequencies are simultaneously provided to the selected small transducer blocks, causing said small transducer blocks to transmit ultrasonic beams from each of them to the interior of the object. Then, waves reflected from the interior of the object are received by each small transducer block. After the echo signals received by each small transducer block are demodulated by a demodulator, these signals are input to a phasing circuit to generate a plurality of received beam signals. The position of the small transducer blocks is moved at each repetition of ultrasonic transmission/repetition. Thus obtained received beam signals are image-processed and made into image data, and thus displayed on a display.

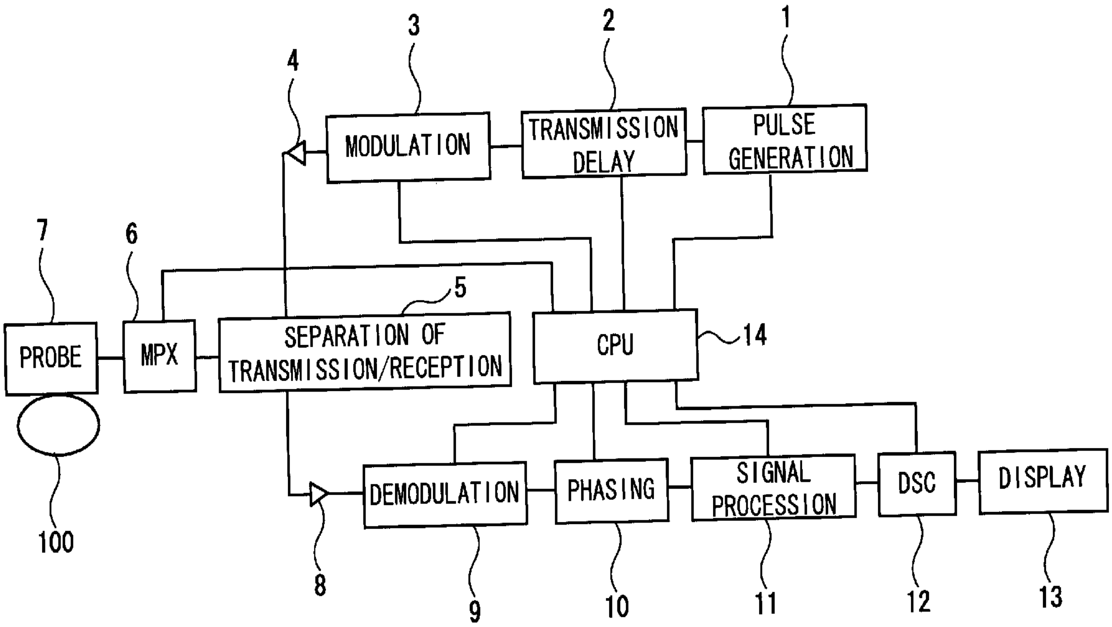


FIG. 1

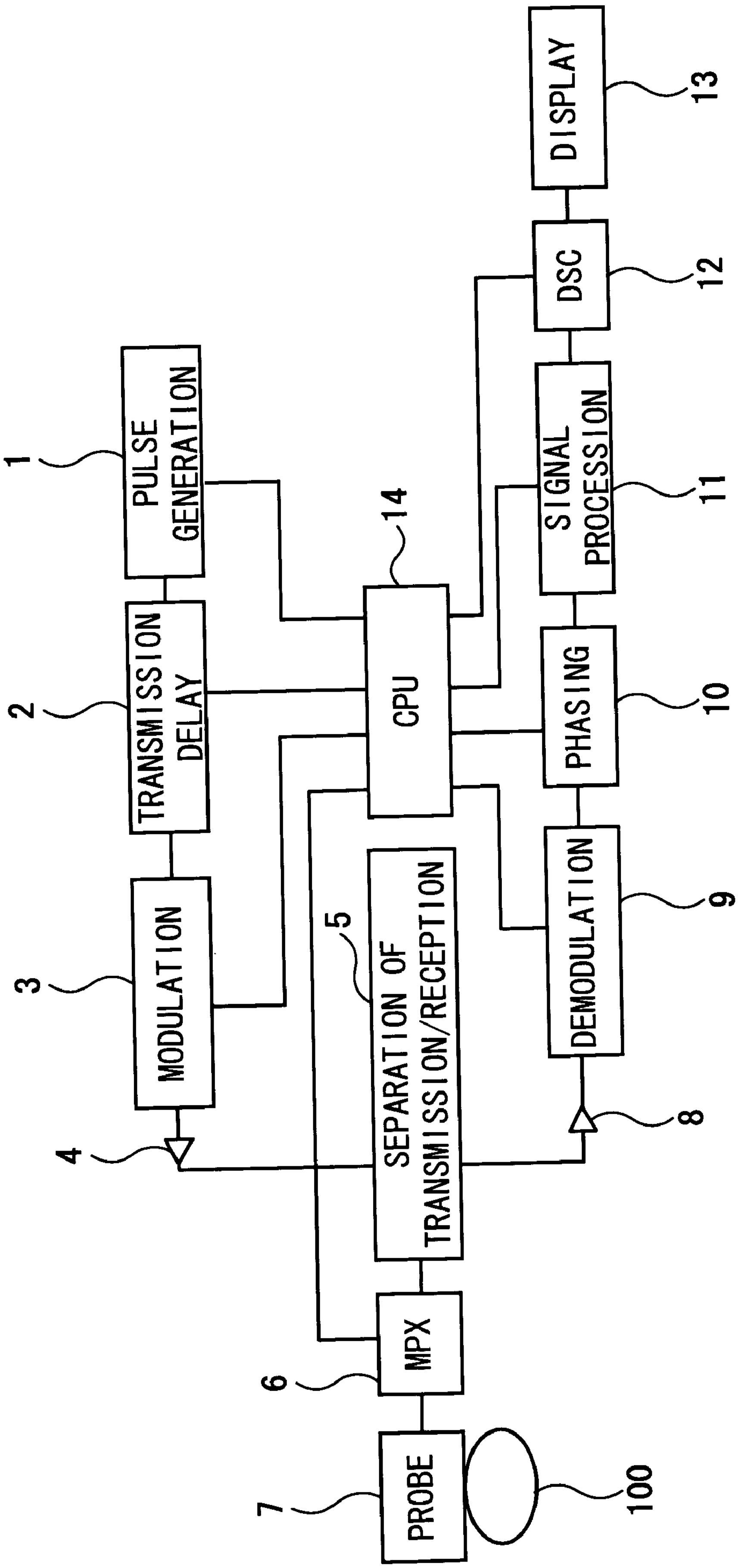

PULSE GENERATION
TRANSMISSION DELAY
MODULATION
SEPARATION OF TRANSMISSION/RECEPTION
MPX
PROBE
CPU
DEMODULATION
PHASING
SIGNAL PROCESSION
DSC
DISPLAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
100

Fig. 2

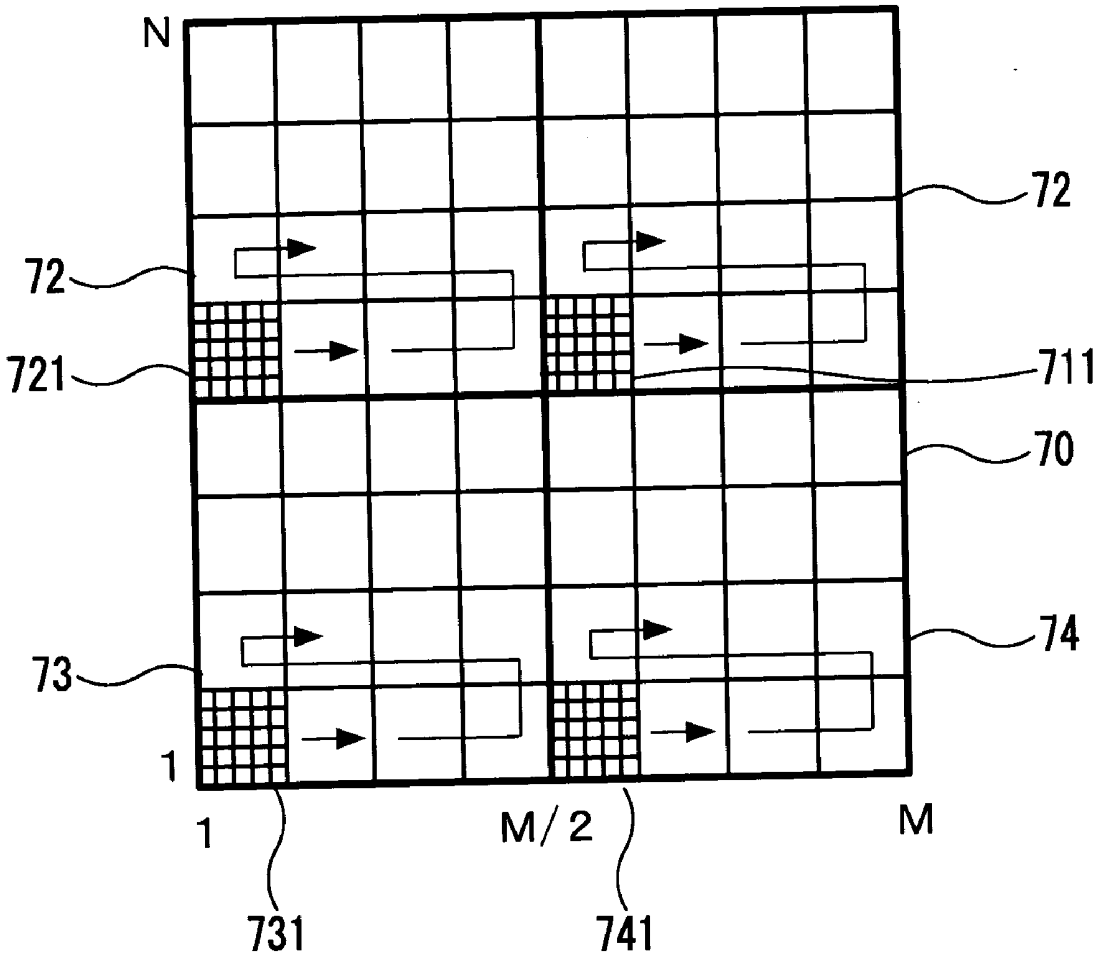


Fig. 3

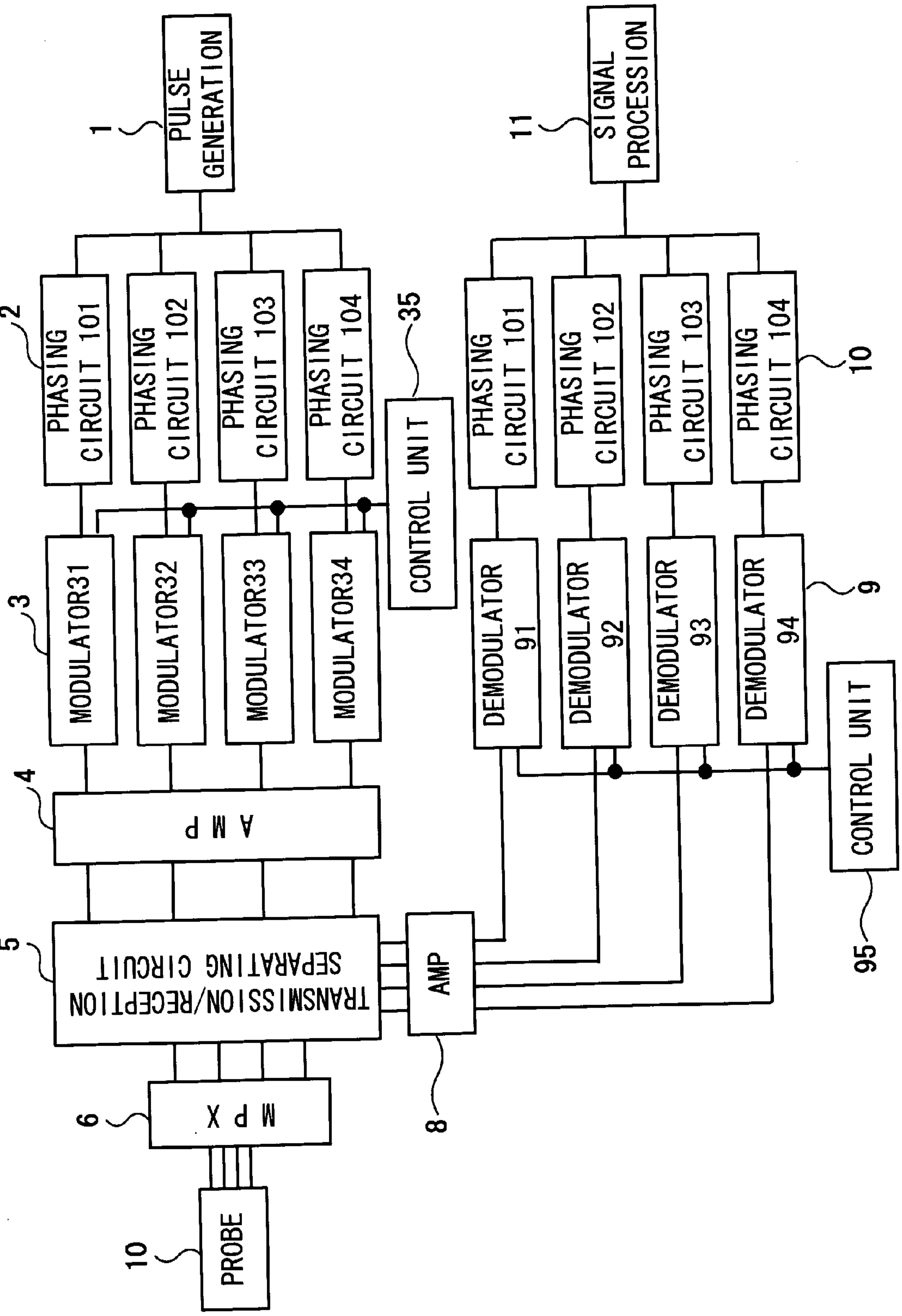

1
PULSE GENERATION
2
PHASING CIRCUIT 101
PHASING CIRCUIT 102
PHASING CIRCUIT 103
PHASING CIRCUIT 104
35
CONTROL UNIT
3
MODULATOR31
MODULATOR32
MODULATOR33
MODULATOR34
4
AMP
5
TRANSMISSION/RECEPTION SEPARATING CIRCUIT
6
MPX
10
PROBE
8
AMP
11
SIGNAL PROCESSION
PHASING CIRCUIT 101
PHASING CIRCUIT 102
PHASING CIRCUIT 103
PHASING CIRCUIT 104
10
DEMODULATOR 91
DEMODULATOR 92
DEMODULATOR 93
DEMODULATOR 94
9
CONTROL UNIT
95

Fig. 4

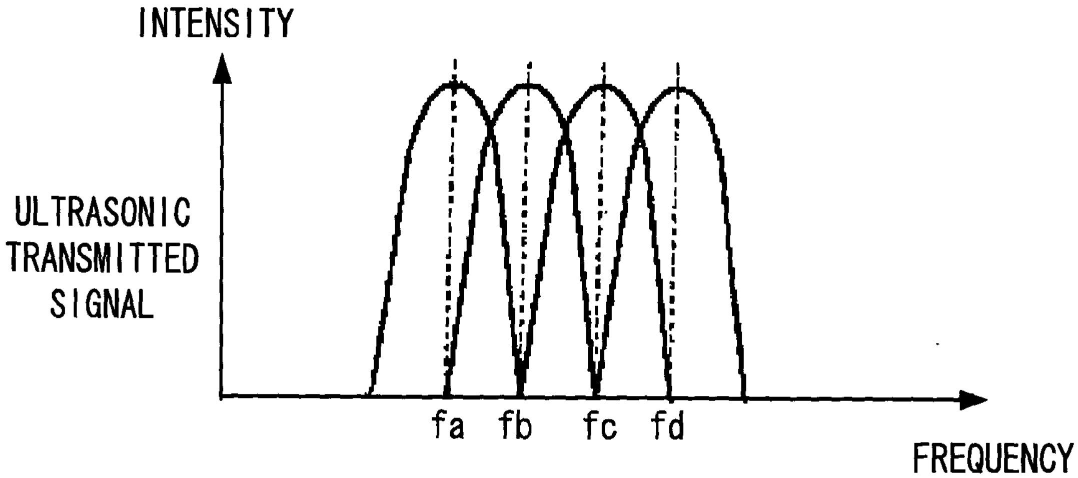


Fig. 5

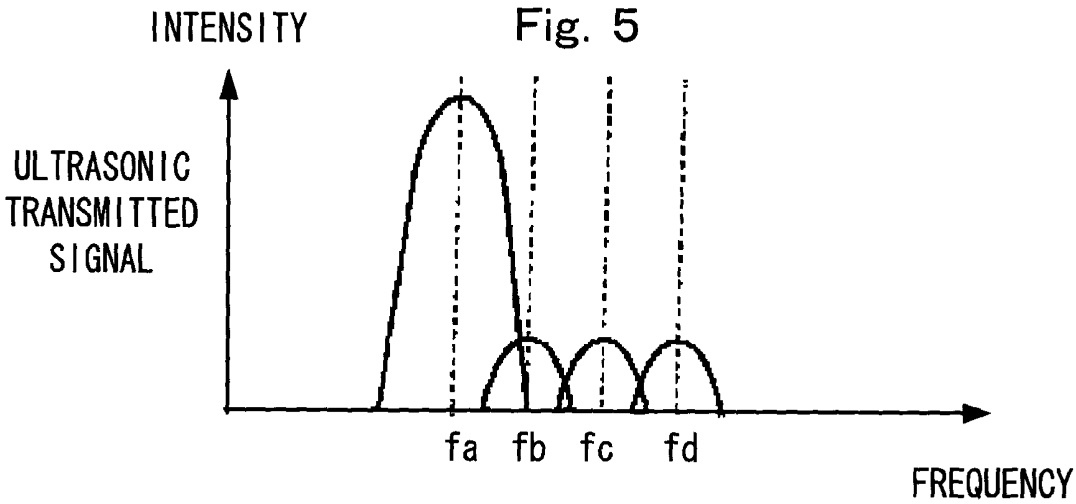
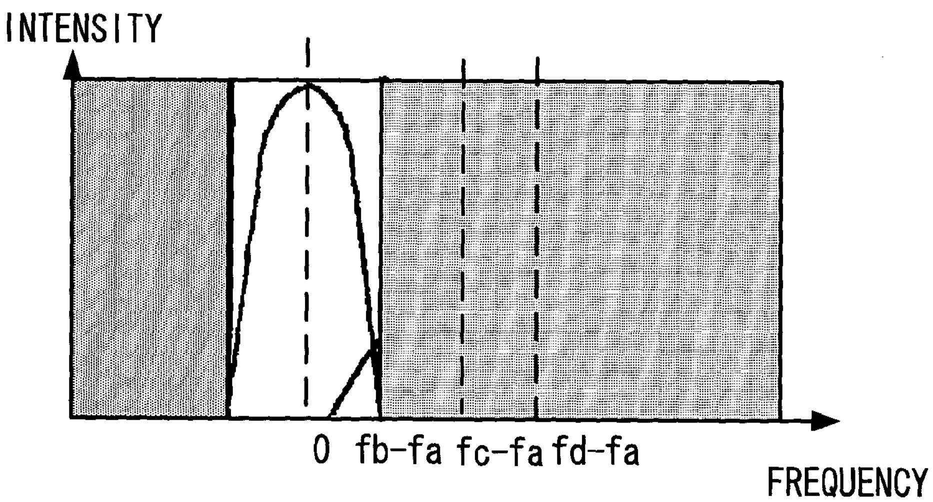


Fig. 6



ULTRASONIC DIAGNOSTIC APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates to an ultrasonic diagnostic apparatus used in the field of the medical image diagnosis, and more particularly to an ultrasonic diagnostic apparatus that can perform three-dimensional scanning at rapid speed in an object to be examined.

BACKGROUND OF THE INVENTION

[0002] In the field of the medical image diagnosis, there has been increasing demand for diagnosing the interior of an object by taking a three-dimensional image of it for observation in recent years, not excepting the field of the ultrasonic diagnosis. The diagnosis using three-dimensional images has been developed especially in the field of the X-ray CT apparatus using X-rays and of the magnetic resonance imaging apparatus using nuclear magnetic resonance. But, the development of three-dimensional imaging has been delayed in the field of the ultrasonic diagnosis because an ultrasonic diagnostic apparatus performs scanning with ultrasonic beams of which the propagation velocity in a living body is as slow as approximately 1,500 m/s, and so it takes a long time to take a three-dimensional image of the interior of an object that requires far more number of beams in comparison with a conventional cross sectional image made from approximately 100 beams. Further, to perform three-dimensional scanning with ultrasonic beams in the object, a method of manually or mechanically moving on the surface of the object a probe having one-dimensional built-in transducers has been proposed. However, it is difficult to actually use this method since the surface of the object is uneven, which is the second reason for the delay of development of the ultrasonic three-dimensional imaging.

[0003] As described above, the propagation velocity of ultrasound in a living body is approximately 1,500 m/s, and so a conventional cross sectional image of the examined region can be displayed at a frame rate of 30 frames/s. Here, the number of ultrasonic scanning lines used for forming the cross sectional image is about 100. If a three-dimensional image is to be obtained with 100 scanning lines, it is necessary to narrow the scanning area, or to expand the interval between scanning lines if the scanning area is not narrowed. However, even if these methods were employed in an ultrasonic diagnostic apparatus, this apparatus could not be used for actual diagnosis. To perform high-speed scanning on the object in real time, there are proposed a method of obtaining several beams to be received with one transmission of one ultrasonic beam and a method of transmitting ultrasonic beams in several directions at one time. However, there is a limit to the speedup obtainable by the former method. In the latter method, there is a problem that an ultrasonic beam interferes with another beam if the simultaneously transmitted beams approach each other, that is, a problem that a transducer or a group of transducers may receive a reflected wave of the ultrasonic beam transmitted by the adjoining transducer or the group of transducers. Therefore, the above-described conventional technology has not achieved the objective to perform three-dimensional measurement using ultrasonic beams in the object at rapid speed.

[0004] However, since there have been proposed various kinds of methods of producing a two-dimensional probe using a fine processing technology that has been recently developed, it is becoming possible to perform three-dimensional scanning with ultrasonic beams in an object by using a electric scanning method without moving the probe on the surface of the object.

[0005] In a conventional technology, as described above, it takes very long time to perform measurement for three-dimensional scanning using ultrasonic beams in an object. The object cannot move throughout the measurement, which puts a great burden on the object. Moreover, it is difficult to observe a three-dimensional image in real time since it requires long measurement time. These problems have not been solved at this stage, and early solution of them is desired.

[0006] The present invention is made in consideration of the above-described circumstances. The first purpose of the present invention is to provide an ultrasonic diagnostic apparatus that can perform three-dimensional scanning with ultrasonic beams at rapid speed.

[0007] And, the second purpose of the present invention is to provide an ultrasonic diagnostic apparatus that can promptly display ultrasonic three-dimensional image.

SUMMARY OF THE INVENTION

[0008] In an embodiment of the present invention to achieve the first purpose, an ultrasonic diagnostic apparatus comprises:

[0009] an ultrasonic probe on which a plurality of ultrasonic transducers are arranged along a two-dimensional plane or a three-dimensional curved surface;

[0010] a transducer group selecting circuit for selecting a plurality of transducer group at different positions on said transducer-arranged surface;

[0011] transmitting and receiving means for sending transmitted signals of which characteristics are different from each other to each of the transducer groups selected by said transducer group selecting circuit to transmit ultrasonic beams at one time from each transducer group to the interior of the object, then receiving the echo signals of them; and

[0012] means for changing the position of the selected transducer group at every repetition of the ultrasonic transmission/reception by controlling said selecting circuit, and for performing three-dimensional scanning with ultrasound within the object by transmitting and receiving the ultrasonic beams controlling said transmitting and receiving means.

[0013] And, in an embodiment of the present invention to achieve the second purpose, an ultrasonic diagnostic apparatus comprises:

[0014] an ultrasonic probe on which a plurality of ultrasonic transducer groups are arranged along a two-dimensional plane or a three-dimensional curved surface;

[0015] a transducer group selecting circuit for selecting a plurality of transducer groups at different positions on said transducer-arranged surface;

[0016] transmitting and receiving means for sending transmitted signals the characteristics of which are different from each other to each of the transducer groups selected by said transducer group selecting circuit to transmit ultrasonic beams at one time to the interior of the object, then receiving the echo signals of them;

[0017] means for changing the position of the transducer group selected at each repetition of the transmission/reception of said ultrasound by controlling said selecting circuit;

[0018] means for extracting the received beam signals that match the characteristics of the signals transmitted by each of said transducer groups from among the echo signals received by said transducer groups;

[0019] image composing means for composing the above-extracted received beam signals to form the data for one image; and

[0020] image display for displaying as an image the image signals output by said image composing means.

[0021] And, in another embodiment of the present invention to achieve the second purpose, an ultrasonic diagnostic apparatus comprises:

[0022] an ultrasonic probe on which a plurality of ultrasonic transducers are arranged along a two-dimensional plane or a three-dimensional curved surface;

[0023] a transducer group selecting circuit for selecting a plurality of transducer groups at different positions on said transducer-arranged surface;

[0024] transmitting and receiving means for sending transmitted signals of which the characteristics are different from each other to each of the transducer group selected by said transducer group selecting circuit to transmit ultrasonic beams at one time to the interior of the object, and receiving the echo signals of them;

[0025] means for changing the position of the selected transducers at each repetition of the ultrasonic transmission/reception by controlling said selecting circuit;

[0026] means for forming received beam signals all of which characteristics are uniform by using the echo signals received by said each transducer groups;

[0027] image composing means for composing the received beam signals of which all characteristics are uniform to form the sole image data; and

[0028] image display for displaying an image for the image signals output by said image composing means.

[0029] In said embodiments, the two-dimensional transducers are divided into a plurality of transducer groups, and still smaller transducer groups are selected in the divided transducer groups for transmitting and receiving ultrasonic beams. These small transducer groups are switched and selected, and thus the position of them is moved with each the repetition of ultrasonic transmission and repetition. Transmitted signals each of which has different characteristics; for example, signals having different frequency characteristics due to modulation, are given respectively to each of the selected small transducer groups, and thus all the small transducer groups simultaneously transmit ultrasonic beams having characteristics different from each other. Thus, since a plurality of ultrasonic beams can be simultaneously transmitted (received) to (from) the interior of the object, the three-dimensional scanning can be performed at rapid speed in the object. The received signals are subject to demodulation and then to image processing to be a three-dimensional image, which is displayed on the display device. In this way, the interior of the object is three-dimensionally imaged at rapid speed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] **FIG. 1** is a block diagram for showing the structure of an ultrasonic diagnostic apparatus as an embodiment of the present invention.

[0031] **FIG. 2** is a diagram for illustrating the operation of ultrasonic transmission/reception by two-dimensional transducers in the present invention.

[0032] **FIG. 3** is a block diagram for illustrating the more detailed structure of the feature of the structure described in **FIG. 1**.

[0033] **FIG. 4** is a graph for showing an embodiment of a plurality of transmitted signals of which frequency characteristics are different from each other.

[0034] **FIG. 5** is a graph for showing an embodiment of the signals received by the small-block transducer groups.

[0035] **FIG. 6** is a graph for showing the state of the demodulated echo signals in which the signals having several frequencies are intermingled.

BEST MODE FOR CARRYING OUT THE INVENTION

[0036] Hereinafter, an embodiment of the present invention will be described using the drawings. In **FIG. 1, 1** is a pulse generating circuit for generating pulse signals to be transmitted to the ultrasonic transducers so as to transmit ultrasound to the interior of the object. **2** is a transmission delay circuit for providing the pulse output by the pulse generating circuit **1** while giving a predetermined delay time to each driven transducer, this transmission delay circuit being comprised of a plurality of delay circuits. **3** is a modulator for performing modulation process, that is, frequency modulation in this embodiment on the output signals of the transmission delay circuit **2** to output them. **4** is an amplifier for amplifying the pulse generated by the pulse generation circuit **1** up to the level of driving the transducer. **5** is a transmission/reception separating circuit for passing the driving pulse to the transducers in transmission of ultrasound and for passing the received signal to the receiver circuit in reception. **6** is a switching circuit (that is, a multiplexer, hereinafter abbreviated as an MPX) for switching the input/output line for the two-dimensional transducer array on the probe. Assuming that the two-dimensional transducers are formed with M×N transducers, M transducers being arranged in a direction and N being arranged in another direction perpendicular to said direction, said switching circuit, for example divides this two-dimensional transducers into four blocks each comprising M/2×N/2 transducers and performs selective connection of an the m×n small-block transducer group within each block for transmitting and receiving ultrasound, these small transducer blocks moved at each repetition of ultrasonic transmission and reception by said MPX **6**. **7** is an ultrasonic probe having a large number of minute transducers arranged on a two-dimensional plane or a three-dimensional curved surface. The frequency characteristics of these minute transducer elements have a predetermined frequency bandwidth.

[**0037**] **8** is a reception amplifier for amplifying weak echo signals output by the transducers. **9** is a demodulator for demodulating the echo signals input by the amplifier **8**. **10** is a reception phasing unit, which is comprised of a plurality of delay circuits and an adder circuit for adding the output of said delay circuits, for example for forming the respective received beams of said four blocks with the echo signals received by the selected small transducer block comprising m×n transducers that are respectively selected from said four blocks. **11** is a signal processing unit for performing pre-procession on the echo signals such as detection process, logarithmic compression, filtering, and y conversion when forming image data. **12** is an image data forming unit, which is comprised of a digital image memory and a control circuit for writing and reading the signal on the image memory. Said image data forming unit is referred to as a digital scan converter (DSC) in this field. **13** is an image displaying unit having a three-dimensional image forming circuit for forming three-dimensional image of the image data that is read from the DSC **12**. This three-dimensional image data is read out from said three-dimensional image forming circuit and converted into luminance signals and provided with hues to display the ultrasonic image on the display such as the picture of a monitor TV. Finally, a central processing unit (CPU) **14** is provided for controlling the above-described components.

[**0038**] Next, a method of ultrasonic scanning using the two-dimensional transducer array in this embodiment will be described. **FIG. 2** is a top view of the two-dimensional transducer array in an embodiment. On the plane surface of the two-dimensional transducer array **70**, M×N minute transducer elements are arranged, M of said elements being arranged in one direction and N arranged in the perpendicular direction. The two-dimensional transducer array **70** is divided into four large blocks each comprising M/2×N/2 transducer elements. In each of these large blocks of transducers, a small transducer block group comprising m×n transducers is selected, m transducers being arranged in the direction in which said M transducers are arranged, and n being arranged in the direction in which N are arranged. These selected blocks of transducers simultaneously perform the operation of transmission/reception and the ultrasonic beam scanning.

[**0039**] That is, as shown in **FIG. 2**, the two-dimensional transducer array **70** having M×N transducers is divided into the large transducer blocks **71**,**72**, **73**, and **74** having M/2× N/2 transducers. Further, in these large transducer blocks **71**, **72**, **73**, and **74**, the small transducer blocks **711**, **721**, **731**, and **741** having m×n transducers are selected respectively. When these small transducer blocks **711**, **721**, **731**, and **741** first transmit or receive ultrasound, the position of them is selected as shown in **FIG. 2**, and it is shifted by one element or plural elements in the direction of the arrow at each repetition of ultrasonic transmission/reception. And thus, these small transducer blocks are selected in order that they are sequentially moved from the initially selected position to the right edge. When the small transducer block selected in each large transducer block reaches the right edge of the large block, the ultrasonic beam scanning is performed for several cross sections and thus the image data for several cross sectional images is obtained. After each small transducer block reaches the right edge of the large transducer block, the next ultrasonic transmission/reception is performed by the small transducer blocks the position of which is shifted upward by one or plural moved upward for one or several elements from the initially selected position shown in the figure. And then, this small transducer block is sequentially selected to move rightward at each repetition of ultrasonic transmission/reception. The small transducer block of a shifted position is selected according to the transducer selective signal that is output by the CPU **14** to the MPX **6**. In this way, the small transducer blocks are selected on the two-dimensional transducer array **70** and these small transducer groups are made to simultaneously perform ultrasonic transmission/reception, and as well the position of said small transducer blocks is sequentially moved each time the ultrasonic transmission/reception is performed. Thus, the ultrasonic three-dimensional scanning of the object can be performed at rapid speed.

[**0040**] Next, a characteristic of the present invention that when several ultrasonic beams are simultaneously transmitted to the interior of the object, each beam can convey different particular information will be described. **FIG. 3** shows an embodiment of a detailed structure of feature of the transmission/reception system provided in the ultrasonic diagnostic apparatus described in **FIG. 1**. In **FIG. 3**, **1** is a pulse generating circuit. **2** is a transmission delay circuit which is comprised of four delay circuits of **21**, **22**, **23**, and **24** for giving delay time respectively to the small transducer blocks **711**, **721**, **731**, and **741** selected respectively from the four large transducer blocks **71**,**72**,**73**, and **74** on said two-dimensional transducer array **70**. Each of these delay circuits **21**, **22**, **23**, and **24** comprises m×n (channels of) delay circuits. **3** is a frequency modulator which comprises four frequency modulator systems **31**, **32**, **33**, and **34**. Outputs of said four delay circuits are input respectively to said frequency modulators, and these modulators output frequency signals different from the input signals. These frequency modulators **31**, **32**, **33**, and **34** can be provided either upstream or downstream of the transmission delay circuit **2**. However, the characteristics of the delay circuits **21**, **22**, **23**, and **24** can be unified by providing said modulators downstream of the delay circuits. **35** is a control unit for controlling each of the frequency modulators **31**, **32**, **33**, and **34**.

[**0041**] **4** is the above-described amplifier. **5** is the transmission/reception separating circuit. **6** is the MPX. **70** is the two-dimensional transducer array. **8** is the reception amplifier. **9** is the demodulator comprising four demodulators **91**, **92**, **93**, and **94**, each of which has m×n demodulators. These demodulators **91**, **92**, **93**, and **94** demodulate the echo signals received by the two-dimensional transducer array **70**. These circuits can be provided either upstream or downstream of the phasing circuit. However, the characteristics of four phasing circuits can be unified by providing the demodulator on the first part of the phasing circuits. **10** is the phasing circuit for reception comprising four phasing circuits of **101**, **102**, **103**, and **104**, each of which has m×n (channels of) phasing circuits. **11** is the above-described signal processing unit.

[**0042**] Next, the operation of the apparatus having the structure shown in **FIG. 3** will be described. First, the focusing depth of wave transmission is set by an operator from the controller provided on the control panel that is not described in the figure in order to match the focusing depth with the depth of the region to be examined from the surface of body around the region. Then, the probe **7** is applied to the region of the object **10** to be examined to begin the ultrasonic scanning.

[**0043**] When the instruction to start the scanning is given from the control panel, CPU **14** gives the order to each unit of the pulse generating circuit **1**, the transmission delay circuit **2**, the modulator **3**, the transmission/reception separating circuit **5**, the MPX **6**, the demodulator **9**, and the phasing circuit **10** to start scanning. Upon receiving the instruction from the CPU **14**, the pulse generating circuit **1** outputs the pulse signals for driving the ultrasonic transducers to the transmission delay circuit **2**. In the output line of the transmission delay circuit **2**, the outputs of the each delay circuit comprised of m×n delay circuit channels are connected to each transducer element that forms each of the small transducer blocks **711**, **721**, **731**, **741** respectively comprising m×n to operation of the MPX **6**. When the pulse signal having a frequency f is sent from the pulse generating circuit **1** to the transmission delay circuits **21**, **22**, **23**, and **24**, the pulse signals are delay-controlled by the delay circuits that are provided with the delay time data corresponding to the above-set transmission focusing depth by the delay data generation unit (not shown). Then, these delay-controlled pulse signals are output to the frequency modulators **31**, **32**, **33**, and **34**. The pulse signals input to the frequency modulator **31**, **32**, **33** and **34** are subject to the frequency modulation in accordance with the frequency modulation data memorized in a memory of the control unit **35**. Thus, four frequency-modulated signals are used as ultrasonic transmission signals. As shown in **FIG. 4**, they have for example the center frequencies fa, fb, fc, and fd. The voltage of the frequency-modulated pulse signals is amplified by the amplifier **4** up to the level for driving the ultrasonic transducers, and then these pulse signals are input to the MPX **6** through the transmission/reception separating circuit **5**. Since the MPX **6** has shifted the output lines of the pulse signals for the transducers as described above, the driving pulses having respective delay time differences are provided to the transducer elements forming the small transducer blocks **711**, **721**, **731**, and **741**.

[**0044**] When the driving signals are provided to the transducer elements forming the small transducer blocks **711**, **721**, **731**, and **741**, the ultrasonic beams are simultaneously transmitted by each of transducer blocks **711**, **721**, **731**, and **741** to the interior of the object. A part of the ultrasounds transmitted from each small transducer block reflects on the border between the tissues of which the acoustic impedances are different from each other, and the rest propagate to deeper regions.

[**0045**] The ultrasound that has reflected in the object is received by the two-dimensional transducer array **70**. However, the frequencies of the signals received by the small transducer blocks **711**, **721**, **731**, and **741** are varied since the ultrasounds respectively having different frequencies are simultaneously transmitted by the small transducer blocks **711**, **721**, **731**, and **741**. That is, the signals with a frequency transmitted by the small transducer block **711** and those with another frequencies transmitted by the small transducer blocks **721**, **731**, and **741** are intermingled in the signals received by the small transducer block **711**. Similarly, in the signals received by each of the small transducer blocks **721**, **731**, and **741**, signals with frequencies different from that transmitted by that transducer block are intermingled. As shown in **FIG. 5**, for example, a small transducer group driven by a transmittal frequency signal fa receives at one time both the echo signals with large intensity transmitted by itself and those with small intensity having frequencies fb, fc, and fd transmitted by other blocks. Because of this phenomenon, ultrasonic beams have been conventionally transmitted and received in several directions at one time by a single probe. But, it is difficult to obtain an image suitable for diagnosis by using said echo signals. In the present invention, said signals with varied frequencies are discriminated by the reception process described later to extract only the echo signals with the frequency transmitted by that small transducer block.

[**0046**] The reflected waves received by the two-dimensional transducer array **70** is converted into electric signals (echo signals) and input to the reception amplifier **8** through the MPX **6** and the transmission/reception separating circuit **5**. Then, these signals are amplified and output to the demodulator **9**. This demodulator **9** comprises four demodulators **91**, **92**, **93**, and **94**, one circuit having m×n channels. Controlled by the control unit **95**, the demodulators **91**, **92**, **93** and **94** demodulate the signals which have been modulated by the frequency modulator **3**. These four circuits **91**, **92**, **93**, and **94** are provided in order to correspond respectively with the four frequency modulators **31**, **32**, **33**, and **34**. Controlled by the control unit **95**, these frequency demodulators **91**, **92**, **93**, and **94** perform this demodulation corresponding to the frequency modulation done by the frequency modulator **3**. As an example of signal demodulation by the demodulator **9**, as shown in **FIG. 6**, the signals having a frequency fa are extracted with a low pass filter from among the echo signals in which the echo signals having a frequency fa of strong level and those having frequencies fb, fc, and fd of weak level are intermingled, and the extracted echo signals having a frequency fa are demodulated in order to acquire signals having a frequency f. Incidentally, to deal with a frequency of strong-level echo signals, a high pass filter and a band pass filter may be used instead of said low pass filter.

[**0047**] The echo signals demodulated by the demodulator **9** are input to the four phasing circuits **101**, **102**, **103**, and **104** that are provided in order to correspond respectively with the small transducer blocks. These phasing circuits **101**, **102**, **103**, and **104** perform delay time control and adding process on the echo signals of each small transducer block, and form a received beam signal for each of the echo signals output by m×n transducers on each small transducer block. Thus, four received beam signals can be acquired at one time.

[**0048**] These received beam signals are subject to detection, logarithmic compression, filtering, and γ conversion in the signal processing unit **11**. And, thus processed signals are written on the memory of the DSC **12** and converted into image data. Image data input to the DSC **12** is stored in the memory. The above is one cycle of ultrasonic transmission/reception.

[**0049**] After said cycle of transmission/reception is completed, the CPU **14** controls the MPX **6** to move the position of the small transducer blocks **711**, **721**, **731**, and **741** selected respectively within the large transducer group **71**, **72**, **73**, and **74** in the direction of the arrow in the figure. After the small transducer blocks are moved, the above-described process of ultrasonic transmission/reception is again performed and the received beams are at a position next to the beam received in the first transmission/reception in the above direction. The echo signals acquired in the second transmission/reception are also provided to the DSC **12** and stored in the memory. Thus, the position of the small transducer block is moved leftward from the initially selected position and the images of two cross sections are obtained by repeating the movement of the small transducer blocks and the ultrasonic transmission/reception. And further, scanning is performed at rapid speed since each cross section is scanned with two ultrasonic beams. After that, the small transducer groups are moved upward by the above-described method to again acquire a pair of two cross sectional images. By repeating said process, the interior of the object is three-dimensionally scanned with ultrasonic beams and the predetermined number of cross sectional images can be acquired.

[**0050**] The three-dimensional image of the diagnostic part is reconstructed with the predetermined number of the above-acquired cross sectional images. As reconstruction algorithm for said three-dimensional images, one that is used in an X-ray CT apparatus and an MRI apparatus is employed.

[**0051**] So far, one embodiment of the present invention has been described according to the drawings. However, the gist of the present invention is that a plurality of ultrasonic beams of which characteristics are different from each other are transmitted at one time to several points in the interior of the object, and ultrasonic scanning is performed while the position of these ultrasonic beams is moved at each repetition of ultrasonic transmission/reception. Thus, the present invention is not limited to the above-described embodiment.

[**0052**] For example, outputs of the four transmission delay circuits are subject to the frequency modulation in said embodiment. However, the following can be also employed as another embodiment: one of the outputs of said transmission delay circuits is not subject to the frequency modulation and the output of the pulse generating circuit is provided as it is to the transducers; the rest are frequency-modulated respectively with different frequency and provided to the transducers; the small transducer blocks are driven by these signals to perform ultrasonic transmission/reception; and the demodulation of the received signals are performed only on said frequency-modulated signals. In this way, one of the filters of the demodulator can be removed.

[**0053**] Further, in said embodiment, the pulse generating circuit and the frequency modulator are separately provided and the signals from the pulse generating circuit are input to a plurality of the frequency modulators to generate the signals respectively having different frequency. However, it is possible in another embodiment to provide signals to transducers with a plurality of a single type of units (pulse generating circuits) and so generate ultrasonic driving pulses of which frequencies are different for each unit. In said embodiment, demodulation is performed on the received beams, but this should be performed as occasion demands, and it is not always needed. Further, in said embodiment the delay circuits and the phasing circuits are provided for transmission and reception. However, if the transmission/reception area of the small transducer block is on the scale of a single transducer, the delay time control for focusing of the transmitted/received ultrasound may be not necessary. And so, these circuits are not indispensable, either.

[**0054**] Further, in said embodiment, four small transducer blocks are selected. However, the number of the blocks can be increased. Thus, scanning time can be further shortened. Further, by using also a technique for generating a plurality of received beams for one transmitted beam of the small transducer blocks, the scanning time can be further shortened.

[**0055**] Further, in said embodiment, the small transducer block is selected as a rectangular block comprising m×n elements. However, said small transducer block is not limited to this form and it can be selected as a circular block.

[**0056**] According to the present invention, since several transmitted beams are simultaneously transmitted to the interior of the object, the ultrasonic three-dimensional scanning can be performed in the interior of the object at rapid speed as described above. Therefore, an ultrasonic three-dimensional image can be obtained within a short time.

What is claimed is:

1. An ultrasonic diagnostic apparatus comprising:

an ultrasonic probe on which a plurality of ultrasonic transducers are arranged as a two-dimensional plane or a three-dimensional curved surface;

a transducer group selecting circuit for selecting a plurality of transducer groups at different positions on said transducer-arranged surface;

transmitting and receiving means for sending the signals characteristics of which are different from each other to each of the transducer groups selected by said transducer group selecting circuit, transmitting ultrasonic beams all at one time from each transducer group to the interior of the object to be examined, and then receiving their echo signals; and

means for performing three-dimensional ultrasonic scanning of the object by changing the position of the selected transducer groups at every repetition of the ultrasonic transmission/reception by controlling said selecting circuit, and by controlling said transmitting and receiving means to transmit and receive the ultrasonic beams.

2. An ultrasonic diagnostic apparatus comprising:

an ultrasonic probe on which a plurality of ultrasonic transducer groups are arranged as a two-dimensional plane or a three-dimensional curved surface;

a transducer group selecting circuit for selecting a plurality of transducer groups to different positions on said transducer-arranged surface;

transmitting and receiving means for sending signals the characteristic of which are different from each other to each of the transducer groups selected by said transducer group selecting circuit, transmitting ultrasonic beams all at one time from each transducer group to the interior of the object to be examined, and then receiving their echo signals;

means for changing the position of the selected transducer group selected at each repetition of the ultrasonic transmission/reception by controlling said selecting circuit;

means for extracting the received beam signals that match the characteristics of the signals transmitted by each of said transducer groups from among the echo signals received by that transducer group;

image composing means for composing the above-extracted received beam signals to form three-dimensional image data; and

means for displaying an image for three-dimensional image data output by said image composing means.

3. An ultrasonic diagnostic apparatus comprising:

an ultrasonic probe on which a plurality of ultrasonic transducers are arranged as a two-dimensional plane or a three-dimensional curved surface;

a transducer group selecting circuit for selecting a plurality of transducer groups at different positions on said transducer-arranged surface;

transmitting and receiving means for sending signals the characteristics of which are different from each other to each of the transducer group selected by said transducer group selecting circuit, transmitting ultrasonic beams all at one time from each transducer group to the interior of the object to be examined, and then receiving their echo signals;

means for changing the position of the selected transducers at each repetition of the ultrasonic transmission/reception by controlling said selecting circuit;

means for forming received beam signals the characteristics of which are uniform from the echo signals received by said each transducer groups;

image composing means for composing the received beam signals the characteristics of which are uniform to form three-dimensional image data; and

image displaying means for displaying three-dimensional image data output by said image composing means.

4. An ultrasonic diagnostic apparatus according to claim **1-3**, wherein the different characteristics of said transmitted signals are their frequency characteristics.

5. An ultrasonic diagnostic apparatus according to claim **1-4** comprising a pulse generating circuit, a transmission delay circuit, and a frequency modulator, wherein output of said pulse generating circuit is input to said frequency modulator to generate transmitted signals of which said frequency characteristics are different from each other.

6. An ultrasonic diagnostic apparatus according to claim 5, wherein said frequency modulator is provided downstream of the transmission delay circuit.

7. An ultrasonic diagnostic apparatus according to claim 5 or **6**, wherein one of said plurality of transducer groups is provided with the transmitted signals that are not frequency-modulated.

8. An ultrasonic diagnostic apparatus according to claim **5-7** comprising a demodulator in the receiving circuit of said transmitting and receiving means, wherein the echo signals received by said plurality of transducer groups are demodulated by the demodulator, then composed into an image by the image composing means.

9. An ultrasonic diagnostic apparatus according to claim 8 comprising a phasing circuit for reception in said transmitting and receiving means, wherein said demodulator is provided upstream of this phasing circuit.

10. An ultrasonic diagnostic apparatus according to claim **1-9**, wherein said transmitting and receiving means comprises means for forming a plurality of received beams from reflected signals of one transmitted beam transmitted by each transducer group.

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patsnap

专利名称(译)	超声波诊断仪

公开(公告)号	JPWO2001085031A1	公开(公告)日	2003-10-21
申请号	JP2001581691	申请日	2001-05-09
[标]申请(专利权)人(译)	株式会社日立医药		
申请(专利权)人(译)	株式会社日立メディコ		
[标]发明人	浅房勝徳		
发明人	浅房 勝徳		
IPC分类号	A61B8/00 G06T1/00 H04R17/00		
FI分类号	A61B8/00 G06T1/00.400.B H04R17/00.332.B H04R17/00.332.Z		
优先权	2000135943 2000-05-09 JP		
其他公开文献	JP4812048B2		

摘要(译)

为了用超声波束高速扫描被检体的内部并在短时间内获取和显示三维图像，对内置于超声波探头中的二维阵列换能器进行选择性连接。 形成多个小块振荡器，并且通过频率调制电路调制由脉冲生成电路生成的振荡器驱动脉冲信号，并且将具有不同频率特性的驱动脉冲信号同时施加到每个选择的小块振荡器。 然后，超声波束从每个小块换能器发射到对象中。 然后，来自被检体内部的反射波被每个小块换能器接收，接收到的回波信号被每个小块换能器的解调电路解调，然后输入到定相电路以获得多个接收到的束信号。 产生。 每个小块换能器的位置针对每次发送/接收而移动，并且对由此获得的多个接收到的束信号进行信号处理，图像数据，并显示在显示装置上。