



(51) International Patent Classification:

G01S 15/89 (2006.01) *G10K 11/32* (2006.01)
G10K 11/34 (2006.01) *B06B 1/06* (2006.01)
G01N 29/26 (2006.01) *G10K 11/35* (2006.01)

(21) International Application Number:

PCT/JP2009/059730

(22) International Filing Date:

21 May 2009 (21.05.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2008-137958 27 May 2008 (27.05.2008) JP

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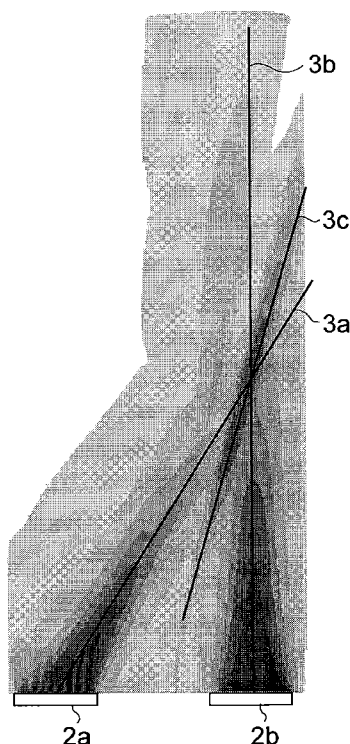
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

(54) Title: ULTRASONIC APPARATUS

FIG.4



(57) Abstract: A transmitting circuit supplies signals to a first and a second ultrasonic probe in such a manner that an observation axis 3a of a first ultrasonic beam transmitted from the first ultrasonic probe and an observation axis 3b of a second ultrasonic beam transmitted from the second ultrasonic probe intersect with each other at a point of intersection, and that a time for a pulse wave transmitted from the first ultrasonic probe to pass through the point of intersection and a time for a pulse wave transmitted from the second ultrasonic probe to pass through the point of intersection overlap with each other. As a result, a third ultrasonic beam is formed on an axis 3c different from the observation axes 3a, 3b. A receiving processing circuit extracts and processes a signal corresponding to a reflected wave from a point on the third axis 3c.



GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR),

OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

DESCRIPTION

Title of Invention
ULTRASONIC APPARATUS

Technical Field

[0001]

The present invention relates to an ultrasonic apparatus that acquires a tomographic image or a three-dimensional image of a sample by using ultrasonic waves, and in particular, it relates to an ultrasonic apparatus that takes pictures by using a plurality of probes.

Background Art

[0002]

An apparatus for acquiring a tomographic image by using conventional general ultrasonic waves is constructed to include, as its components, a transmitting unit for transmitting an ultrasonic wave to an object to be inspected (sample), a receiving unit for receiving a reflected wave, a scanning unit for scanning the transmitting and receiving waves, and a unit for converting a received reflection signal into a luminance signal for visualization. The interior of the sample is observed by using time series tomographic images acquired by these components. In addition, in one form of the apparatus, a three-dimensional image is obtained by scanning an ultrasonic wave in the up and down directions

as well as in the right and left directions by means of the above-mentioned scanning unit.

[0003]

A living body is taken as an object to be observed by an ultrasonic wave. It is well known that an ultrasonic wave is often used to observe the interior of a living body due to advantages such as real time, handiness, non-invasiveness, and so on, possessed by an ultrasonic apparatus.

[0004]

Ultrasonic waves used to observe the interior of a living body are transmitted and received by a plurality of electromechanical transducers (mainly piezoelectric elements). The transmitting unit acts to make the phases of the ultrasonic waves transmitted from the respective elements coincide with one another at a focal position by displacing timings, at which electric signals (drive signals) are supplied to the respective elements, with respect to one another. As a result, the ultrasonic waves converging at the focal position can be generated.

The region through which such ultrasonic waves pass is a region around a straight line connecting between the center of the plurality of elements (the center of an opening) and the focal position. This area is referred to as a transmitting beam (an ultrasonic beam). On the other hand, the receiving unit receives electric signals that are produced from the reflected waves received by the respective

elements, and adds the electric signals of the respective elements to one another after correcting their time delays corresponding to the focal position. As a result, reflection signals of the ultrasonic waves at the focal position are acquired. Here, note that the focal position at the time of the reception can be caused to change in real time. In addition, in contrast to the previously mentioned transmitting beam, the region for which the reflection signals are acquired upon receiving may sometimes be referred to as a received beam.

[0005]

By performing such transmitting and receiving control, the ultrasonic apparatus can cause the ultrasonic waves to converge into a part to be observed, so that the interior of the living body can be imaged according to the intensities of the reflected waves therefrom.

[0006]

The reasons why the formation of the transmitting and receiving beams is needed are that the intensity of reflection of an ultrasonic wave inside a living body is small, and that attenuation thereof due to propagation losses is very large.

[0007]

The attenuation due to propagation will be described. In general, the attenuation of an ultrasonic wave in a living body is 0.5 - 1 dB/(MHz·cm). For example, when a region at a depth of 10 cm is observed by an ultrasonic wave of 3 MHz,

an attenuation of 30 - 60 dB is generated only by the travel of the ultrasonic wave to and from that region. In addition, if a reflection factor is set to about 1% (i.e., corresponding to -40 dB), an attenuation of as much as 70 - 100 dB will be generated in total. In order to suppress the reduction of the SN ratio of a received signal due to such an attenuation, the formation of transmitting and receiving beams as stated above is performed.

[0008]

Japanese patent application laid-open No. 2001-299750 describes a technique for improving the SN ratio by the use of a Golay code matched to a frequency band of an ultrasonic transducer.

Summary of Invention

[0009]

However, the magnitude of attenuation depends on the distance, so in particular, in case where a part far from ultrasonic probes is observed, it becomes difficult to ensure a satisfactory SN ratio. Nevertheless, safety standards are set for the ultrasonic wave power that can be input to the living body, and hence there is a limitation in the technique of improving the SN ratio by increasing the input power.

[0010]

In addition, the half width (full width at half maximum) of the transmitting and receiving beams for determining the

azimuth resolution of an image is represented by the following expression.

$$\Delta y = d/2 \approx 1.22\lambda/D \times X$$

where d denotes the width of a beam; D denotes the width of an opening; and X denotes a depth. It is found that if the magnitude of the opening is fixed, the width of a beam becomes wider in accordance with an increasing depth of a region to be observed, and hence the SN ratio decreases when considering in terms of the intensity of reflection per unit volume of the part to be observed. In this regard, note that the opening here indicates a region formed by elements which actually perform the transmitting and receiving operations.

[0011]

The present invention has been made in view of the above-mentioned problems, and provides an ultrasonic apparatus which is capable of acquiring a signal with a high SN ratio even in a deep portion of an object to be inspected.

[0012]

The present invention provides an ultrasonic apparatus including: a first ultrasonic probe that has a plurality of transducers; a second ultrasonic probe that has a plurality of transducers; a transmitting circuit that supplies signals for transmitting ultrasonic waves to the first and second ultrasonic probes; a receiving processing circuit that processes signals obtained from the ultrasonic waves received by the first and second ultrasonic probes; an image

processing unit that forms image information by using information output from the receiving processing circuit; and a control unit that controls the transmitting circuit and the receiving processing circuit, wherein the transmitting circuit supplies signals to the first and second ultrasonic probes in such a manner that (i) a first axis and a second axis intersect with each other at a point of intersection, the first axis being an axis of a first ultrasonic beam transmitted from the first ultrasonic probe, the second axis being an axis of a second ultrasonic beam transmitted from the second ultrasonic probe, and that (ii) a time for a pulse wave transmitted from the first ultrasonic probe to pass through the point of intersection and a time for a pulse wave transmitted from the second ultrasonic probe to pass through the point of intersection at least partially overlap with each other, and thereby serves to form a third ultrasonic beam on a third axis different from the first and second axes; and wherein the receiving processing circuit extracts and processes a signal corresponding to a reflected wave from a point on the third axis.

[0013]

According to the present invention, the third ultrasonic beam can be formed, whereby it becomes possible to acquire a signal with a high SN ratio even in a deep portion of an object to be inspected.

Further features of the present invention will become apparent from the following description of exemplary

embodiments with reference to the attached drawings.

Brief Description of Drawings

[0014]

Fig. 1 is a block diagram showing an ultrasonic apparatus according to a first embodiment of the present invention.

Fig. 2 is a view showing an example of a first ultrasonic beam transmitted from a first ultrasonic probe.

Fig. 3 is a view showing an example of a second ultrasonic beam transmitted from a second ultrasonic probe.

Fig. 4 is a view showing an example of a third ultrasonic beam formed by the first ultrasonic beam and the second ultrasonic beam according to the first embodiment.

Fig. 5 is a view showing another example of a third ultrasonic beam according to the first embodiment.

Fig. 6 is a view showing another example of a third ultrasonic beam according to the first embodiment.

Fig. 7 is a view showing another example of a third ultrasonic beam according to the first embodiment.

Fig. 8 is a view showing another example of a third ultrasonic beam according to the first embodiment.

Fig. 9 is a view showing an example of a third ultrasonic beam according to a second embodiment of the present invention.

Fig. 10 is a view for explaining transmitting timing of ultrasonic waves according to the second embodiment.

Fig. 11 is a block diagram showing an ultrasonic apparatus according to the second embodiment and a third embodiment of the present invention.

Fig. 12 is a view showing an example of a third ultrasonic beam according to the third embodiment.

Description of Embodiments

[0015]

Hereinafter, preferred embodiments of the present invention will be described in detail by way of example while referring to the accompanying drawings. Although a medical ultrasonic diagnostic apparatus is shown herein as one example of an ultrasonic apparatus, the present invention is preferably applicable to a variety of kinds of ultrasonic inspection apparatuses in which objects other than a living body are made the objects to be inspected.

[0016]

<First Embodiment>

Fig. 1 is a system schematic diagram showing an ultrasonic apparatus according to a first embodiment of the present invention.

[0017]

The ultrasonic apparatus is provided with a plurality of ultrasonic probes 1a, 1b. Each of the ultrasonic probes 1a, 1b is provided with a plurality of transducers (not shown). A transducer is an element that performs interconversion between an electric signal and a mechanical vibration

(ultrasonic wave), and a piezoelectric element, for example, is used therefor. Position sensors 5a, 5b are mounted on the probes 1a, 1b, respectively.

[0018]

Here, for the sake of convenience, the ultrasonic probe 1a is called a first ultrasonic probe, and the ultrasonic probe 1b is called a second ultrasonic probe. In addition, an ultrasonic beam formed by an ultrasonic wave transmitted from the first ultrasonic probe is called a first ultrasonic beam or a first transmitting beam, and the central axis of the beam is called a first observation axis or a first axis. Similarly, an ultrasonic beam formed by an ultrasonic wave transmitted from the second ultrasonic probe is called a second ultrasonic beam or a second transmitting beam, and the central axis of the beam is called a second observation axis or a second axis.

[0019]

The ultrasonic apparatus is provided with a transmitting circuit 6, a receiving processing circuit 7, a probe position processing unit 8, an image processing unit 11, an image display unit 12, and a system control unit 13. The transmitting circuit 6 is a circuit that supplies electric signals (drive signals) for transmitting ultrasonic waves to the ultrasonic probes 1a, 1b. Also, the receiving processing circuit 7 is a circuit that processes signals obtained from the ultrasonic waves (reflected waves) received by the ultrasonic probes 1a, 1b. The probe position

processing unit 8 is a circuit that acquires three-dimensional position information of the respective ultrasonic probes 1a, 1b based on the outputs of the position sensors 5a, 5b. The image processing unit 11 is a circuit that forms image information (e.g., a B mode image, an M mode image, etc.) by using information output from the receiving processing circuit 7. The image display unit 12 is a display device that displays an image signal output from the image processing unit 11. The image display unit 12 can be constructed separately from a main body of the ultrasonic apparatus. The system control unit 13 is a circuit that controls the transmitting circuit 6, the receiving processing circuit 7, the probe position processing unit 8, the image processing unit 11, and so on.

[0020]

Reference will be made to the flow of signals by using Fig. 1. In Fig. 1, the probe position processing unit 8 acquires the position information of the ultrasonic probes 1a, 1b, and transmits the information thus acquired to the system control unit 13. The system control unit 13 decides, based on the position information, the directions of transmitting of the individual ultrasonic probes in such a manner that the observation axes of the ultrasonic beams transmitted from the individual ultrasonic probes intersect with one another inside an object to be inspected. The system control unit 13 transmits information on the transmitting directions and focal depths separately set to the

transmitting circuit 6. The transmitting circuit 6 decides, based on the information, the time delays and magnitudes of the individual transducers of the individual ultrasonic probes, and supplies electric signals for driving the respective transducers to the ultrasonic probes 1a, 1b.

[0021]

Reference will be made to the formation of the transmitting beams inside the object to be inspected by using Fig. 2 through Fig. 4. Fig. 2 and Fig. 3 are plots of maximum sound pressures which, after an ultrasonic wave transmitted from each one of the ultrasonic probes has passed, were obtained by calculation. Fig. 4 is a plot of maximum sound pressure after the ultrasonic waves transmitted from the two ultrasonic probes have passed. Those portions which are larger in sound pressure are illustrated by thicker color.

[0022]

Looking at Fig. 2, an ultrasonic wave transmitted from an opening 2a of the first ultrasonic probe 1a forms a first transmitting beam along a first observation axis 3a. Also, looking at Fig. 3, an ultrasonic wave transmitted from an opening 2b of the second ultrasonic probe 1b forms a second transmitting beam along a second observation axis 3b. Here, note that in the calculation, attenuation accompanying the propagation of the ultrasonic waves is taken into consideration.

[0023]

Fig. 4 shows a maximum sound pressure distribution in

case where the first observation axis 3a and the second observation axis 3b intersect with each other, and the ultrasonic wave (pulse wave) transmitted from the opening 2a and the ultrasonic wave transmitted from the opening 2b arrive at a point of intersection of the observation axes 3a, 3b at the same time. When the transmitting beams of the individual probes are controlled in this manner, a region with high sound pressure is formed along an axis 3c that is different from the first observation axis 3a and the second observation axis 3b. Hereinafter, this high sound pressure region is called a third ultrasonic beam or a third transmitting beam, and the axis 3c is called a third observation axis or a third axis. The position of this third observation axis 3c can be calculated from the positions of the first and second observation axes 3a, 3b and the transmitting timings (phase difference) of the ultrasonic waves from the individual openings 2a, 2b. In the example of Fig. 4, the third observation axis 3c is formed in such a manner that it passes through the point of intersection of the observation axes 3a, 3b, and divides an angle formed by the observation axes 3a, 3b into two equal halves.

[0024]

As can be seen from Fig. 4, the third transmitting beam converges at a deeper portion of the object to be inspected than the first and second transmitting beams do, and the half width (full width at half maximum) of the third transmitting beam is sufficiently narrower than the half

widths of the first and second transmitting beams.

Accordingly, by using a reflected wave generated by this third transmitting beam, it is possible to obtain a signal having a high reflection intensity per unit volume and a high SN ratio even in a deep portion of the object to be inspected.

[0025]

Further, reference will be made to a different form of formation of transmitting beams by using Fig. 5 through Fig. 8. Fig. 5 through Fig. 8 also show examples in which the first observation axis 3a and the second observation axis 3b intersect with each other, similar to Fig. 4, and the transmitting beams are controlled in such a manner that the ultrasonic wave transmitted from the opening 2a and the ultrasonic wave transmitted from the opening 2b can arrive at the point of intersection of the observation axes 3a, 3b at the same time. However, in Fig. 5 through Fig. 8, the positional relation of the point of intersection of the observation axes 3a, 3b and the focal points 4a, 4b on the observation axes 3a, 3b is changed. That is, Fig. 5 is an example in which the focal points are set to positions that are sufficiently nearer to the openings than the point of intersection of the observation axes. Fig. 6 and Fig. 7 are examples in which the focal points are set in the vicinity of the point of intersection of the observation axes, wherein in Fig. 6, the focal points are nearer to the openings than the point of intersection, and in Fig. 7, the point of

intersection is nearer to the openings than the focal points. In addition, Fig. 8 is an example in which the focal points are set to positions that are sufficiently distant from the point of intersection of the observation axes. It is found that in any case, a third transmitting beam with a narrow half width is formed in a deeper part than first and second transmitting beams are formed.

[0026]

Reverting to Fig. 1, reference will be made to the receiving of signals. The ultrasonic probes 1a, 1b receive the reflected waves from the object to be inspected by means of the plurality of transducers. The received reflected waves are converted into corresponding electric signals, respectively, which are then input to the receiving processing circuit 7. In addition, the system control unit 13 produces information on the positional relation between the respective ultrasonic probes 1a, 1b and an observation point on the third observation axis 3c by using position information from the probe position processing unit 8, and transmits it to the receiving processing circuit 7. Specifically, the system control unit 13 calculates the position at which the third observation axis 3c is to be formed, from the positions of the first and second observation axes 3a, 3b and the transmitting timings of the individual ultrasonic probes 1a, 1b, and sets the observation point on the third observation axis 3c thus obtained. Here, note that in this embodiment, the observation point is set on

a straight line that passes through the point of intersection of the first and second observation axes 3a, 3b, and it is further set in such a manner that the ultrasonic waves transmitted from two openings 2a, 2b pass through the point of intersection at the same timing as the timing at which they pass through their point of intersection.

[0027]

The receiving processing circuit 7 extracts the signals related to the reflected waves from the specified observation point by performing time delay processing on input time series electric signals by the use of this positional relation information and adding them to one another. Then, the receiving processing circuit 7 detects an envelope of the extracted signals, and transmits the electric signals to the image processing unit 11. The image processing unit 11 produces luminance signals at respective positions in an observation region by using the position information of the observation points transmitted from the system control unit 13 and the electric signals transmitted from the receiving processing circuit 7, and outputs the luminance signals thus produced to the image display unit 12.

[0028]

An image in the observation region can be formed by sequentially performing the above-mentioned processing while changing the transmitting direction. Here, note that it is preferable to form the image by using not only the reflected wave from the point on the third axis but also

the reflected waves from the point on the first axis and the point on the second axis for the purpose of increasing the observation field of view. In that case, it is desirable to perform merging or filtering processing so as to make unostentatious or indistinctive the boundaries of image data obtained on the respective observation axes.

[0029]

It is possible to acquire signals with a high SN ratio even in the deep portion by using an ultrasonic diagnostic apparatus as described above.

[0030]

Although in this embodiment, reference has been made to the case in which two ultrasonic probes are used, it is possible to obtain similar effects even in case where three or more probes are used. Further, although in this embodiment, the description has been made on a two-dimensional surface, it is also possible to achieve similar effects in a three-dimensional space by means of similar processing.

[0031]

In addition, it is also preferable to construct that the plurality of ultrasonic probes be fixed to jigs. In this case, since the relative positions between the probes are already known and do not change, there is no need to acquire the position information of the probes for the calculation of the observation axes 3a through 3c.

Accordingly, the position sensors and the probe position

processing unit can be omitted.

[0032]

In this embodiment, an opening is used in the meaning of a region which is formed by a plurality of transducers that are performing transmitting or receiving operations. For example, in the case of a linear scanning ultrasonic probe comprising 128 transducers, when transmitting and receiving are carried out by the use of 32 transducers, the size of an opening is equal to that of 32 elements or transducers. Also, in the case of a sector scanning ultrasonic probe comprising 64 transducers, when 64 transducers are used, the size of an opening is equal to that of 64 elements or transducers.

[0033]

<Second Embodiment>

Next, reference will be made to a second embodiment of the present invention. In the first embodiment, transmitting timings are controlled so that the ultrasonic wave transmitted from the opening 2a and the ultrasonic wave transmitted from the opening 2b can arrive at the point of intersection of the observation axes 3a, 3b at the same time. In contrast to this, in the second embodiment, transmitting timings are displaced from each other in a manner such that the respective ultrasonic waves do not arrive at the point of intersection of the observation axes 3a, 3b at the same time.

[0034]

Fig. 9 shows a maximum sound pressure distribution when ultrasonic waves are transmitted from two openings 2a, 2b. Fig. 10 shows a sound pressure waveform 20a on the time axis of an ultrasonic wave (pulse wave) transmitted from the opening 2a and a sound pressure waveform 20b on the time axis of an ultrasonic wave (pulse wave) transmitted from the opening 2b at the point of intersection of the two observation axes 3a, 3b. In the sound pressure waveform 20a, the waveform 21a of the ultrasonic wave transmitted from the opening 2a is plotted, and in the sound pressure waveform 20b, the waveform 21b of the ultrasonic wave transmitted from the opening 2b is plotted. Although in actuality, a sound pressure in which these two sound pressure waveforms are superposed on each other is observed, but it is displayed by being separated into two sound pressure waveforms for the purpose of explanation. These two ultrasonic waveforms 21a, 21b overlap with each other for the length of a superposition time 22.

[0035]

If a time for the ultrasonic wave transmitted from the opening 2a to pass through the point of intersection and a time for the ultrasonic wave transmitted from the opening 2b to pass through the point of intersection have an overlap at least a part thereof, as shown in Fig. 10, a third transmitting beam will be formed, as shown in Fig. 9. However, a third observation axis 3c in this case does not pass through the point of intersection of the two observation axes 3a,

3b.

[0036]

An ultrasonic apparatus of this embodiment uses a signal related to a reflected wave from a specified observation point on this third observation axis 3c. In this embodiment, the third observation axis 3c does not pass through the point of intersection, so it is necessary to separately calculate the position at which the third observation axis 3c is formed. Therefore, the ultrasonic apparatus of this embodiment is provided with a beam position calculation unit 14, as shown in Fig. 11.

[0037]

The system control unit 13 transmits information on the direction of transmitting, the depth of focus and the positions of the probes to the beam position calculation unit 14, prior to the control of transmitting and receiving. The beam position calculation unit 14 calculates the timing and position at which the third observation axis 3c is formed. The result of the calculation is saved or retained in the form of a table in a storage unit (memory) in the beam position calculation unit 14. In this calculation, techniques such as Rayleigh integration from the transmitting sound pressure, a sound pressure distribution estimation by Green's function, and a calculation using a spatial response function can be used.

[0038]

A technique for transmitting ultrasonic waves performs

processing similar to that in the first embodiment, and hence an explanation thereof is omitted. When receiving signals, the receiving processing circuit 7 extracts the signals received from the observation points on the third axis by referring to the calculation result on the memory of the beam position calculation unit 14. In that case, the receiving processing circuit 7 performs processing on the received signals by using a signal obtained by one of the ultrasonic probes 1a, 1b, whose distance between a corresponding observation point and its opening is shorter. By performing such processing, receiving can be performed in a place nearer to the observation point, and hence, reduction in intensity of the reflected waves can be prevented. In Fig. 9, the opening 2b is nearer to an observation point than the opening 2a, so image information is formed by using the received signal from the ultrasonic probe 1b.

[0039]

The beam position calculation unit 14 can calculate an MI (mechanical index) value and a TI (thermal index) value, and displays those values on the image display unit 12 through the system control unit 13. When the MI value or the TI value exceeds an allowable range for a corresponding predetermined reference, it is more preferable to perform appropriate processing such as stopping transmitting, or displaying a warning on a display screen, or lowering the intensity of transmitting, or the like.

[0040]

It is possible to acquire signals with a high SN ratio even in a deep portion by performing processing as described above.

[0041]

Here, note that the above-mentioned processing can be done by using a system for signal processing, similar to the one used in the first embodiment.

[0042]

<Third Embodiment>

Next, reference will be made to a third embodiment of the present invention.

[0043]

Fig. 12 shows a maximum sound pressure distribution when ultrasonic waves are transmitted from two openings 2a, 2b. In this embodiment, the openings 2a, 2b are arranged in a non-parallel positional relation to each other. In case where a plurality of ultrasonic probes are actually used, the opening surfaces of the probes might not be parallel to one another, so such a case is assumed. Even in such a positional relation, a third transmitting beam is formed, and the half width thereof is narrower than those of a first transmitting beam and a second transmitting beam.

[0044]

However, the sensitivity of each probe in transmitting and receiving ultrasonic waves has angular dependence. When the projection component of an opening area of each probe becomes small, there is a tendency that the sensitivity

thereof becomes high in a front direction of the opening, but becomes low in the other directions, because the transducers of each probe respectively have angular dependence.

[0045]

Since each probe has such angular dependence, it is desirable that reflected waves be able to be acquired in the vertical direction of the opening as much as possible. Accordingly, in this embodiment, when acquiring the reflected waves from observation points (10a, 10b) on the third observation axis 3c, the receiving processing circuit 7 decides, based on the angles (9a, 9b; 9c, 9d) of the reflected waves with respect to the vertical directions of the openings 2a, 2b, respectively, which of the received signals of the ultrasonic probes should be used.

[0046]

For example, in case where the reflected waves from the observation point 10a are acquired, the receiving processing circuit 7 makes a comparison between the angle 9a, which is formed by a straight line connecting between the center of the opening 2a and the observation point 10a and a straight line perpendicular to the opening 2a, and the angle 9d, which is formed by a straight line connecting between the center of the opening 2b and the observation point 10a and a straight line perpendicular to the opening 2b, with each other. In the example of Fig. 12, the angle 9a is smaller than the angle 9d, so image information

corresponding to a reflected wave from the observation point 10a is formed by using the signal obtained by the ultrasonic probe 2a. On the other hand, in case where the reflected waves from the observation point 10b are acquired, similarly, the angle 9b and the angle 9c are compared with each other, and the signal obtained by the ultrasonic probe 1b, for which the angle is smaller, is used.

[0047]

By performing processing as described above, it is possible to receive the reflected waves from the third axis in an efficient manner.

[0048]

Here, note that the processing of this embodiment can be carried out by means of the system of Fig. 11 which has been described in the second embodiment.

[0049]

In the foregoing, the present invention has been described by taking the plurality of embodiments, but these merely exemplarily illustrate some specific examples of the present invention. The scope of the present invention is not limited to the above-mentioned embodiments, and various changes and modifications can be made within the range of the technical concept thereof. In addition, it is also possible to appropriately combine the constructions described in the respective embodiments.

[0050]

While the present invention has been described with

reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0051]

This application claims the benefit of Japanese Patent Application No. 2008-137958, filed on May 27, 2008, which is hereby incorporated by reference herein in its entirety.

CLAIMS

1. An ultrasonic apparatus comprising:
 - a first ultrasonic probe that has a plurality of transducers;
 - a second ultrasonic probe that has a plurality of transducers;
 - a transmitting circuit that supplies signals for transmitting ultrasonic waves to the first and second ultrasonic probes;
 - a receiving processing circuit that processes signals obtained from the ultrasonic waves received by the first and second ultrasonic probes;
 - an image processing unit that forms image information by using information output from the receiving processing circuit; and
 - a control unit that controls the transmitting circuit and the receiving processing circuit,
- wherein the transmitting circuit supplies signals to the first and second ultrasonic probes in such a manner that
 - (i) a first axis and a second axis intersect with each other at a point of intersection, the first axis being an axis of a first ultrasonic beam transmitted from the first ultrasonic probe, the second axis being an axis of a second ultrasonic beam transmitted from the second ultrasonic probe, and that
 - (ii) a time for a pulse wave transmitted from the first ultrasonic probe to pass through the point of

intersection and a time for a pulse wave transmitted from the second ultrasonic probe to pass through the point of intersection at least partially overlap with each other, and thereby serves to form a third ultrasonic beam on a third axis different from the first and second axes; and wherein

the receiving processing circuit extracts and processes a signal corresponding to a reflected wave from a point on the third axis.

2. The ultrasonic apparatus according to claim 1, further comprising:

a probe position processing unit that acquires position information on the first ultrasonic probe and the second ultrasonic probe;

wherein the control unit calculates the positions of the first, second and third axes based on the position information of the first and second ultrasonic probes acquired by the probe position processing unit.

3. The ultrasonic apparatus according to claim 1, wherein

the transmitting circuit supplies the signals to the first and second ultrasonic probes in such a manner that the pulse wave transmitted from the first ultrasonic probe and the pulse wave transmitted from the second ultrasonic probe arrive at the point of intersection at the same time, and thereby serves to form the third ultrasonic beam so that

the third axis passes through the point of intersection.

4. The ultrasonic apparatus according to claim 1, wherein

the receiving processing circuit extracts and processes a signal(s) corresponding to a reflected wave(s) from a point on the first axis and/or a point on the second axis.

5. The ultrasonic apparatus according to claim 4, wherein

the image processing unit merges image information, which is formed from the signal corresponding to the reflected wave from the point on the third axis, and image information, which is formed from the signal(s) corresponding to the reflected wave(s) from the point on the first axis and/or the point on the second axis.

6. The ultrasonic apparatus according to claim 1, wherein

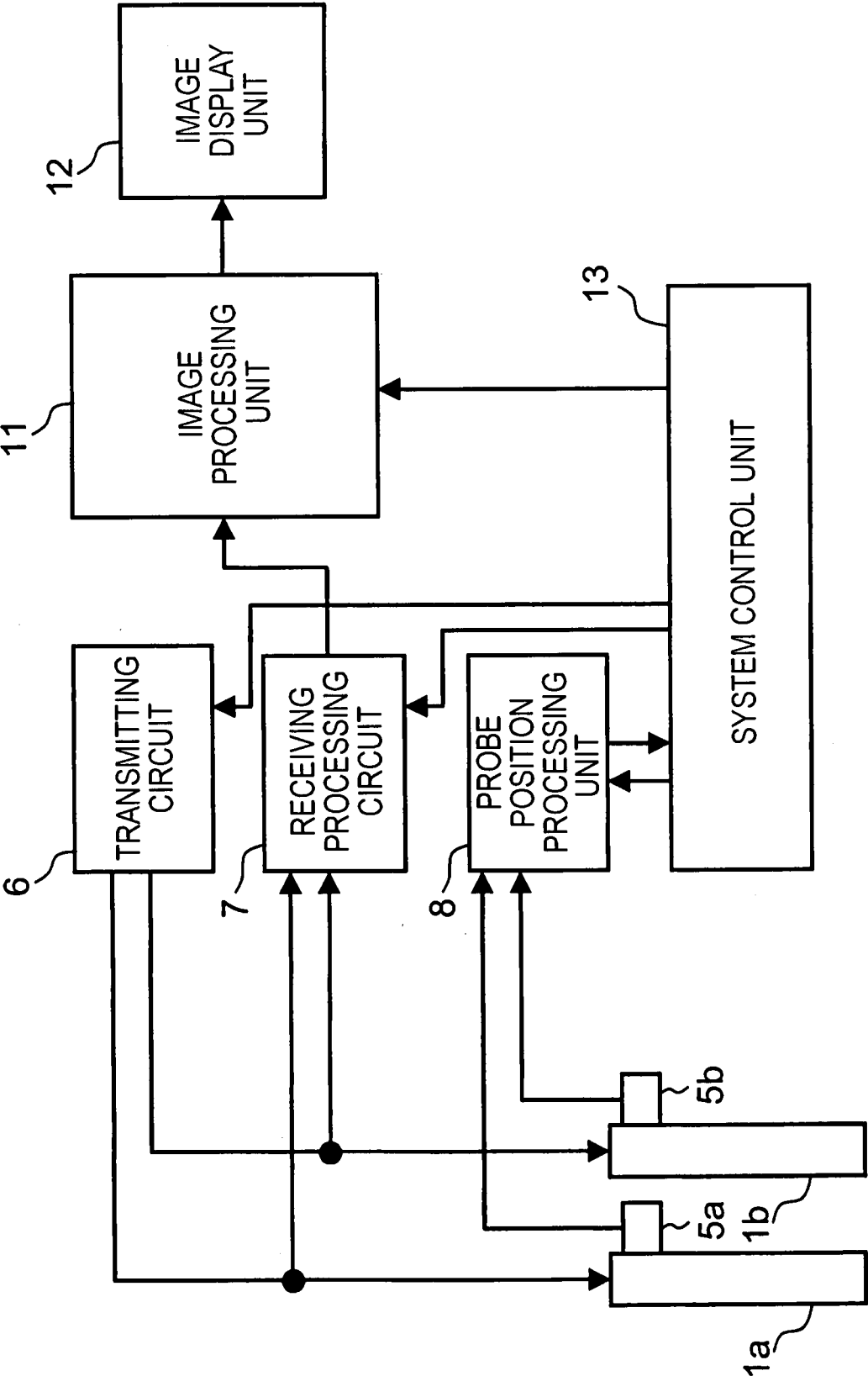
the receiving processing circuit extracts the signal corresponding to the reflected wave from the point on the third axis by using a signal obtained by one of the first ultrasonic probe and the second ultrasonic probe, of which a distance from the point on the third axis is shorter.

7. The ultrasonic apparatus according to claim 1,

wherein

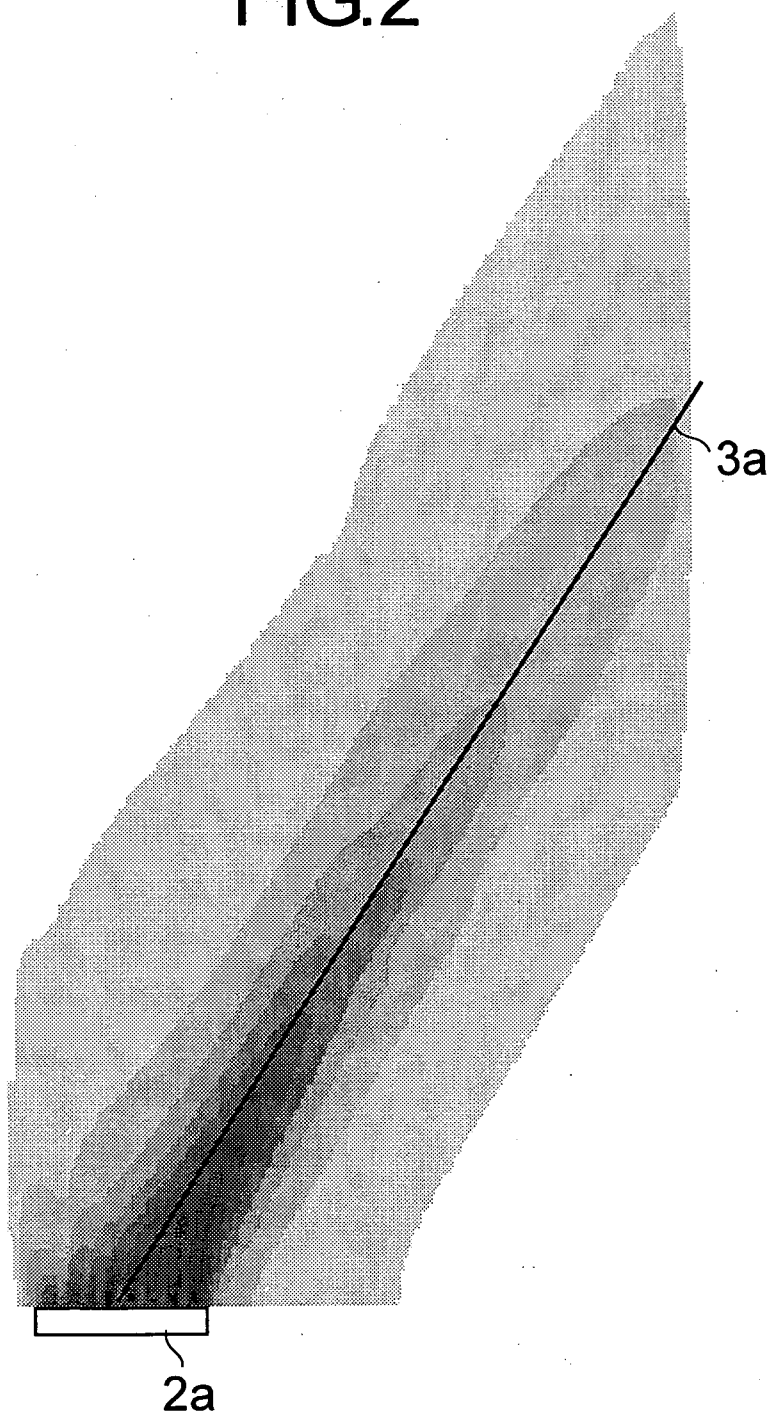
the receiving processing circuit extracts the signal corresponding to the reflected wave from the point on the third axis by using a signal obtained by one of the first ultrasonic probe and the second ultrasonic probe, of which an angle formed by a straight line connecting between the center of an opening of the one ultrasonic probe and the point on the third axis and a straight line perpendicular to the opening is smaller.

FIG.1



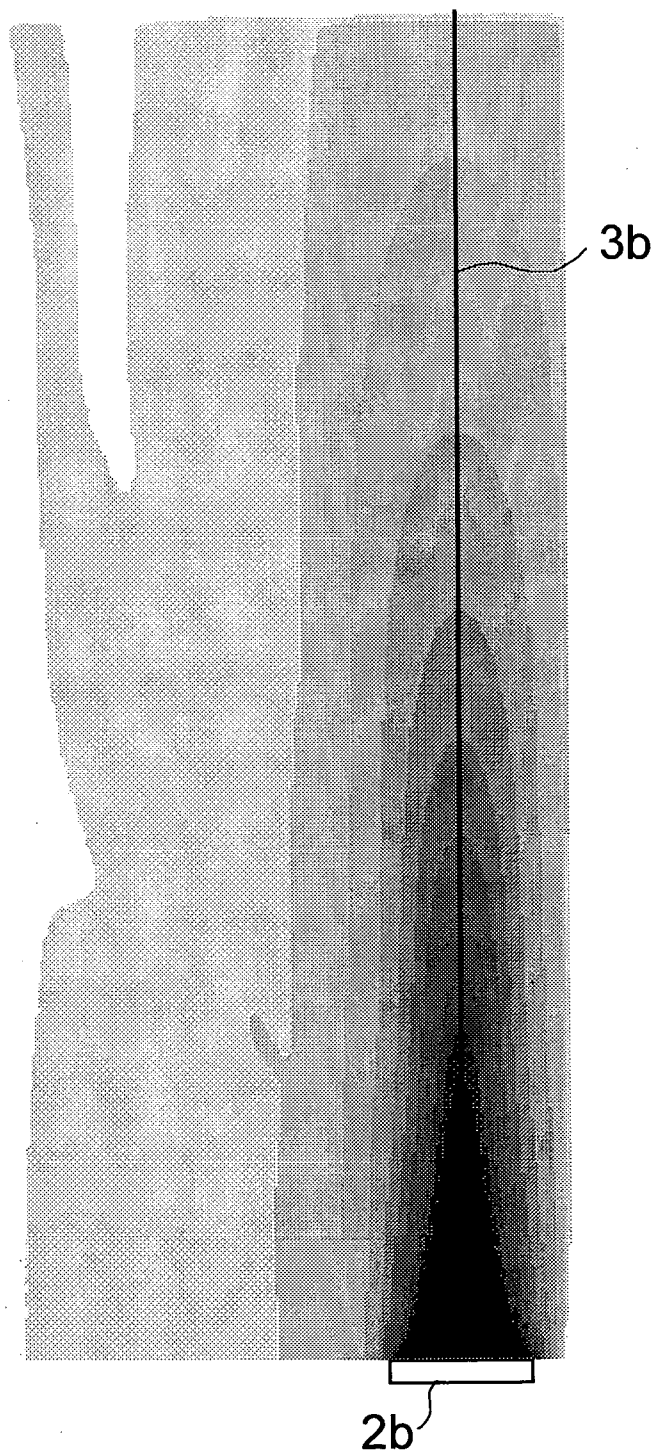
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FIG.2



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FIG.3



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FIG.4

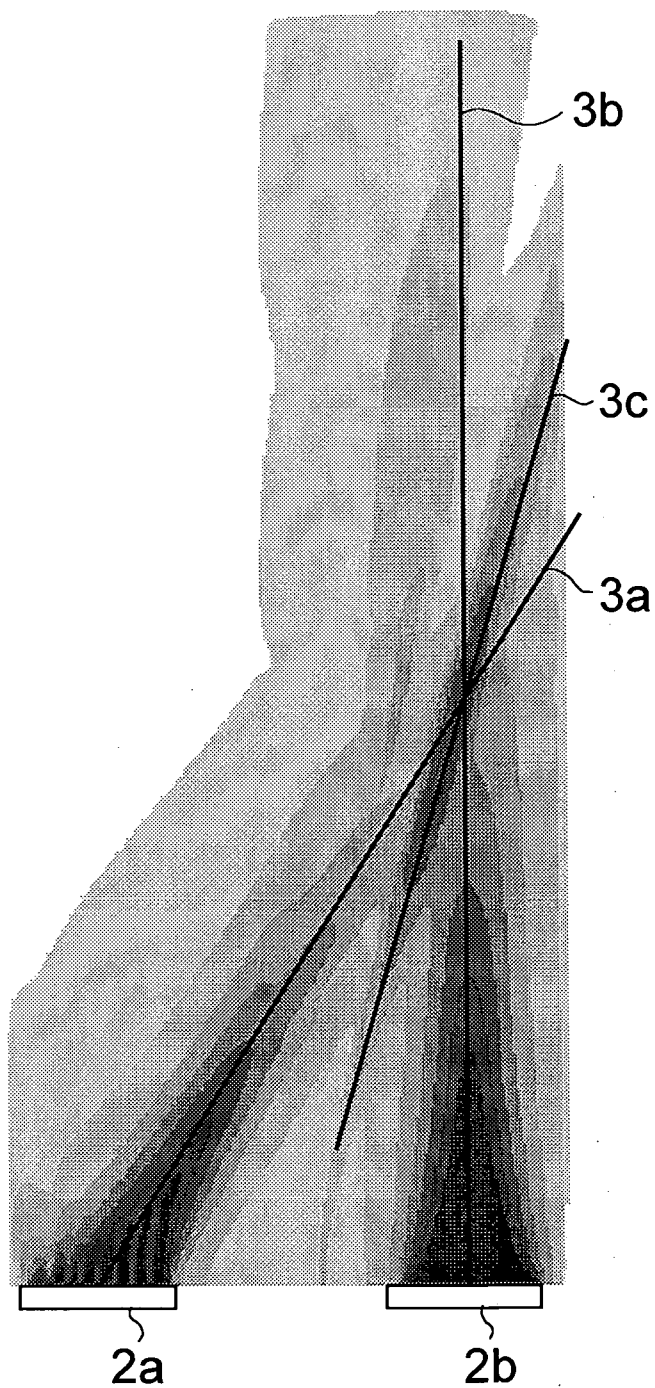


FIG.5

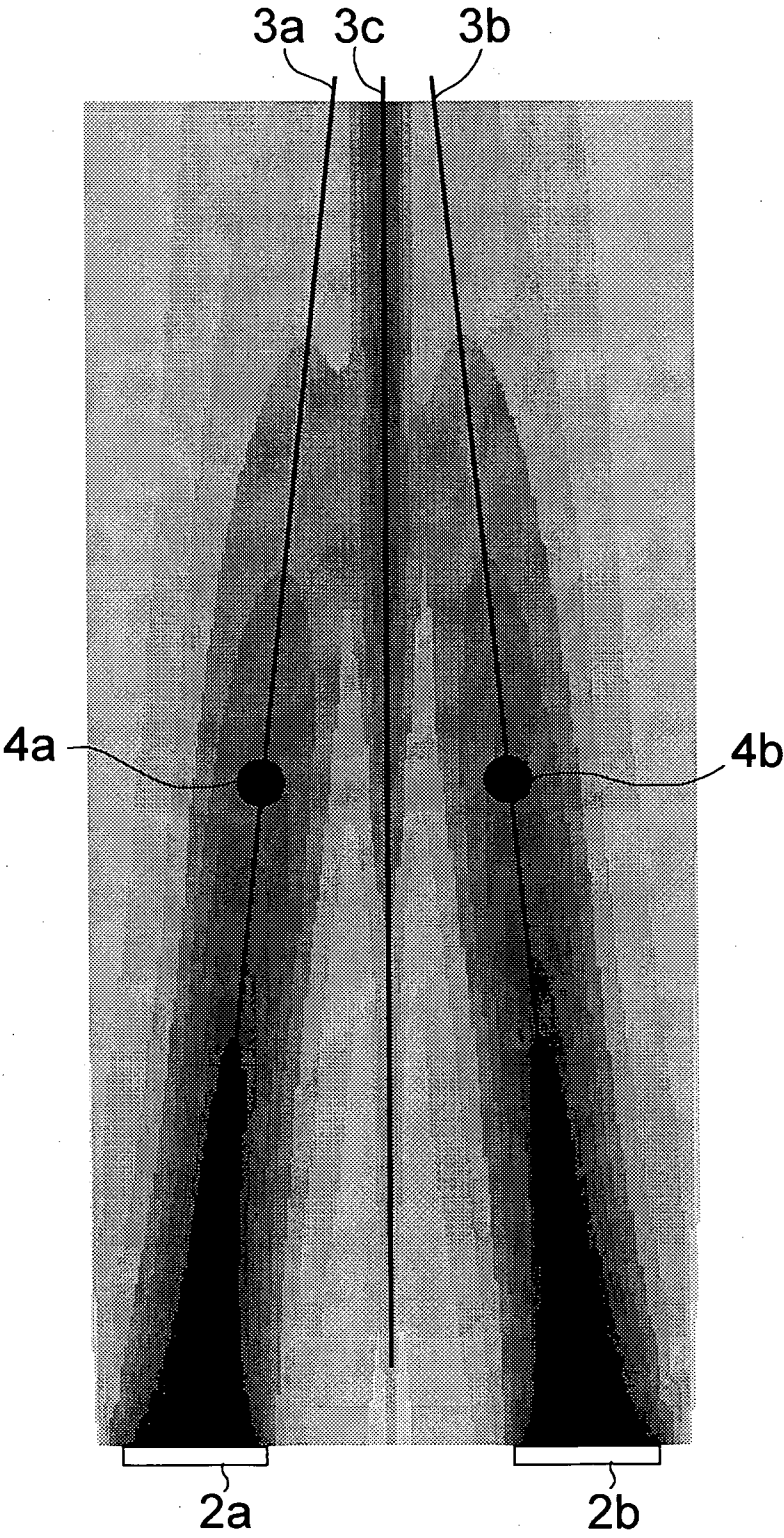
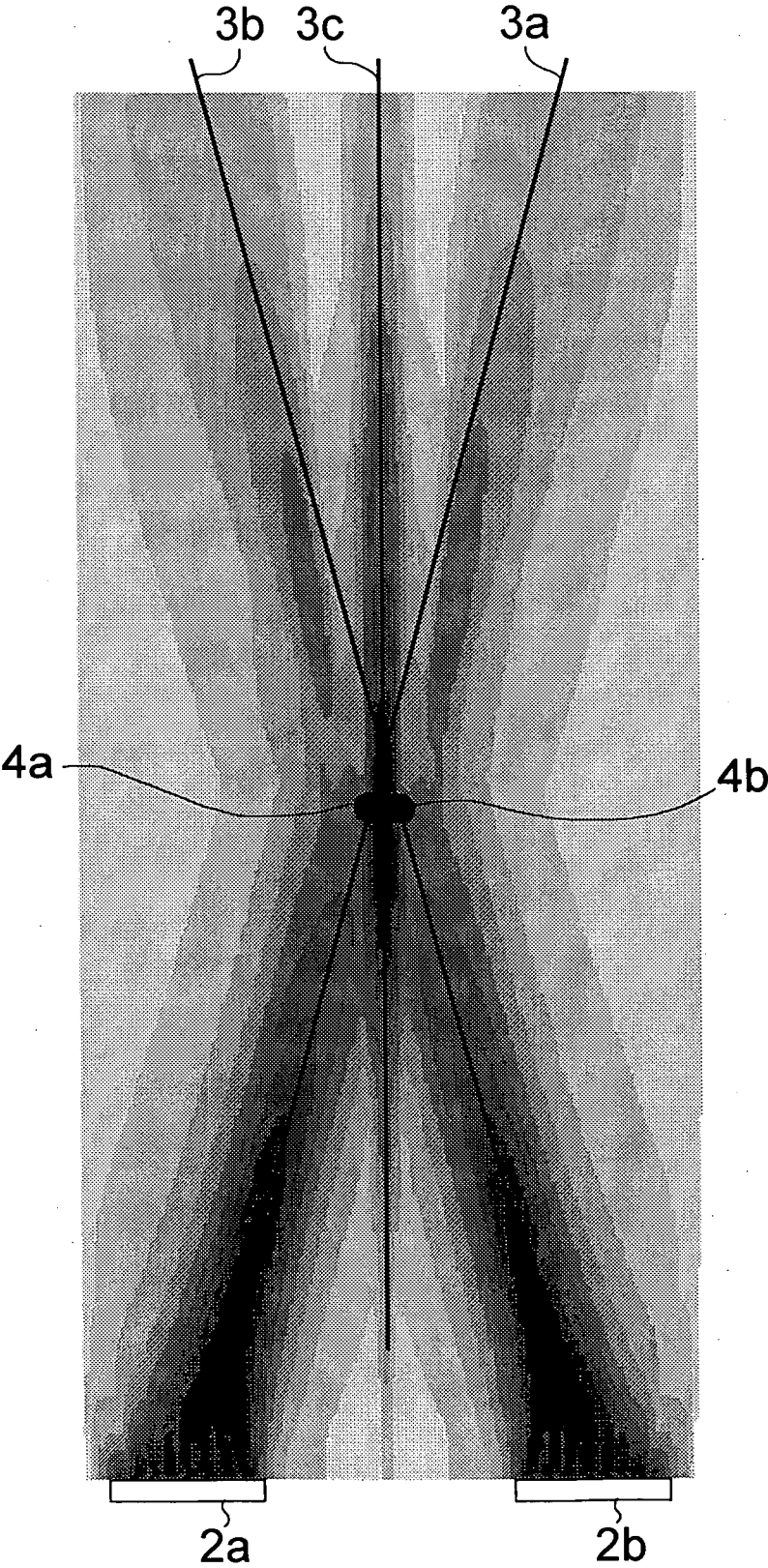


FIG.6



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FIG.7

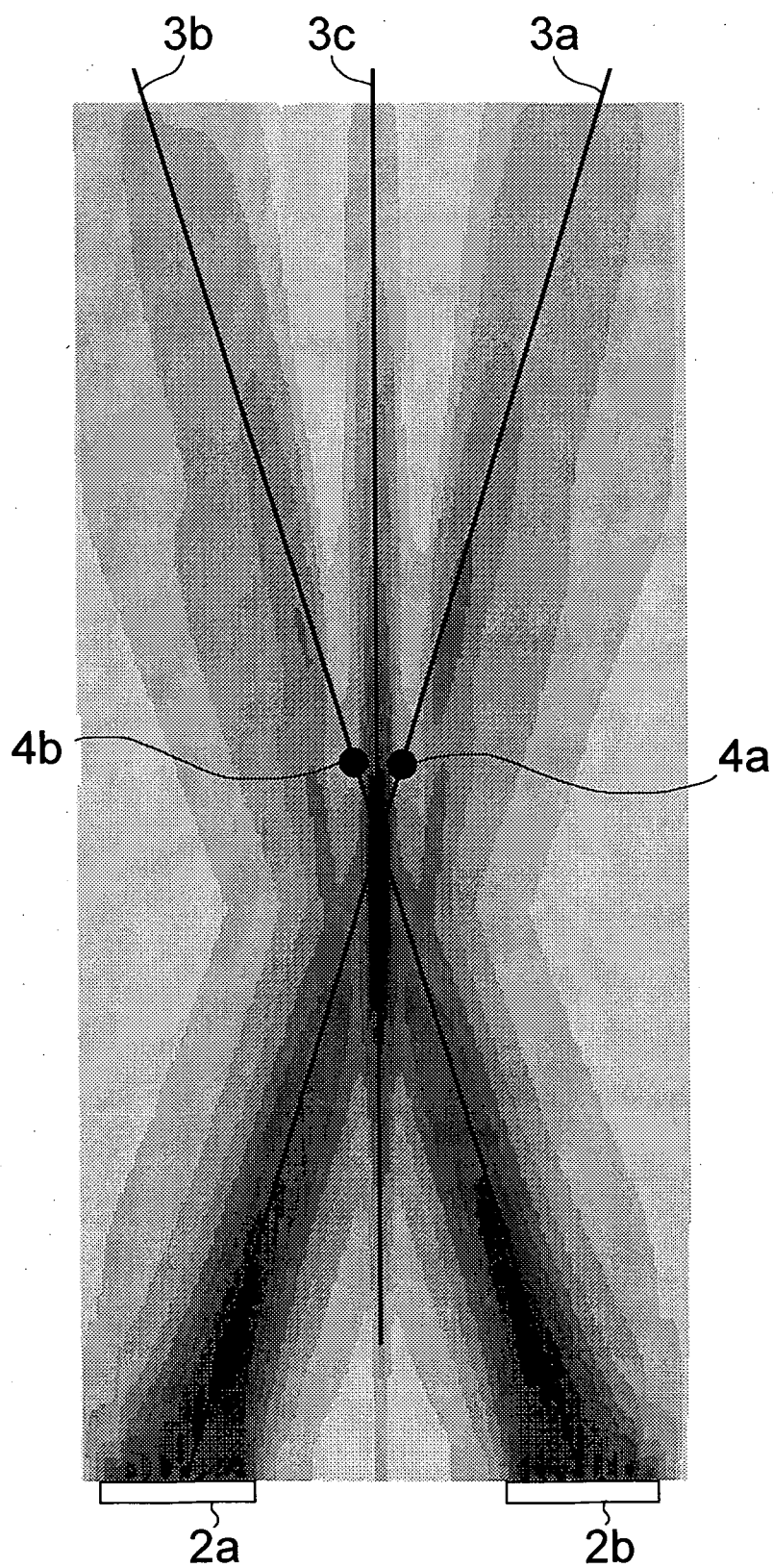
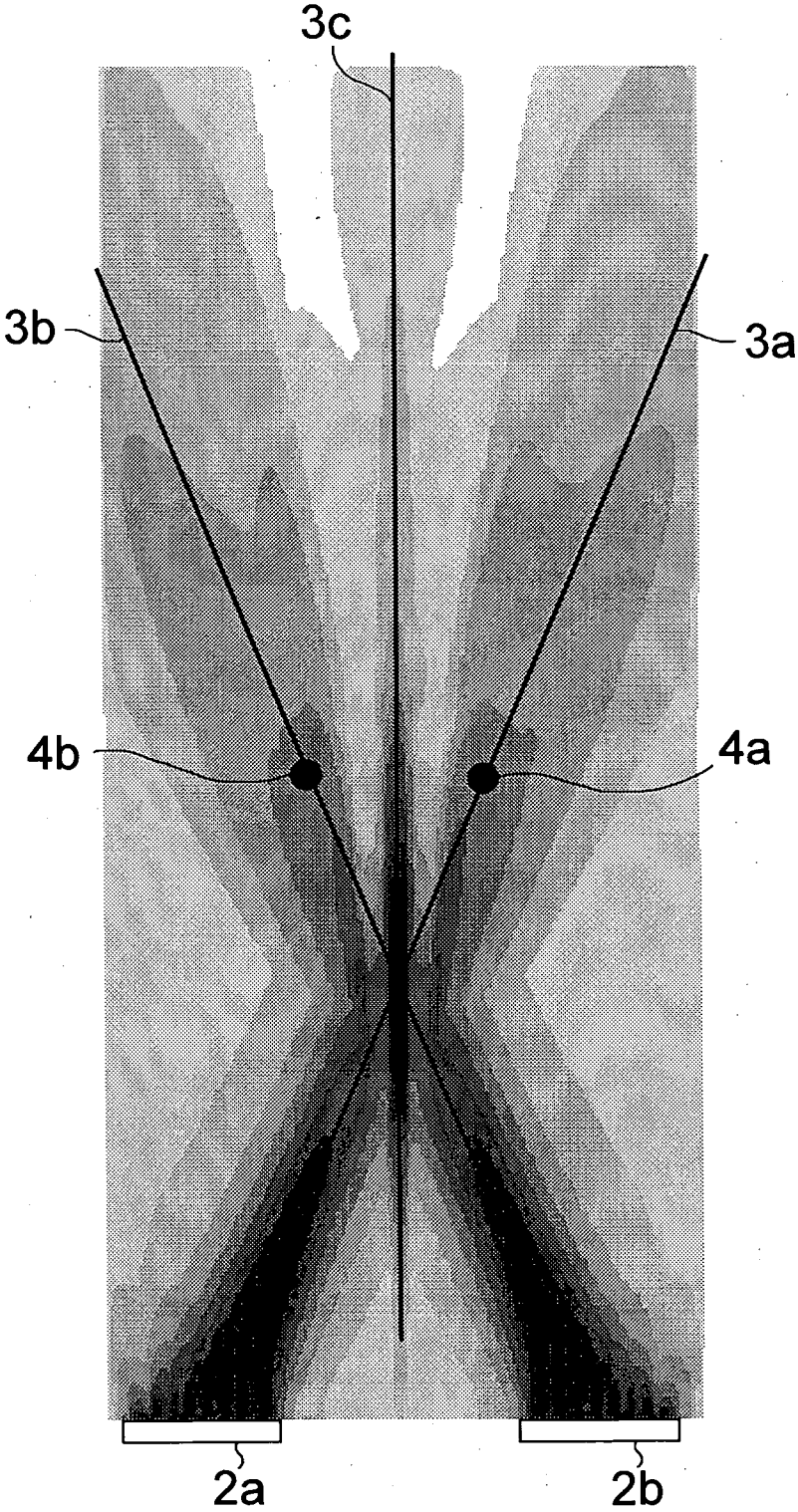
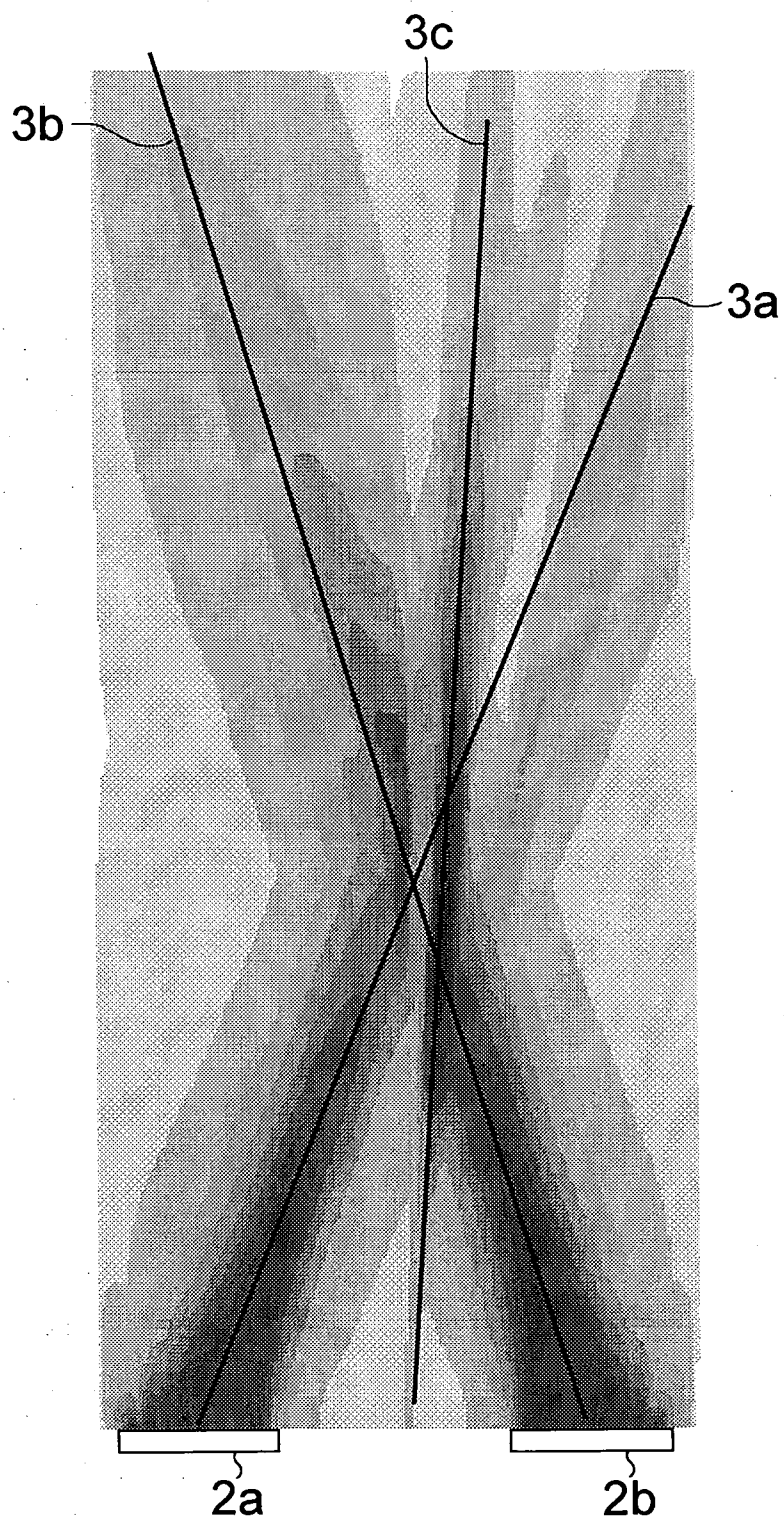


FIG.8



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FIG.9



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FIG.10

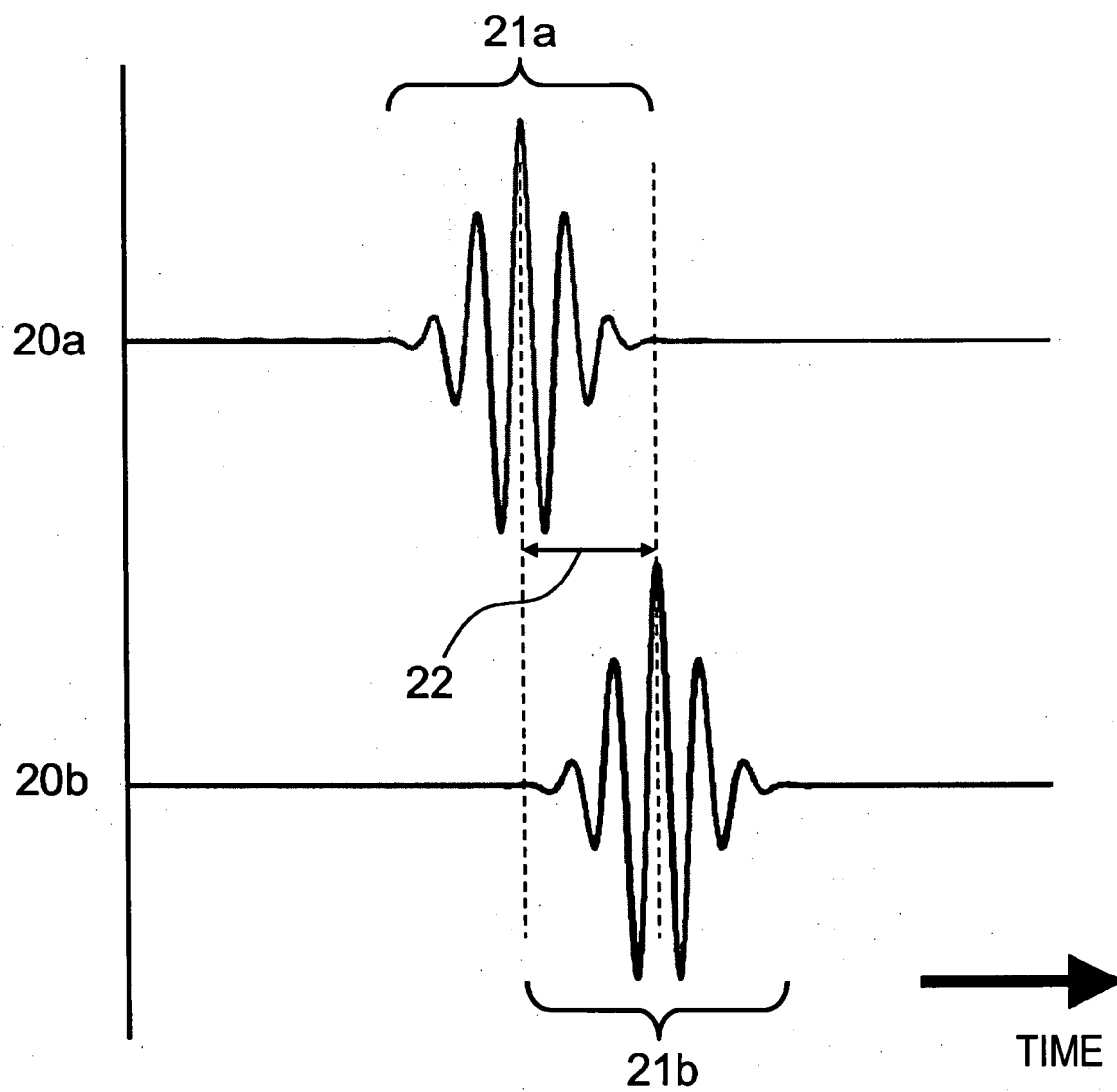
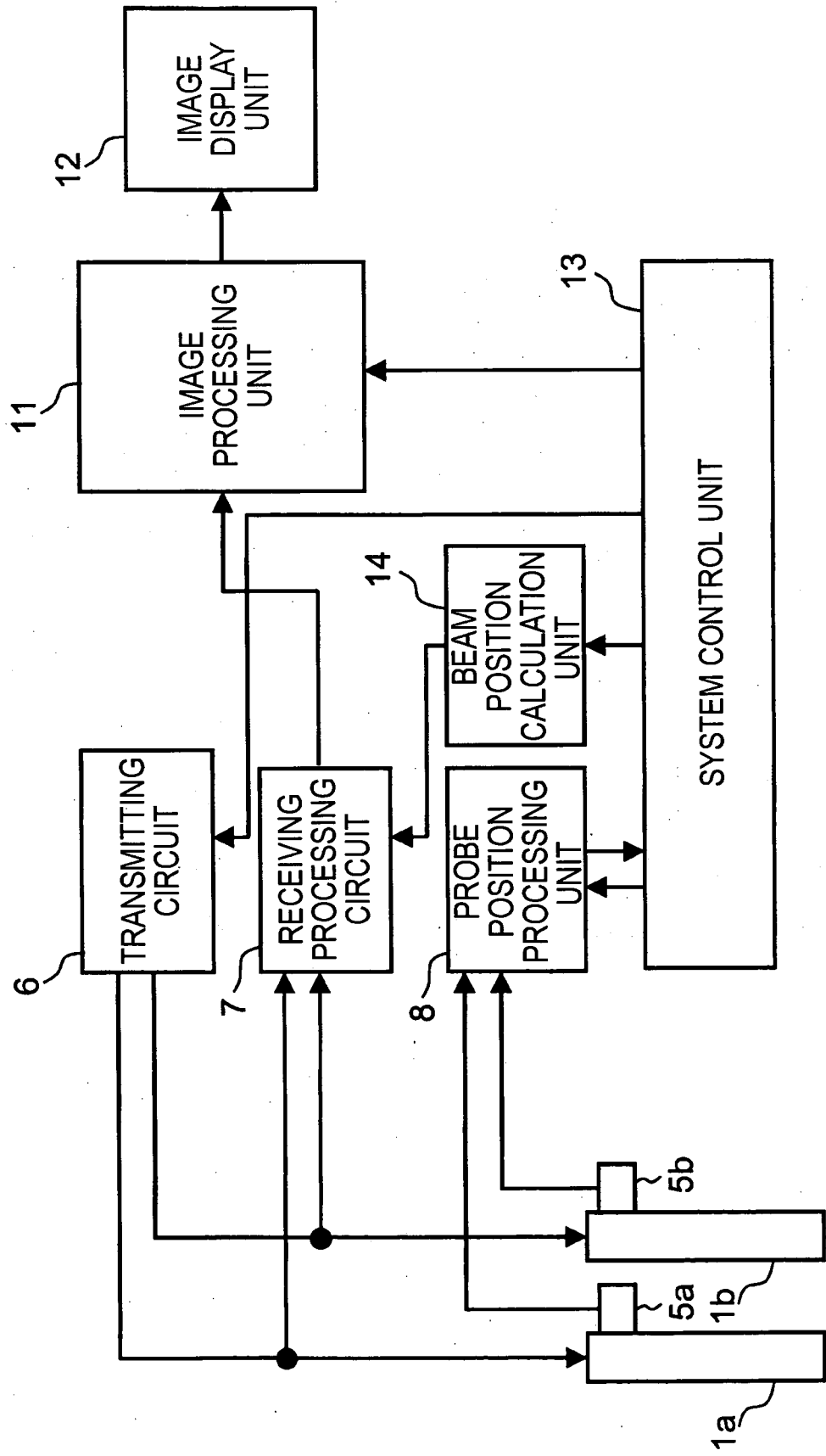
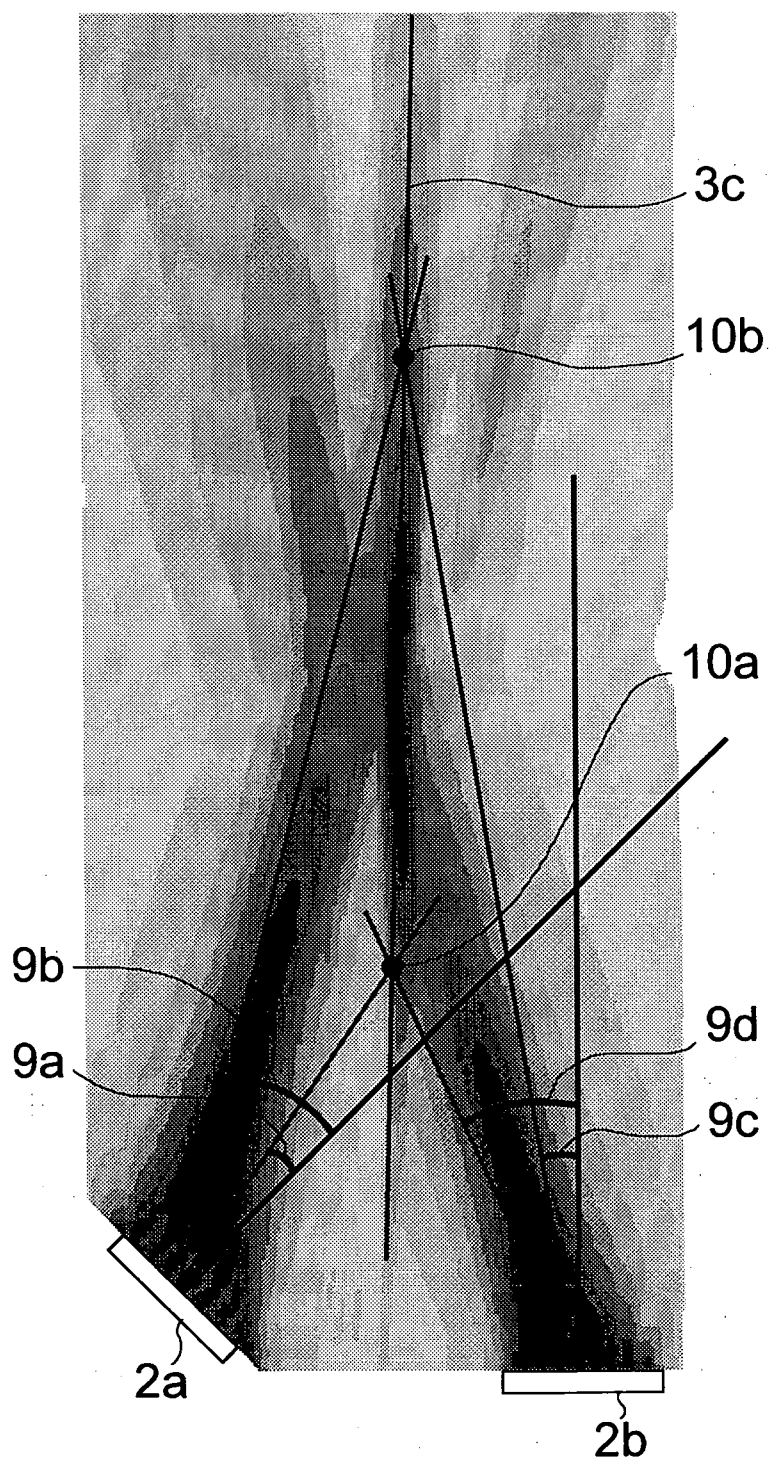


FIG.11



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FIG.12



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2009/059730

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S15/89 G10K11/34 G01N29/26 G10K11/32 B06B1/06
G10K11/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B G01S G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 200 858 A (TAKASHIMA MATSUO [JP]) 29 April 1980 (1980-04-29)	1,3-7
Y	column 4, line 34 - column 6, line 4 figures 4,16	2
Y	US 3 990 300 A (KOSSOFF GEORGE) 9 November 1976 (1976-11-09)	2
	column 5, line 31 - column 6, line 16 figures 3-5	
X	US 4 103 677 A (LANSIART ALAIN; GAUCHER JEAN-CLAUDE; LEQUAIS JEAN; MORETTI JEAN-LUC; Q) 1 August 1978 (1978-08-01)	1-7
	column 3, line 18 - column 4, line 41 figure 2	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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- *G* document member of the same patent family

Date of the actual completion of the international search

21 August 2009

Date of mailing of the international search report

31/08/2009

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2009/059730

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4200858	A	29-04-1980	NONE	
US 3990300	A	09-11-1976	AT 354777 B	25-01-1979
			AU 490475 B1	26-08-1976
			CA 1015443 A1	09-08-1977
			DE 2507177 A1	04-09-1975
			GB 1482722 A	10-08-1977
			JP 1066493 C	30-09-1981
			JP 50158386 A	22-12-1975
			JP 56006508 B	12-02-1981
US 4103677	A	01-08-1978	DE 2653367 A1	23-06-1977
			FR 2332531 A1	17-06-1977
			GB 1526130 A	27-09-1978