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(54) ULTRASONOGRAPHIC APPARATUS, ULTRASONOGRAPHIC DATA PROCESSING METHOD, AND ULTRASONOGRAPHIC DATA PROCESSING PROGRAM

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- **KARAMAN M; BILGE H S; O'DONNELL M: "ADAPTIVE MULTI-ELEMENT SYNTHETIC APERTURE IMAGING WITH MOTION AND PHASE ABERRATION CORRECTION" IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS AND FREQUENCY CONTROL, IEEE, US, vol. 45, no. 4, 1 July 1998 (1998-07-01), pages 1077-1087, XP000777839 ISSN: 0885-3010**

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Description

TECHNICAL FIELD

[0001] The present invention relates to an ultrasonic imaging apparatus used in, for example, medical diagnosis, its imaging data processing method and imaging data processing program, and more particularly, to a technique for obtaining a cross-sectional image of high image quality, generally referred to as a compound scan image, in which image signals acquired by scanning in various directions are synthesized and displayed as a single image.

BACKGROUND OF THE INVENTION

[0002] An ultrasonic imaging apparatus is designed to transmit ultrasonic waves to an object to be examined through an ultrasound probe applied to a body surface of the object, and receive reflected waves (echo signals) from the inside of the object to display cross-sectional images of portions of the object on the basis of the echo signals for medical diagnosis and the like.

[0003] Generally, an ultrasound probe is formed by arranging a plurality of transducers at even intervals in a straight line, a curved line, or a plane. For example, in an ultrasonic imaging apparatus of linear scan type, an aperture is formed by selecting a transducer group to be driven at the same time by an aperture selecting switch, and this aperture is sequentially moved so as to scan ultrasonic beams inside an organism or an inorganic object. Scanning is performed in the same manner as that in an ultrasonic imaging apparatus of convex scan type.

[0004] In both of the apparatuses of the linear scan type and the convex scan type, when a direction or an angle of ultrasonic beam is predetermined, a plurality of received beam signals acquired by the scan are stored in memory cells at addresses set in correspondence with each beam direction or angle, and an image is displayed.

[0005] On the other hand, in an ultrasonic imaging apparatus of compound scan type, as disclosed in Japanese Unexamined Patent Publication No. JP-A-64-62133 and JP-A-5-285146, a probe is moved along the surface of the object, and an image is obtained from a received beam signal corresponding to an ultrasonic beam signal at various angles and at various positions and these images are combined in real time. In this case, because the positions and the angles of ultrasonic beams vary, the position and the angle of the received beam signal are calculated by detecting positional information of the probe in real time, and then images are synthesized. Accordingly, by superposing same cross-sectional images, a boundary between mediums in parallel with an ultrasonic beam and inside of an object to be examined, which boundary is insufficiently depicted through a cross-sectional image in a single direction, can be clearly depicted. Further, a dark portion appears due to a small luminance signal caused by multiple reflection or behind strong reflection body. There is an effect that the portion is improved by superposing images taken from various directions.

[0006] However, according to the above conventional method of compound image generation, the image synthesis is performed after converting received beam signals into luminance signals. Therefore, the method does not demonstrate an effect of improving the ratio of noise to signals (S/N ratio) in the known opening synthesis by superposing the received beam signals having phase information and obtaining the resulting interference.

[0007] Besides, since am ultrasonic image can be obtained only within an effective FOV (field of view) of probe, for example, the image of a portion of an object to be examined having a size larger than the effective FOV is obtained such that a plurality of ultrasonic images are obtained by moving the probe in a longitudinal direction and joining these. Thus-obtained image is referred to as a panoramic image, and disclosed in Japanese Unexamined Patent Publication No. JP-A-2001-104312.

[0008] In the above-described method of panoramic image generation, an angle and a position of the probe are detected by ultrasonic images are jointed to make a panorama image.

[0009] However, since the panoramic image synthesis based on detection of the angle and position deals with luminance signals, signal processing in consideration of phase signal components of echo signals is not considered in processing the signals.

[0010] An object of the present invention is to improve the S/N ratio of a compound image.

[0011] US 4 252 025 discloses an ultrasound apparatus for single or compound B-mode ultrasound images and suggests using sound speed divergence information within the object for improving resolution and clarity of single B-mode ultrasound images.

SUMMARY OF THE INVENTION

[0012] To achieve the above-stated object, the ultrasonic imaging apparatus and method according to the present invention are defined in claims 1 and 3, respectively. Further advantageous features are set out in the dependent claims.

[0013] Because the plurality of received beam signals are combined before conversion into luminance signals, phase information of the received beam signals is not lost, whereby an S/N ratio can be improved by combining the received beam signals to make them interfere with each other.

[0014] The compound signal constructing means may include a memory having memory cells, in which addresses are arranged in correspondence with a scanning plane of ultrasonic beams. By stacking and memorizing the received beam signal output by digital phase adding means in the corresponding memory cell addresses, the signal can be combined with another received beam signal. Further, at the time of the synthesis, the view angle of the joint cross-sectional image can be easily enlarged by adjusting the memory addresses at a certain ratio.

[0015] The position detecting means finds the position and the direction of the ultrasound probe based on interrelation between a plurality of sequential images. According to this method, it is possible to avoid complication of scanning on the object while detecting the position and direction of the probe attached to a mechanical position detecting device. Meanwhile, according to the present invention, a mechanical position detecting device may be employed, or a magnetic sensor may be used. Moreover, a position sensor may be built in the probe.

[0016] Further, there are provided sound speed distribution measuring means for finding a sound speed distribution in a medium on an ultrasonic scanning plane on the basis of interrelation among the echo signals forming the received beam signals of the respective transducers and correct the positional relations between the received beam signals and the object on the basis of the found sound speed distribution in the compound signal constructing means. According to it, it is possible to correct error of the positional relation among the received beam signals generated due to distortion in path distance and time of the beams due to the difference in sound velocities of the various mediums in the object. Accordingly, the compound signals can be precisely synthesized, and the image contrast can be clearly created.

[0017] Further, signal alternating means for alternating a polarity of a received beam signal may be provided. The compound signal constructing means may be designed to respectively generate a signal obtained by combining the received beam signal and a signal obtained by combining reverse received beam signals output by the signal alternating means respectively, and may add up the generated synthesized received beam signals. In other words, a higher harmonic cross-sectional image having high image quality can be obtained by synthesizing a received beam signal of the regular phase and that of the reverse phase. Particularly, because a higher harmonic cross-sectional images can be obtained by using an identical received beam signal, the number of pictured images obtained per unit time (frame rate) is not deteriorated in comparison with the cases where two ultrasonic beams, of the regular phase and of the reverse phase, are separately scanned so as to obtain the higher harmonic cross-sectional image as in the conventional.technique.

[0018] Further, by controlling the direction of ultrasonic beams in accordance with the position and direction of the ultrasound probe with respect to the object found by the position detecting means, a transmitted wave focusing function may be added to the apparatus. Accordingly, a cross-sectional image acquired from a direction different from that of a standard cross-sectional image is superposed so as to create an accurate cross-sectional image.

[0019] Further, there may be sound speed layer structure measuring means for measuring the structure of a sound speed layer in a medium on the ultrasonic wave scanning plane on the basis of interrelation among the echo signals of the respective transducers, forming the received beam signals. It is desirable that the compound signal constructing means corrects for distortion in path distance and time of the received beam signals on the basis of the sound speed layer structure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig.1 is a block diagram showing one embodiment of an ultrasonic imaging apparatus according to the present invention;
Fig.2 is a block diagram showing another embodiment of an ultrasonic imaging apparatus according to the present invention;
Fig.3 is a block diagram showing still another embodiment of an ultrasonic imaging apparatus according to the present invention;
Fig.4 is a block diagram showing still another embodiment of an ultrasonic imaging apparatus according to the present invention;
Fig.5 is a diagram showing one mode of a compound scan performed by a linear-type scanning probe;
Fig.6 is a diagram showing one mode of a compound scan performed by a convex-type scanning probe;
Fig.7 is a diagram showing one mode of the compound synthesis based on a oblique scan;
Fig.8 is a diagram illustrating a method of the compound synthesis based on a oblique scan;
Fig.9 is a diagram showing another mode of the compound scan performed by a linear-type scanning probe;
Fig.10 is a diagram showing another mode of the compound scan performed by a convex scanning probe; and
Fig.11 is a flow chart illustrating the embodiments of an ultrasonic imaging apparatus according to the present invention operated by software.

BEST MODE FOR CARRYING OUT THE INVENTON

[0021] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

[0022] Exemplary ultrasonic imaging apparatus Fig.1 is a block diagram showing an ultrasonic imaging apparatus. In this figure, an ultrasonic pulse signal for driving a probe 4 is supplied from a transmission circuit 1 via a transmission/reception separating circuit 2 and a transducer selecting switch (SW) 3. The probe 4 has a plurality of transducers. The transducer selecting switch 3 is formed by a multiplexer circuit, which is designed to select and thus switch a plurality of transducer groups (aperture) to be driven at the same time. The transmission circuit 1 is designed to generate an ultrasonic pulse signal for driving the transducer, and to apply delay to the ultrasonic pulse signals to be supplied to a plurality of the transducers forming the aperture, so as to control the direction and the focal point of the ultrasonic beams transmitted to the inside of the object.

[0023] Reflected signals (echo signals) of the ultrasonic beams generated from the object are received by each transducer and converted into electrical signals. The echo signals converted into electrical signals are routed from the transmission/reception separating circuit 2 to a reception circuit 5 via the transducer selecting SW 3. That is, the transmission/reception separating circuit 2 passes a signal from the transmission circuit 1 to the transducer when an ultrasonic wave is transmitted, and passes a signal from the transducer to a reception circuit 5 when receiving a signal.

[0024] The reception circuit 5 amplifies weak echo signals, converts them into digital signals, and outputs them to a digital phasing/adding circuit 6. The digital phasing/adding circuit 6 makes uniform the phases of the digital echo signals output by the reception circuit 5, adds up the phased signals to form a received beam signal, and outputs it to a compound signal constructing unit 7. The compound signal constructing unit 7 combines the input received beam signals and other received beam signals previously measured, adjusting for the respective positional relation to the object, so as to generate a compound signal. A signal processing circuit 8 performs processes for creating an image of the compound signal output by the compound signal constructing unit 7. That is, it performs detection, logarithmic compression, and γ -correction on the compound signal, and thus generates an image signal being a luminance signal. The image signal generated by the signal processing circuit 8 is routed to a display unit 9, where the ultrasonic beam scan is converted into image display scan and an image is displayed on a display monitor.

[0025] A cross-sectional image displacement detecting unit 10 detects an amount of relative displacement between the object and the probe 4, and detects phenomenon generally referred to as body movement, such as beats inside the object like a human body, as a displacement amount, and outputs them to the compound signal constructing unit 7. In the cross-sectional image displacement detecting unit 10, for example, a system which detects displacement of a probe from correlation between images sequentially obtained may be employed. A system utilizing a probe position detecting arm and a magnetic sensor also may be used. The point is, any conventional method may be applied as long as it can detect the positional relation between the wave probe 4 and the object. A CPU (central processing unit) 11 is designed to integrate and control the above-described constituents.

[0026] Operations of the thus-constructed ultrasonic imaging apparatus will be described next. First, an operator gives initial instructions for functions of the ultrasonic imaging apparatus. For example, before beginning examination, it is instructed to the apparatus that a compound image is to be obtained. In this case, the operator can select from among creating a compound image from an ultrasonic beam signal, combining images using a luminance signal, performing compound image creation with the field angle enlarged, and combining images without enlarging the field angle. For this purpose, an image combining mode switching device may be provided to a console so as to perform creation of a compound image with a selected mode.

[0027] After selecting functions of the ultrasonic imaging apparatus in the above-described manner, the operator applies the probe 4 to a body surface of a region examined of the object, and inputs instructions to begin an ultrasonic scan from the console. In response thereto, the aperture selection, transmission delay data, and reception delay data are set to the transducer selecting switch 3, transmission circuit 1, and reception circuit 5, respectively. Then, in response to the instruction of selecting the compound image creation mode, the compound image signal constructing unit 7 is selected and scan of ultrasonic beams is begun. Driving pulses respectively provided with time delay are input from the transmission circuit 1 to the transducer selecting switch 3 via the transmission/reception separating circuit 2 corresponding to each transducer forming the aperture on the probe 4. The transducer selecting switch 3 switches connection of the driving pulses so that they are output to each corresponding transducer, whereby a selected transducer group is driven by the driving pulse output by the transducer selecting switch 3.

[0028] The transducers of the selected transducer group are driven in the order from the less-delayed signals to transmit ultrasonic waves. Delay time of the ultrasonic waves transmitted to the inside of the living body is adjusted by the transmission circuit 1 so that wave surfaces of the ultrasonic waves arrive at a predetermined focal point of the transmitted wave with the same phase at the same time. If a wave passes through tissues having different acoustic impedances inside the living body in the process of propagation, a part of the ultrasonic beams is reflected at that interface and echoes return toward the probe. The echoes sequentially return toward the probe in order of the depth inside the living body through which they propagate. These echoes are received by the transducers which have been driven for transmission, or transducer groups having larger apertures with the passage of time are selected and switched over, and the received echoes are converted into electrical echo signals.

[0029] The echo signals which are made into electrical signals by the transducer are input into the reception circuit 5 via the transducer selecting switch 3 and the transmission/reception separating circuit 2, where the echo signals are separately amplified at each element line (channel) of the transducers and are converted into digital signals at each channel. The thus-digitalized echo signals are input into the digital phasing/adding circuit 6. In the digital phasing/adding unit 6, the digitalized echo signals which have been provided with time delay corresponding to the respective ultrasonic transducers are delayed at each channel and added up. That is, the echo signals are added and their time phases are made uniform so that the echoes reflected at a certain point (each point on received beams) in the object seem to appear at each channel at the same time, whereby a noise included in the echoes is reduced. Further, by performing filtering, signals in a necessary signal band are extracted to acquire a received beam signal. Those processes in the reception circuit 5 are known as a dynamic focus method.

[0030] The received beam signal generated by the reception circuit 5 is input into the compound signal constructing unit 7, where compound processing according to the present invention is done. That is, received beam signals having phase information, as yet converted into luminance signals, are combined, and they are made to interfere with each other, whereby the S/N ratio can be improved. Accordingly, the compound signal constructing unit 7 is designed to be able to deal with a complex signal and to operate rapidly, different from a conventional apparatus. Here, the purpose of creating a compound image is, as described above, to clearly image the interface between mediums parallel to an ultrasonic beam in the object, and to reduce dark portions appearing behind a body producing multiple reflections or a strongly reflecting body by superposing images obtained from various directions. Accordingly, when one cross-sectional image is obtained, another image of this cross-sectional image is taken with ultrasonic beams at a different position or in a different direction, and these two images are combined. In this synthesis, because received beam signals obtained from the same portion of the object have to be combined, it is necessary in creating a compound image to measure the direction of the received beams, the relation between the received beams and depth, and the positional relation between those and the object, and to make adjustments for the positional relation between received beams for two images.

[0031] The compound signal constructing unit 7 has two RAMs constituted of memory cells, addresses of which are two-dimensionally arranged in correspondence with the scanning plane of ultrasonic beams. One is a received beam signal RAM for storing a received beam signal input in one measurement, and the other is a compound signal RAM for storing a received beam signal measured in a preceding measurement or a compound signal already created. Addresses of these RAMs are set corresponding to a two-dimensional scanning plane based on the center of the probe in each measurement and the direction of the probe (vertical direction).

[0032] Here, the central position and the direction of the probe are detected by the cross-sectional image displacement detecting unit 10. In the cross-sectional image displacement detecting unit 10 is applied a conventional method of finding a position and a direction of the ultrasound probe relative to the object from correlation between a plurality of images sequentially obtained, for example. It is thus possible to avoid the complication of performing a scan on the object while detecting the position and the direction of the probe attached to a mechanical position detecting device. However, the present invention is not limited thereto, and a mechanical position detecting device also may be employed. Further, a known magnetic sensor also may be used.

[0033] Setting the measurement standard as the thus-detected central position and direction of the probe, and on the basis of an estimated value of a sound speed in a medium and information of time length between ultrasonic transmission and reception, the relation between a received beam signal and its depth is determined from the path distance of the ultrasonic waves, and the signals of the respective portions corresponding to received beam signals in the depth direction are stored in memory cells at the corresponding addresses of the received beam signal RAM.

[0034] Meanwhile, in the same manner as in the above-described received beam signal RAM, in the compound signal RAM are stored compound signals created in the preceding measurement (in an initial state, received beam signals). Accordingly, by reading out the signals corresponding to the same portion from both RAMs and performing calculation, the received beam signal and the compound signal can be combined. However, it is necessary to coordinate the position of the addresses of the compound signal RAM and that of the received beam signal RAM because the position and the direction of the probe are different. Next, the compound processing will be described in detail.

[0035] For example, on the basis of a compound signal RAM, the address of a memory cell of a received beam signal RAM, in which the received beam signal are superposed and recorded on the memory cell, is searched. If a portion corresponding to the received beam signal is not stored in the memory cell corresponding to the retrieved address, the correct address is found by appropriately interpolating by a known method. Then, the portion corresponding to the received beam signal is stacked and recorded on the memory cell of the compound signal RAM. By executing this processing on all memory cells of the compound signal RAM, the received beams obtained in two measurements can be combined on the memory. The compound signals in the compound signal RAM are output to the signal processing circuit 8. In the signal processing circuit 8, detection, logarithmic compression, and γ -correction are performed on the compound signals so as to generate an image signal being a luminance signal. The image signal is displayed on the display monitor via the display unit 9.

[0036] A formula for finding an address of a memory cell of the received beam signal RAM used for creating the above-described compound signal is, for example:

$$Xb=\{(Xc-X)\cos\theta+(Yc-Y)\sin\theta\}/\alpha \quad Yb=\{(Yc-Y)\cos\theta+(Xc-X)\sin\theta\}/\beta$$

wherein

- X: a probe position on a coordinate axis in a horizontal direction in relation to an initial image;
- Y: a probe position on a coordinate axis in a vertical direction in relation to an initial image;
- θ: a beam direction in relation to the direction downward from the initial image;
- Xb: an address of the received beam signal RAM (scanning direction of the received beam);
- Yb: an address of the received beam signal RAM (direction of received beams);
- Xc: an address of the compound signal RAM (horizontal direction of display monitor);
- Yc: an address of the compound signal RAM (vertical direction of a display monitor);
- α: an amplification coefficient between the received beam signal RAM and the compound signal RAM (scanning direction of the received beams); and
- β: an amplification coefficient between the received beam signal RAM and the compound signal RAM (direction of received beams).

[0037] In the above formula, the initial image means the cross-sectional image which is first constructed after an operator instructs to begin synthesis of a compound image, or an image immediately preceding a currently noticed cross-sectional image even when initiation of synthesis of the compound image is not instructed. The cross-sectional images input after the initial image are rotated and moved with regard to coordinate axes of the initial image, and combined, and are output as a compound image.

[0038] In this manner, ultrasonic transmission and reception and signal processing therefor are repeatedly performed while selecting and switching the transducers or changing the direction of ultrasonic beams, and an image is produced by received beam signals input at the each repetition of transmission and reception. Stored contents in the memory which have been made into an image are read out in sync with a scan of a CRT display device or the like, and the inside of a living body is thus imaged by the ultrasonic scan. This imaging is repeatedly performed a plurality of times, and the thus-obtained images are sequentially processed by the compound signal constructing unit 7, and are displayed as a compound image.

[0039] Fig.5(a) to (d) show one example of the compound image synthesis of the linear scan type. In the figures, a probe 20 is schematically illustrated so as to show positional relation to an ultrasonic image. (a) shows an initial image 21, (b) shows an ultrasonic image 22 obtained in the subsequent ultrasonic imaging, (c) shows an ultrasonic image 23 obtained in the further subsequent ultrasonic imaging, and (d) shows a compound image 24 created by combining these images. In the apparatus of convex scan type, as shown in Fig.6(a) and (b), after an image 27 is obtained by a probe 26 of convex type the position of the probe 26 is moved to obtain an ultrasonic image 28, and a compound image 29 is created by combining these images.

[0040] The method of performing compound synthesis on a RAM is conventionally known in ultrasonic imaging utilizing a luminance signal. However, this embodiment is characteristic in that the compound synthesis is performed using a complex signal after phasing and addition before conversion into a luminance signal. Accordingly, because phase information of received beam signals is not lost, the S/N ratio can be improved by combining the signals and thus making them interfere with each other.

First embodiment

[0041] Generally, it is known as a problem in performing compound operation that image quality is deteriorated when a plurality of received beam signals cannot be superposed correctly in regard to positional relation because of certain errors. For example, if errors increase to accumulate of slight errors in beam position information, accuracy of a superposed position is deteriorated. One of the factors causing errors to occur in beam position information is that an object to be examined is formed by mediums having various sound speeds. That is, if there are mediums having various sound speeds, the speed of an ultrasonic beam passing through the plurality of mediums is increased or decreased, and as a result, a cross-sectional image might be distorted. Particularly, each of the cross-sectionalimages measured from different angles and positions by the probe has a different degree of distortion. In a method of performing the compound synthesis by storing phase information as disclosed above, when a compound signal is constructed from received beam signals which are obtained from two directions and are differently distorted, image quality is extremely deteriorated in comparison with a conventional method which superposes luminance signals, and the compound image becomes blurred. Therefore, it is effective to correct positional information of received beam signals to be superposed in correspondence with variation of the sound speeds in the medium.

[0042] Fig.2 is a block diagram showing a main part of an ultrasonic imaging apparatus according to an embodiment of the present invention, where positional information of received beam signals is corrected according to a sound speed in the medium. As shown in this figure, in addition to the above example, an ultrasonic imaging apparatus according to this embodiment is provided with a sound speed calculating unit 17 for calculating sound speed in each portion in a cross-sectional image and a cross-sectional sound speed map 12 for storing the calculated sound speed, a compound signal constructing unit 7 for correcting for positional information of received beam signals on the basis of sound speed distribution data of the cross-sectional sound speed map 12 and performing compound synthesis. Echo signals of each channel before being added together and made into a beam signal by the digital phasing/adding circuit 6 are input into the sound speed calculating unit 17, where phase difference between the respective channels is found by calculating mutual correlation between those channel signals. The phase difference is not detected as long as a sound speed in a medium estimated in advance coincides with an actual sound speed in the medium. However, since the estimated sound speed is generally different from the actual sound speed in the medium, the phase difference is detected. For example, when values of the phase difference for each channel are arranged on a graph, they are made into a straight line in the graph indicating phase difference zero at all channels if the phase difference cannot be detected. Also, if the estimated sound speed is different from the actual sound speed, values of the phase difference at the respective channels make a straight line having an inclination. It has been already found that the inclination becomes steeper as the difference between the estimated sound speed and the actual sound speed is larger. By using the above-described relation, it is possible to simulate the gap between the estimated sound speed and the actual sound speed in the medium and thus derive in advance the relation between the inclination of the straight line made by phase difference at each channel and sound speeds in mediums. And, by creating a chart of this relation between the sound speeds in mediums and the inclination of the phase difference distribution and storing this in an internal memory, a sound speed in a medium can be easily found. That is, phase differences between each channel are calculated, the inclination of a phase difference distribution of all channels is calculated using a method of least square error or the like, and the above-created comparison chart of the relation between the inclination and the sound speeds is referred, whereby an average sound speed in mediums included in the path to the focal point can be found. By storing the value of sound speed measured at each focal point in this manner in an address corresponding to each focal point in a memory unit of the cross-sectional sound speed map 12, a sound speed map can be easily created.

[0043] When the compound signal constructing unit 7 calculates a value of a received beam signal input from the digital phasing/adding circuit 6, the value is stored superposed in the compound signal RAM, a sound speed in a medium in the object is read out from the cross-sectional sound speed map 12 and the address of the received beam signal RAM is corrected in accordance with the sound speed in the medium. Then, components of the received beam signal stored at the corrected address and the value stored in the compound signal storing RAM are superposed and calculation is performed, and the result is written on the compound signal RAM.

[0044] At this time, a formula for finding the address of a memory cell of the received beam signal to create a compound signal is, for example, as below. Incidentally, a value of the sound speed map 12 is an average sound speed at between a portion near the probe and a deeper region, and the addresses are constructed to have an identical interval of data in both the received beam signal RAM scanning direction and the received beam direction (sampling intervals between adjoining addresses is made identical in the RAMs in those directions). Further, because the distortion mentioned above is generated by mediums having different sound speeds in the received beam direction, correction of addresses of the received beam signal RAM is performed and it is hypothesized that ultrasonic beams are lining at an interval of beam scanning determined by the pitch between the arranged transducers in the beam scanning direction.

$$Xv=\{(Xc-X)\cos\theta+(Yc-Y)\sin\theta\}/\alpha \quad Yv=\{(Yc-Y)\cos\theta+(Xc-X)\sin\theta\}/\beta$$

$$Xb=Xv \quad Yb=Yv\times V/\gamma\,(Xv,Yv)$$

X: a position of the probe on a coordinate axis in a horizontal direction in relation to an initial image
Y: a position of the probe on a coordinate axis in a vertical direction in relation to the initial image
θ: a beam direction in relation to the direction downward from the initial image
Xb: an address of the received beam signal RAM (direction of received beam scanning)
Yb: an address of the received beam signal RAM (direction of a received beam)
Xc: an address of the compound signal RAM (horizontal direction of the display monitor)
Yc: an address of the compound signal RAM (vertical direction of the display monitor)

Xv: an address of the sound speed map RAM (direction of received beam scanning)

Yv: an address of the sound speed map RAM (direction of received beam)

α : an amplification coefficient between the beam signal RAM and the sound speed map RAM (direction of received beam scanning)

β : an amplification coefficient between the beam signal RAM and the sound speed map RAM (direction of a received beam)

γ (Xv,Yv): a value of the sound speed map RAM (value of an address Xv, Yv)

V: a standard sound speed in medium (1530m/s according to JIS for medical ultrasound cross-sectional image apparatus)

First further example

[0045] Generally, it is known that when an ultrasonic wave passes through the inside of an object to be examined, its waveform is distorted due to the physical nature of the medium, the degree of distortion gradually becoming larger as the path length becomes longer, and the ratio of higher harmonic wave components to fundamental wave components increasing. Also, it is known that among the higher harmonic components, the second harmonic wave is particularly extracted and is made visible. In a known method therefor, for example, a transducer is driven by a normal-phase waveform to transmit ultrasonic waves to the inside of the object, reflected ultrasonic wave signals are received, and these signals are added and phased to be made into a received beam signal having phase information to be stored. Next, the phase of the waveform transmitted is made opposite, ultrasonic waves are similarly transmitted and received, and these waves are phased and added to generate a received beam signal having phase information. Then, a sum of this signal and the above-described received beam signal of the normal-phase waveform is calculated so as to make the signal visible. By doing so, the fundamental wave can be substantially removed from the signal transmitted and received first, and the size of the second higher harmonic wave is substantially doubled. Accordingly, it is a very effective method of second harmonic visualization. However, in this method, it is always necessary to perform transmission and reception two times for obtaining one second harmonic image, whereby the number of images per time unit (frame rate) is cut in half in comparison with the normal case. Therefore, a method of visualizing second harmonic waves without reducing the frame rate is desired.

[0046] Fig.3 is a block diagram showing an ultrasonic imaging apparatus for obtaining a second harmonic image. As shown in the figure, the apparatus disclosed in Fig. 1 is further provided with two compound signal constructing units 7a and 7b; a signal inverting unit 13 for inverting a phase of a received beam signal output by the digital phasing/adding unit 13; an inverting/non-inverting signal selecting unit 14 for determining whether to send the received beam signal to the signal inverting unit 13 or to the compound signal constructing unit 7a as it is; and a signal superposing unit 15 for adding two compound signals which are respectively synthesized by the two-system compound signal constructing units 7a and 7b and extracting higher harmonic signals.

[0047] Since the apparatus is constructed as described above, received beam signals output by the digital phasing/adding circuit 6 are transmitted to the inverting/non-inverting signal selecting unit 14, and received beam signals for the image first input are transmitted to the compound signal constructed unit 7a, without inverting the phase of the signals. Then, as in the case shown in Fig.1, a compound signal is created and is transmitted to the signal superposing unit 15. Next, the received beam signals for the image input to the inverting/non-inverting signal selecting unit 14 are phase-inverted by the signal inverting unit 13, and are then output to the signal superposing unit 15. In the signal superposing unit 15, compound signals output by the compound signal constructing units 7a and 7b are added up and output to the signal processing circuit 8. In this manner, when the compound signals are output by the compound signal constructing unit 7a, this signal is promptly added by the signal superposing unit 15 to the immediately preceding signal output by the compound signal constructing unit 7b, and the result is output. When a new compound signal is output by the compound signal constructing unit 7b, this signal is added to the immediately preceding signal output by the compound signal constructing unit 7a. Thus, a second harmonic signal can be extracted and visualized without lowering the frame rate when compound signals are input to the compound signal constructing units 7a and 7b.

[0048] In the above description, the calculation is performed while inverting phases of received beam signals: however, the same effect is obtainable by inverting the phase of the transmitted waveform. Further, because the apparatus according to this example also is characterized by acquisition of the above-mentioned compound signal image, a cross-sectional image having high quality which cannot be obtained by a mere higher harmonic cross-sectional image is obtainable.

(Fourth embodiment) Second further example

[0049] According to the above-described embodiment and examples, it is possible to construct a compound image while enlarging and displaying the field angle of an ultrasonic cross-sectional image. Even when the field angle does not need to be enlarged, if a compound image can be displayed, not only is the user's option broadened but also is provided a compound image with high quality.

[0050] Fig.4 is a block diagram showing an ultrasonic imaging apparatus according to the second further example. This apparatus is that disclosed in Fig. 1 equipped with an ultrasonic beam direction control unit 16 for controlling the direction of transmitted and received ultrasonic beams in accordance with an amount of positional displacement between a cross-sectional image and an ultrasound probe.

[0051] When the apparatus is thus constructed, by controlling ultrasonic beams so that the beams are constantly superposed on a initial image to be the standard, a compound cross-sectional image with higher quality is obtainable. The displacement amount output by the cross-sectional image displacement detecting unit 10 is transmitted to the compound signal constructing unit 7 and to the ultrasonic beam direction control unit 16. In the compound signal constructing unit 7, a compound signal is created from the displacement amount and received beam signals output by the digital phasing/adding circuit 6, as in the case of Fig.1. Meanwhile, in the ultrasonic beam direction control unit 16, a beam direction is controlled so that beams are constantly directed to an area of the initial image. For example, if a position of the probe 20 obtaining an initial image 21 shown in Fig.7(a) is moved laterally as shown in Fig. 7(b), the direction of ultrasonic beams is controlled so that the beams are constantly directed to the initial image area and an ultrasonic image 30 is acquired. In this case, as shown in Fig.8, a beam passing position (Xp, Yp) for constructing a desired image in relation to a beam located on the center of the initial image 21 is set. Then, the beam direction is calculated by a formula shown below:

$$\kappa=\mathrm{atan}\{(X-Xp)/Yp\}-$$

κ: a direction of the beams constructing the scanning plane desired in relation to the beam direction in an initial image
Xp: a beam passage address in relation to the initial image (direction of received beam scanning)
Yp: a beam passage address in relation to the initial image (direction of received beam)

[0052] Here, (Xp, Yp) may be input from a console by a user, or it may be automatically set to be the center of a displayed image. A formula utilizing the formula κ for finding the address of the received beam signal RAM in which is stored the original received beam signal from displacement information of a cross-sectional image and a memory address for creating a compound signal is as below, for example:

$$\{(Xc-X)(1+\sin\theta)(1-\sin\theta)+(Yc-Y)\cos\theta\sin\theta\}/\{(\alpha(1+\sin\theta)(1-\sin\theta)Yb=(Yc-Y)\cos\theta/\{\beta(1+\sin\theta)(1-\sin\theta)\}=Xb$$

X: a probe position on a coordinate axis horizontal to the initial image
Y: a probe position on a coordinate axis vertical to the initial image
θ: a beam direction in relation to the direction downward from the initial image
Xb: an address of the received beam signal RAM (direction of received beam scanning)
Yb: an address of the received beam signal RAM (direction of received beam)
Xc: an address of the compound signal RAM (horizontal direction of the display monitor)
Yc: an address of the compound signal RAM (vertical direction of the display monitor)
α : an amplification coefficient between the beam signal RAM and the sound speed map RAM (direction of received beam scanning)
β : an amplification coefficient between the beam signal RAM and the sound speed map RAM (direction of received beam)

[0053] The example shown in Fig.7 is the case where the probe is moved. However, as shown in Fig.9(a) to (d), a compound synthesis can be conducted not by moving a probe 20 but instead by controlling the direction of ultrasonic beams to be oblique, whereby the same effect is obtainable.

[0054] Further, in a scan using a convex probe on which transducers are arranged in an arcuate line, in addition to the above-mentioned method of performing the oblique scan, there is a method of moving the field angle as shown in Fig.10(a) and (b). In this case, conversion in the compound signal synthesizing unit is simple, it is not necessary to prepare in advance focus data for the oblique scan, and focus data acquired from the front of an opening can be utilized. Of course, when a convex probe is used, the oblique scan and the shift of the field angle may be utilized in combination.

[0055] In the embodiment described above, a two-dimensional cross-sectional image is obtained by using a onedimensional transducer array: however, the present invention is not limited thereto, and it may be applied when a two-dimensional image or a three-dimensional image is displayed by using a ring array or a two-dimensional transducer array.

Second embodiment

[0056] Fig.11 is a flow chart showing the process in the case where the embodiment of an ultrasonic imaging apparatus is operated by software. The CPU 1 of the ultrasonic imaging apparatus in Fig.1 uses the respective components in Fig.1 and is operated according to the process shown in Fig.11.

(Step111. signal synthesizing process)

[0057] First, an operator gives an initial instruction for functions of the ultrasonic imaging apparatus. For example, before beginning examination an instruction to obtain a compound image is given to the apparatus. In this case, the operator can select producing a compound image from ultrasonic beams or performing image synthesis using luminance signals, or performing compound image synthesis while enlarging the field angle or performing compound image synthesis without enlarging the field angle. For this purpose, an image synthesis mode switching device may be provided to a console so as to perform compound image synthesis in a selected mode.

[0058] After thus selecting functions of the ultrasonic imaging apparatus, the operator applies a probe 4 to a portion examined of the object and inputs instructions to begin an ultrasonic scan from an operating device. In response thereto, selection of an aperture, transmission delay data, and reception delay data are set from the CPU 11 to a transducer selecting switch 3, a transmission circuit 1, and a reception circuit 5, respectively. Further, a compound signal constructing circuit 7 is selected in response to instructions to select a mode of compound image synthesis, and an ultrasonic beam scan is started. In the scan, driving pulses to which time delays are respectively applied are input from the transmission circuit 1 into the transducer selecting switch 3 via a transmission/reception separating circuit 2 corresponding to each of transducers forming an aperture of the probe 4. Connection switching is done by the transducer selecting switch 3 so that the driving pulses are output to corresponding transducers. By this operation, the selected transducer group is driven by the driving pulses output by the transducer selecting switch 3.

[0059] In the selected transducer group, the transducers are driven in ascending order of time delay to transmit ultrasonic waves to the inside of a living body. The time delay of the ultrasonic waves transmitted to the inside of the living body is adjusted by the transmission circuit 1 so that wave surfaces of the ultrasonic waves transmitted by the respective transducers arrive at a predetermined transmitted wave focal point with the same time phase. If there are tissues encountered having different acoustic impedances in the path of propagation, a part of the ultrasonic waves is reflected at its interface, and reflected waves (echo) return towards the probe. Echoes sequentially return towards the probe in accordance with the depth at which they are propagated. These echoes are received by the transducers driven in ultrasonic wave transmission or successive transducer groups whose aperture is switched to become large with the passage of time, and are converted into electrical echo signals.

[0060] The echo signals converted into electrical signals by the transducers are input to the reception circuit 5 via the transducer selecting switch 3 and the transmission/reception separating circuit 2, and here, they are separately subject to amplification processing at each element line (channel) of the transducers, and are converted into digital signals in the respective channels. In a digital phasing/adding unit 6, digitalized echo signals separately given time delay in correspondence with the respective transducers are delayed at each channel and are added up. That is, additions are made to the signals so as to make them have uniform time phases, as if echoes reflected at a certain point in the object (each point on received beams) appeared at the same time, and a noise included in the echoes is thus reduced. Further, filtering processing is performed so as to extract a signal in a necessary signal band and acquire a received beam signal. These processings at the reception circuit 5 are known as a dynamic focus method.

[0061] The received beam signal generated by the reception circuit 5 is input into a compound signal constructing unit 7 and is subject to compound synthesis processing according to the present invention. That is, it is characteristic in the present invention that received beam signals having phase information before conversion into luminance signals are generated and are made to interfere with each other, whereby improving the S/N ratio. Accordingly, the compound signal constructing unit 7 is constructed so as to be able to utilize a complex signal and to operate at high speed, which is different from the conventional system. Here, an object of producing a compound image is, as described above, to clearly image the interface of mediums parallel to one ultrasonic beam in the object to be examined and to reduce dark portions generated behind a body producing multiple reflections or a strongly reflecting body by superposing images obtained from multiple directions. Therefore, another image of one cross-section is obtained with ultrasonic beams at different position or in a different direction, and those two images are combined. Since, in this synthesis, received beam signals acquired from an identical portion of the object have to be combined, it is necessary to find the relation among directions of the received beams, received beam signals, and depth, to find the positional relation between these beams and the object, and to make adjustments for the positional relation between the received beam signals of two images so as to combine them.

[0062] The compound signal constructing unit 7 according to this embodiment has two RAMs including memory cells with addresses which are two-dimensionally arranged corresponding to a scanning plane of ultrasonic beams. One is a received beam signal RAM for storing a received beam signal which is currently measured and input, and the other is a compound signal RAM for storing a received beam signal measured previously or a compound signal. Addresses of those RAMs are set corresponding to a two-dimensional scanning plane based on the transducer direction (vertical direction).

[0063] Here, the central position and the direction of the probe are detected by a cross-sectional image displacement detecting unit 10. This cross-sectional image displacement detecting unit 10 employs, for example, a known method of finding the position and direction of the ultrasound probe to the object from mutual relation between a plurality of sequentially obtained images. It is thereby possible to avoid the difficulty of performing a scan on the object while detecting the position and the direction of the probe attached to a mechanical position detecting device. However, the present invention is not limited thereto, and a mechanical position detecting device also may be employed. Further, a known magnetic sensor also may be used.

[0064] On the basis of the thus-detected central position and direction of the probe, and of the estimated value of a sound speed in the medium and the time between ultrasonic transmission and reception, the relation between a received beam signal and depth is calculated from path distance of ultrasonic waves, and portions of received beam signals corresponding to that depth are stored in the memory cells of the received beam signal RAM with corresponding addresses.

[0065] Meanwhile, in the compound signal RAM, produced compound signals measured before the previous transmission (in the initial state, a received beam signal) are stored in the same manner as the above-described received beam signal RAM. Therefore, by reading out signals from these two RAMs corresponding to the same portion of the object and performing calculation, the received beam signal and the compound signal can be synthesized. However, it is necessary to make correspondence between the address of the compound signal RAM and the received beam signal RAM because the position and the direction of the probe are different in these two RAMs.

[0066] Next, the compound processing will be described in detail.

[0067] For example, on the basis of the compound signal RAM, the address of the memory cell of the received beam signal RAM which stores the received beam signal which should be stored superposed in the memory cell of the compound signal RAM is found. If the corresponding received beam signal is not stored in the memory cell at the above-calculated address, the address is accordingly calculated by interpolation using a known method. Then, the corresponding received beam signal is stored superposed in the memory cell of the compound signal RAM. By performing this processing over all the memory cells of the compound signal RAM, the received beam signals obtained in the two measurements can be combined. The compound signal of the compound signal RAM is output to a signal processing circuit 8. The signal processing circuit 8 performs detection, logarithmic compression, and γ -correction on the compound signal so as to generate an image signal, i.e., a luminance signal, and displays it on a display monitor via a display unit 9.

[0068] As a formula for finding the address of the memory cell of the received beam signal RAM to synthesize the above-described compound signal, for example, one shown in First embodiment is used.

(Step 112. processing of converting into a luminance signal)

[0069] In the above-described manner, ultrasonic wave transmission and reception and signal processing of the reflected signal are repeatedly performed while transducers are selected and switched or the direction of ultrasonic beams is changed, and an image is formed from the received beam signals input after each transmission. Stored contents made into an image in the memory are read out in sync with a scan of a CRT display monitor or the like, and those images are sequentially processed by the compound signal constructing unit 7.

(Step 113. display processing)

[0070] The compound signals sequentially processed are displayed as a compound image.

[0071] According to this embodiment, it is characteristic that the compound synthesis is performed using a complex signal before conversion into a luminance signal and after being subjected to phasing and addition, as in the First embodiment. Consequently, because phase information of the received beam signals is not lost, the S/N ratio can be improved by combining the beams and thus making them interfere with each other.

[0072] Further, according to the second embodiment, the First embodiment is operated by software.

[0073] Further, in the first embodiment, it is also possible to perform the compound synthesis by using a received beam signal after conversion into a luminance signal, i.e., a received beam signal in which phase information has disappeared.

[0074] Further, in a known ultrasonic imaging apparatus constructed to attenuate a high-luminance portion producing multiple reflections, signals in a portion originally having a multiple signal are attenuated in some cases, and thereby sensitivity therein might be deteriorated. However, by utilizing these embodiments in combination, it is possible to effectively reduce the low-luminance portion so as to be insignificant.

[0075] Further, when an ultrasonic signal in the object passes through an interface between extremely different acoustic impedances, ultrasonic energy is scattered in a portion deeper than this interface and is thus attenuated (back scattering). By using in combination a known ultrasonic imaging apparatus constructed to correct such phenomenon and this embodiment, image quality can be further improved.

[0076] As described above, according to the present invention, the S/N ratio of a compound image can be improved.

Claims

1. An ultrasonic imaging apparatus comprising:

means (2, 3) for acquiring first received beam signals from an ultrasound probe (4) and means for acquiring second received beam signals from the ultra-sound probe, the first and second received beam signals respectively having different first and second positional relations to an object to be examined;
position detecting means (10) for detecting an amount of relative displacement between the object and the ultrasound probe (4) by using correlations between images obtained from the first and second received beam signals;
sound speed distribution measuring means (17) for finding a distribution of a sound speed in a medium on an ultrasonic scanning plane on the basis of cross correlation among echo signals of the respective transducers forming the received beam signals;
combined signal constructing means (7) for correcting errors in the first and second positional relations generated due to distortions in path distance and time of the beams due to differences in sound speeds of the various media inside the object, in accordance with the measured sound speed distribution, and for combining the first received beam signals and the second received beam signals on the basis of the corrected first and second positional relations and the detected amount of relative displacement;
means (8) for converting the combined signal into a luminance signal; and
means (9) for displaying the above-converted luminance signal.

2. An ultrasonic imaging apparatus according to claim 1, wherein the combined signal constructing means (7) are adapted to perform field angle enlargement processing by performing the compound synthesis.

3. An imaging data processing method for an ultrasonic imaging apparatus comprising the steps of:

acquiring first and second received beam signals from an ultrasound probe, the first and second received beam signals having respective first and second positional relations to an object to be examined, which are different from one another;
detecting an amount of relative displacement between the object and the ultrasound probe by using correlations between images obtained from the first and second received beam signals;
finding a distribution of a sound speed in a medium on an ultrasonic scanning plane on the basis of cross correlation among echo signals of the respective transducers forming the received beam signals;
correcting errors in the first and second positional relations generated due to distortions in path distance and time of the beams due to differences in sound speeds of the various media inside the object, in accordance with the measured sound speed distribution;
combining (111) the second received beam signals and the first received beam signals on the basis of the corrected first and second positional relations and the detected amount of relative displacement;
converting (112) the combined signal into a luminance signal; and
displaying (113) the above-converted luminance signal.

4. An imaging data processing method for an ultrasonic imaging apparatus according to claim 3, wherein the combining step (111) includes the step of adding up the second received beam signals subjected to a coordinate transformation and the first received beam signals.

5. An imaging data processing method for an ultrasonic imaging apparatus according to claim 4, wherein, in the adding step, luminance information and phase information of the second received beam signals which have been subjected to coordinate transformation, and information of the first received beam signals are subjected to complex addition.

Patentansprüche

1. Ultraschall-Bildgebungsvorrichtung, umfassend:

   eine Einrichtung (2, 3) zum Erhalten erster empfangener Strahlensignale von einer Ultraschallsonde (4) und eine Einrichtung zum Erhalten zweiter empfangener Strahlensignale von der Ultraschallsonde, wobei die ersten und die zweiten empfangenen Strahlensignale jeweils verschiedene erste und zweite Positionsbeziehungen zu einem zu untersuchenden Objekt haben;
   eine Positionsdetektionseinrichtung (10) zum Detektieren eines Maßes an relativer Ortsveränderung zwischen dem Objekt und der Ultraschallsonde (4) unter Verwendung von Korrelationen zwischen aus den ersten und den zweiten empfangenen Strahlensignalen erhaltenen Bildern;
   eine Schallgeschwindigkeitsverteilung-Messeinrichtung (17) zum Auffinden einer Verteilung einer Schallgeschwindigkeit in einem Medium auf einer Ultraschall-Scanebene auf der Grundlage von Kreuzkorrelation zwischen Echosignalen der jeweiligen Transducer, die die empfangenen Strahlensignale bilden;
   eine Aufbaueinrichtung (7) für Kombinationssignale zum Korrigieren von Fehlern in den ersten und zweiten Positionsbeziehungen, die aufgrund von Störungen in Pfadentfernung und Zeit der Strahlen wegen Differenzen in Schallgeschwindigkeiten der verschiedenen Medien innerhalb des Objekts erzeugt wurden, gemäß der gemessenen Ultraschallgeschwindigkeitsverteilung und zum Kombinieren der ersten empfangenen Strahlensignale und der zweiten empfangenen Strahlensignale auf der Grundlage der korrigierten ersten und zweiten Positionsbeziehungen und des detektierten Maßes an relativer Ortsveränderung;
   eine Einrichtung (8) zum Umwandeln des kombinierten Signals in ein Helligkeitssignal und
   eine Einrichtung (9) zum Anzeigen des wie oben umgewandelten Helligkeitssignals.

2. Ultraschall-Bildgebungsvorrichtung nach Anspruch 1, wobei die Aufbaueinrichtung (7) für Kombinationssignale dazu ausgelegt ist, durch das Ausführen der Zusammensetzungssynthese eine Vergrößerung des Feldwinkels zu bewirken.

3. Bildgebungsdaten-Verarbeitungsverfahren für eine Ultraschall-Bildgebungsvorrichtung, die die folgenden Schritte umfasst:

   Erhalten erster und zweiter empfangener Strahlensignale von einer Ultraschallsonde, wobei die ersten und die zweiten empfangenen Strahlensignale jeweils erste und zweite Positionsbeziehungen zu einem zu untersuchenden Objekt haben, die voneinander verschieden sind;
   Detektieren eines Maßes an relativer Ortsveränderung zwischen dem Objekt und der Ultraschallsonde unter Verwendung von Korrelationen zwischen aus den ersten und den zweiten empfangenen Strahlensignalen erhaltenen Bildern;
   Auffinden einer Verteilung einer Schallgeschwindigkeit in einem Medium auf einer Ultraschall-Scanebene auf der Grundlage von Kreuzkorrelation zwischen Echosignalen der jeweiligen Transducer, die die empfangenen Strahlensignale bilden;
   Korrigieren von Fehlern in den ersten und zweiten Positionsbeziehungen, die aufgrund von Störungen in Pfadentfernung und Zeit der Strahlen wegen Differenzen in den Schallgeschwindigkeiten der verschiedenen Medien innerhalb des Objekts erzeugt wurden, gemäß der gemessenen Schallgeschwindigkeitsverteilung;
   Kombinieren (111) der zweiten empfangenen Strahlensignale und der ersten empfangenen Strahlensignale auf der Grundlage der korrigierten ersten und zweiten Positionsbeziehungen und des detektierten Maßes an relativer Ortsveränderung,
   Umwandeln (112) des kombinierten Signals in ein Helligkeitssignal und
   Anzeigen (113) des wie oben umgewandelten Helligkeitsignals.

4. Bildgebungsdaten-Verarbeitungsverfahren für eine Ultraschall-Bildgebungsvorrichtung nach Anspruch 3, wobei der Kombinationsschritt (111) das Aufaddieren der einer Koordinatentransformation unterzogenen zweiten empfangenen Strahlensignale und der ersten empfangenen Strahlensignale beinhaltet.

5. Bildgebungsdaten-Verarbeitungsverfahren für eine Ultraschall-Bildgebungsvorrichtung nach Anspruch 4, wobei im Additionsschritt Helligkeitsinformationen und Phaseninformationen der zweiten empfangenen Strahlensignale, die einer Koordinatentransformation unterzogen wurden, und Informationen der ersten empfangenen Strahlensignale einer komplexen Addition unterzogen werden.

Revendications

1. Appareil d'imagerie ultrasonore, comprenant :

des moyens (2, 3), pour acquérir des premiers signaux de faisceaux reçus depuis une sonde ultrasonore (4), et des moyens pour acquérir des deuxièmes signaux de faisceaux reçus depuis la sonde ultrasonore, les premiers et deuxièmes signaux de faisceaux reçus ayant respectivement des premières et deuxièmes relations de position différentes par rapport à un objet devant être examiné;
un moyen de détection de position (10) pour détecter un degré de déplacement relatif entre l'objet et la sonde ultrasonore (4), en utilisant des corrélations entre les images obtenues à partir des premiers et deuxièmes signaux de faisceaux reçus;
un moyen de mesure de répartition de vitesse du son (17) pour trouver une répartition d'une vitesse du son dans un milieu sur un plan de balayage ultrasonique, sur la base d'une corrélation croisée parmi des signaux d'écho des transducteurs respectifs formant les signaux de faisceaux reçus;
des moyens de construction de signaux combinés (7) pour corriger des erreurs dans les premières et deuxièmes relations de position générées en raison de distorsions dans la distance et le temps de parcours des faisceaux suite aux différences dans les vitesses de son des différents milieux à l'intérieur de l'objet, selon la répartition mesurée de vitesse du son, et pour combiner les premiers signaux de faisceaux reçus et les deuxièmes signaux de faisceaux reçus, sur la base des premières et deuxièmes relations de position corrigées et du degré de déplacement relatif détecté;
un moyen (8) pour convertir le signal combiné en un signal de luminance; et
un moyen (9) pour afficher le signal de luminance converti ci-dessus.

2. Appareil d'imagerie ultrasonore selon la revendication 1, dans lequel les moyens de construction de signaux combinés (7) sont adaptés pour effectuer un traitement de grandissement d'angle de champ en réalisant la synthèse composée.

3. Procédé de traitement de données d'imagerie pour un appareil d'imagerie ultrasonore, comprenant les étapes suivantes :

acquisition de premiers et deuxièmes signaux de faisceaux reçus depuis une sonde ultrasonore, les premiers et deuxièmes signaux de faisceaux reçus ayant des premières et deuxièmes relations de position respectives par rapport à un objet devant être examiné, qui sont différentes l'une de l'autre;
détection d'un degré de déplacement relatif entre l'objet et la sonde ultrasonore, en utilisant des corrélations entre les images obtenues à partir des premiers et deuxièmes signaux de faisceaux reçus;
détermination d'une répartition de vitesse du son dans un milieu sur un plan de balayage ultrasonique, sur la base d'une corrélation croisée parmi des signaux d'écho des transducteurs respectifs formant les signaux de faisceaux reçus;
correction d'erreurs dans les premières et deuxièmes relations de position générées en raison de distorsions dans la distance et le temps de parcours des faisceaux suite à des différences dans les vitesses de son des différents milieux à l'intérieur de l'objet, selon la répartition mesurée de vitesse du son;
combinaison (111) des deuxièmes signaux de faisceaux reçus et des premiers signaux de faisceaux reçus, sur la base des premières et deuxièmes relations de position corrigées et du degré de déplacement relatif détecté;
conversion (112) du signal combiné en un signal de luminance; et
affichage (113) du signal de luminance converti ci-dessus.

4. Procédé de traitement de données d'imagerie pour un appareil d'imagerie ultrasonore selon la revendication 3, selon lequel l'étape de combinaison (111) inclut l'étape d'addition des deuxièmes signaux de faisceaux reçus, soumis à une transformation de coordonnées, et des premiers signaux de faisceaux reçus.

5. Procédé de traitement de données d'imagerie pour un appareil d'imagerie ultrasonore selon la revendication 4, selon lequel, à l'étape d'addition, des informations de luminance et des informations de phase du deuxième signal de faisceau reçu, qui a été soumis à une transformation de coordonnées, et des informations du premier signal de faisceau reçu sont soumises à une addition complexe.

Fig. 1

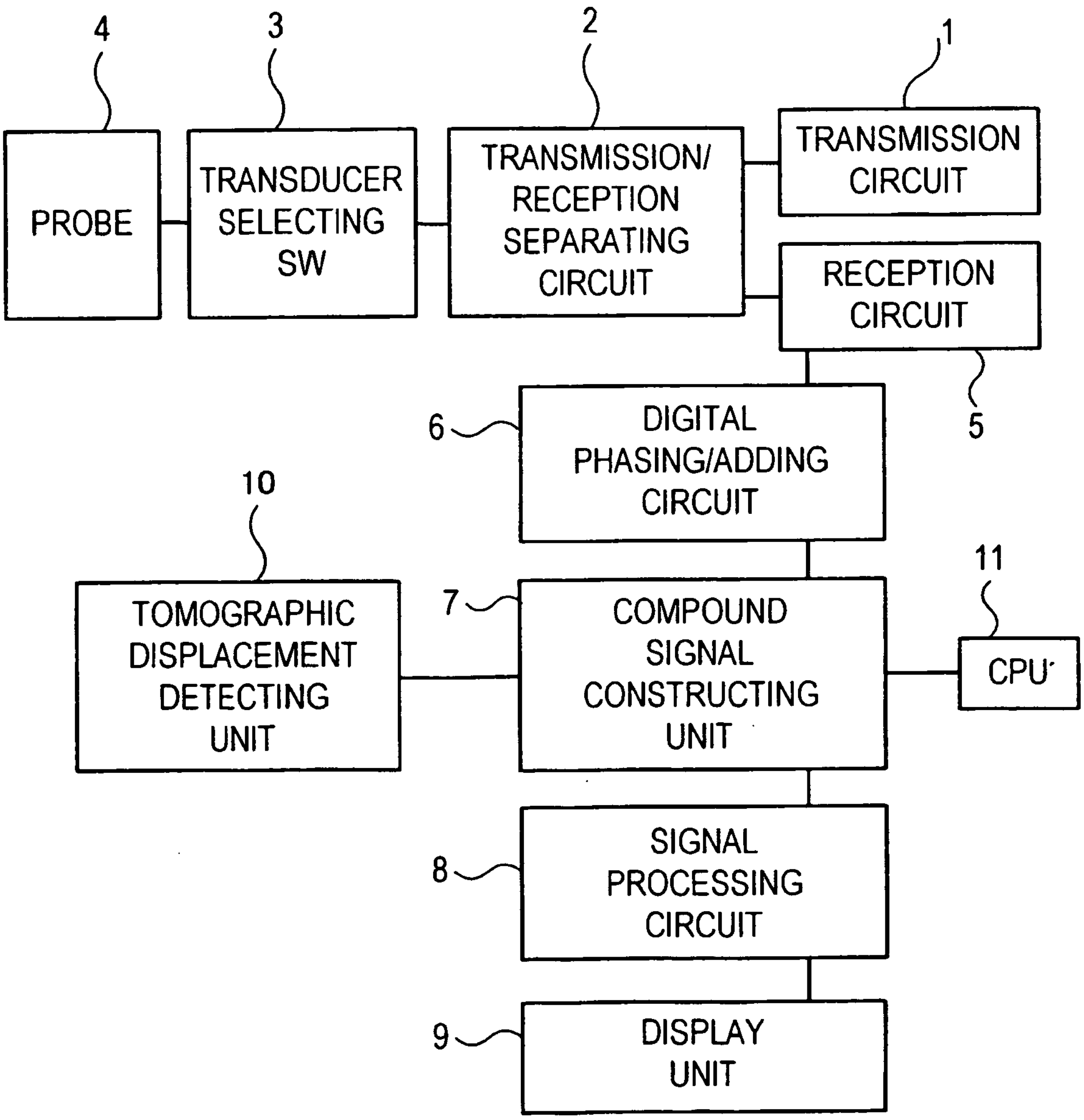

4
3
2
1
PROBE
TRANSDUCER SELECTING SW
TRANSMISSION/ RECEPTION SEPARATING CIRCUIT
TRANSMISSION CIRCUIT
RECEPTION CIRCUIT
5
6
DIGITAL PHASING/ADDING CIRCUIT
10
11
TOMOGRAPHIC DISPLACEMENT DETECTING UNIT
7
COMPOUND SIGNAL CONSTRUCTING UNIT
CPU
8
SIGNAL PROCESSING CIRCUIT
9
DISPLAY UNIT

Fig. 2

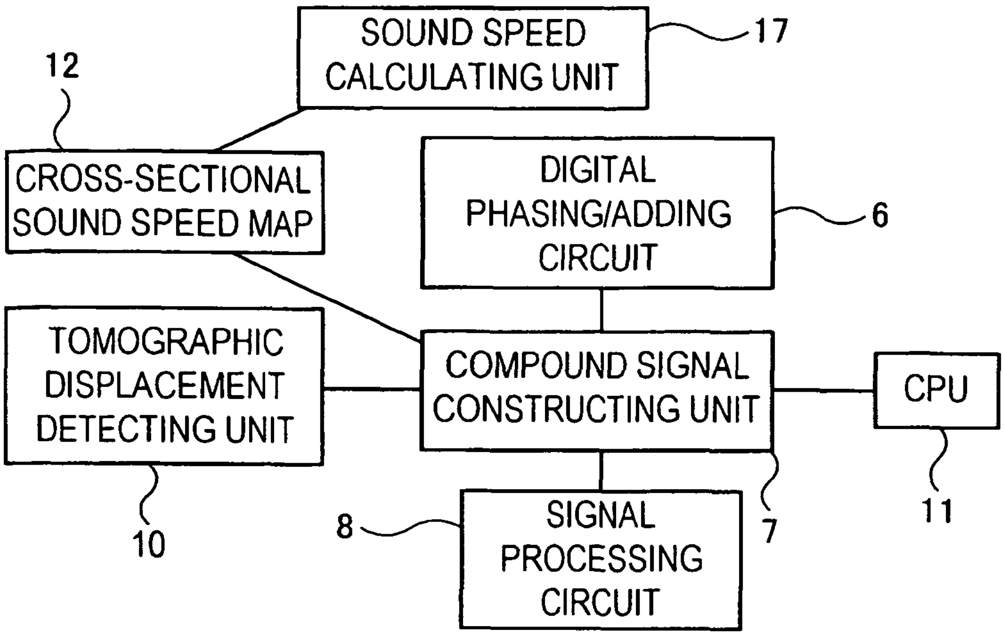

SOUND SPEED CALCULATING UNIT
17
12
CROSS-SECTIONAL SOUND SPEED MAP
DIGITAL PHASING/ADDING CIRCUIT
6
TOMOGRAPHIC DISPLACEMENT DETECTING UNIT
COMPOUND SIGNAL CONSTRUCTING UNIT
CPU
10
8
SIGNAL PROCESSING CIRCUIT
7
11

Fig. 4

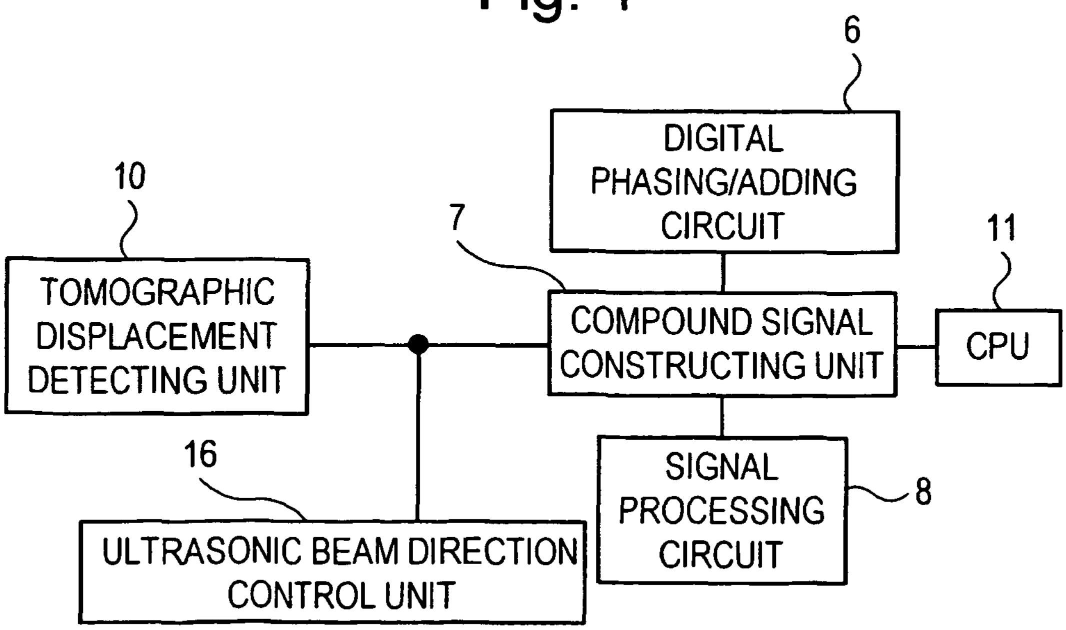

6
DIGITAL PHASING/ADDING CIRCUIT
10
7
11
TOMOGRAPHIC DISPLACEMENT DETECTING UNIT
COMPOUND SIGNAL CONSTRUCTING UNIT
CPU
16
SIGNAL PROCESSING CIRCUIT
8
ULTRASONIC BEAM DIRECTION CONTROL UNIT

Fig. 3

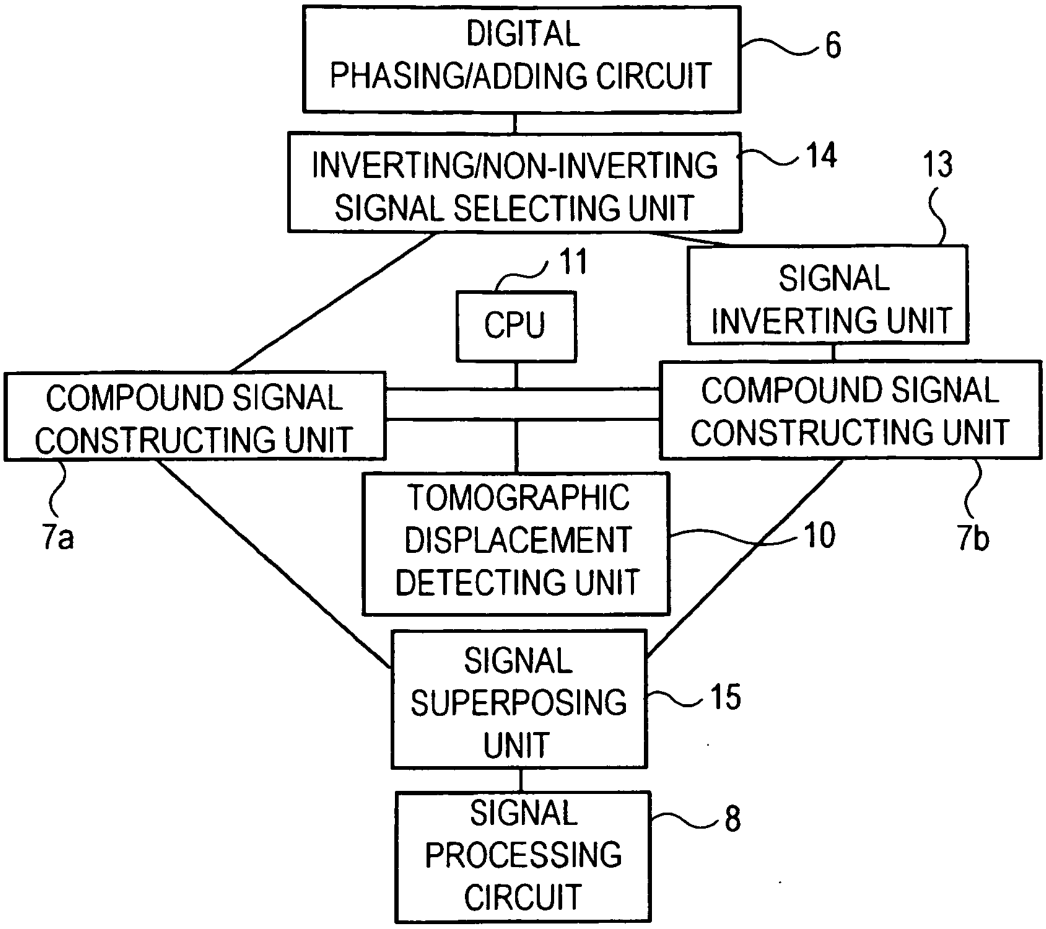

DIGITAL PHASING/ADDING CIRCUIT
6
INVERTING/NON-INVERTING SIGNAL SELECTING UNIT
14
13
SIGNAL INVERTING UNIT
11
CPU
COMPOUND SIGNAL CONSTRUCTING UNIT
COMPOUND SIGNAL CONSTRUCTING UNIT
7a
TOMOGRAPHIC DISPLACEMENT DETECTING UNIT
10
7b
SIGNAL SUPERPOSING UNIT
15
SIGNAL PROCESSING CIRCUIT
8

Fig. 11

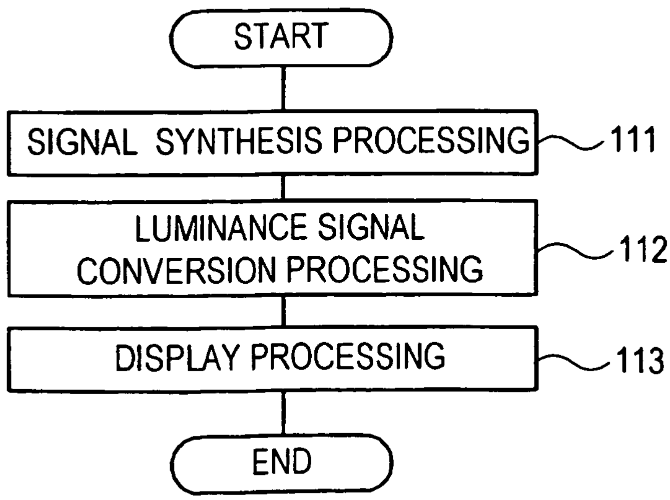

START
SIGNAL SYNTHESIS PROCESSING
111
LUMINANCE SIGNAL CONVERSION PROCESSING
112
DISPLAY PROCESSING
113
END

Fig. 5a

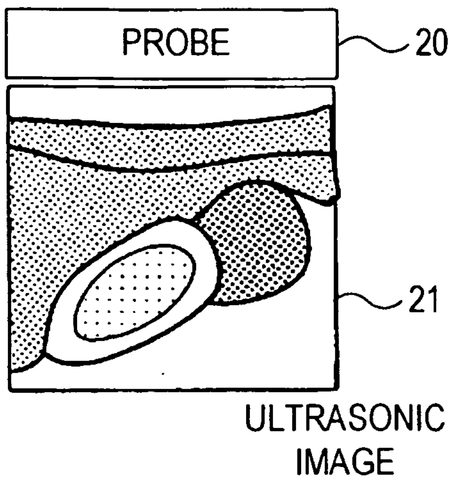


Fig. 5b

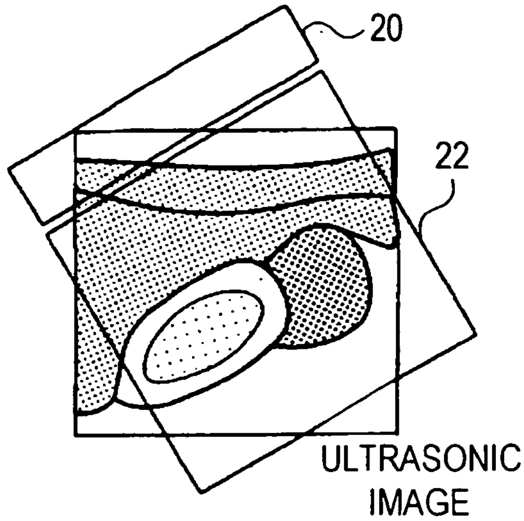


Fig. 5c

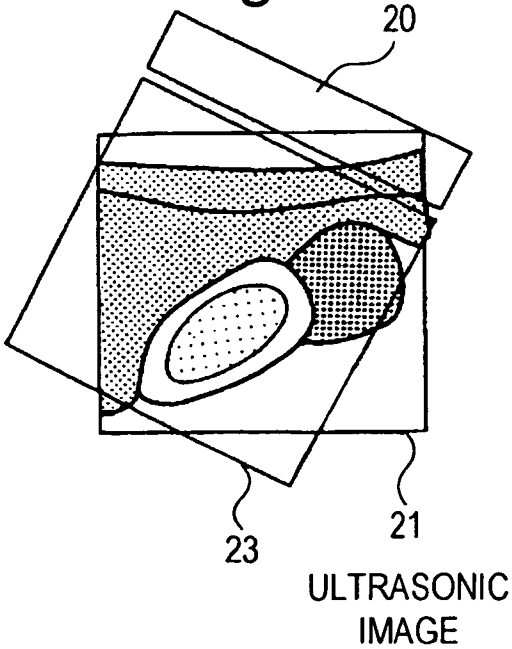


Fig. 5d

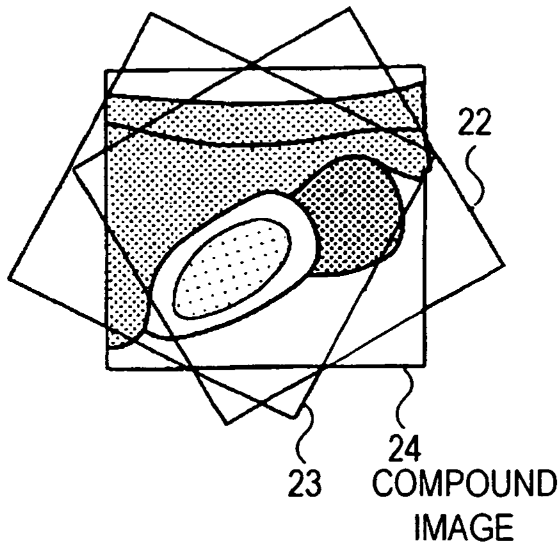


Fig. 6a

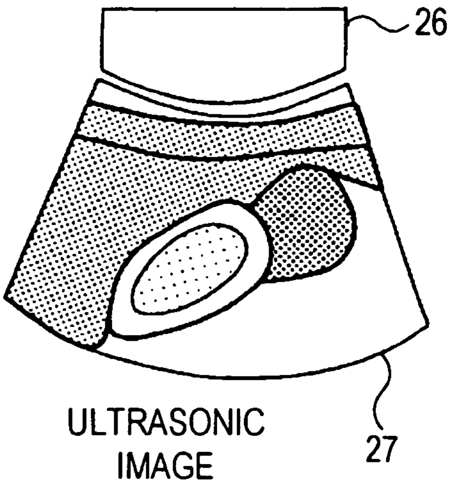


Fig. 6b

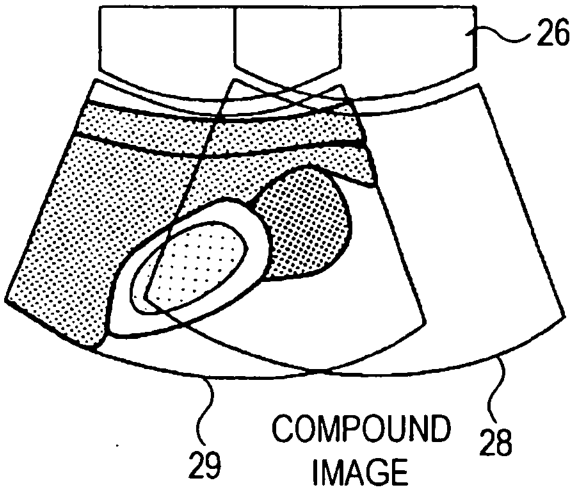


Fig. 7a

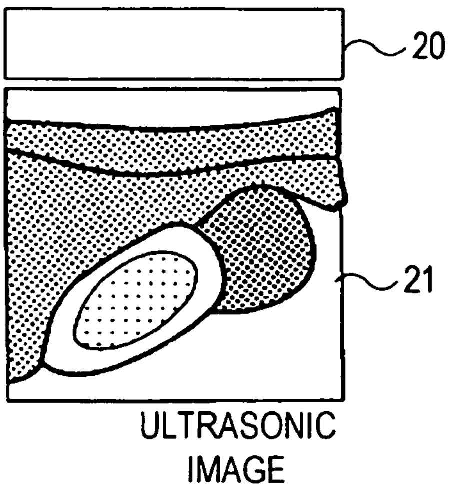


Fig. 7b

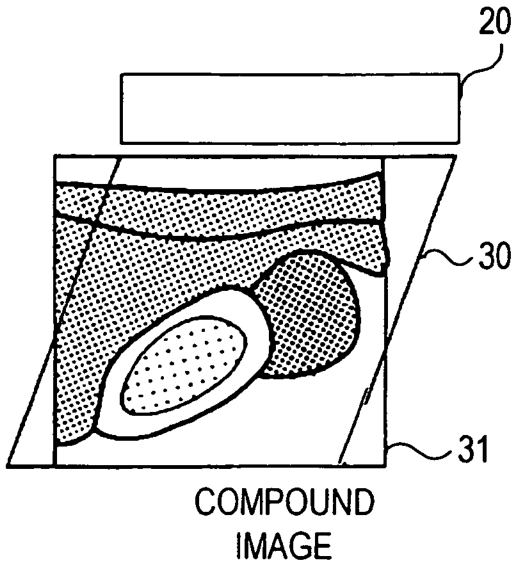


Fig. 8

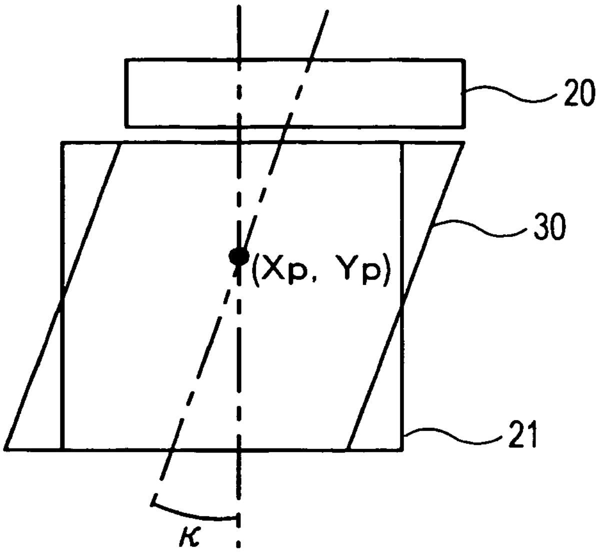


Fig. 10a

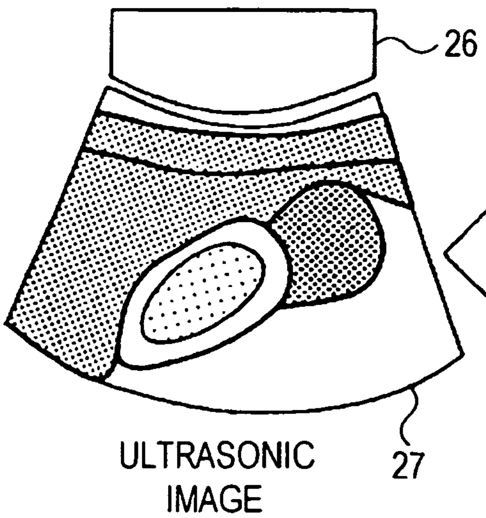


Fig. 10b

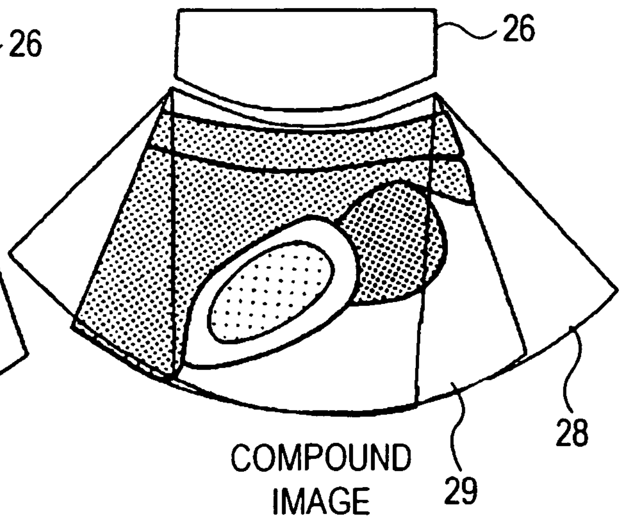


Fig. 9a

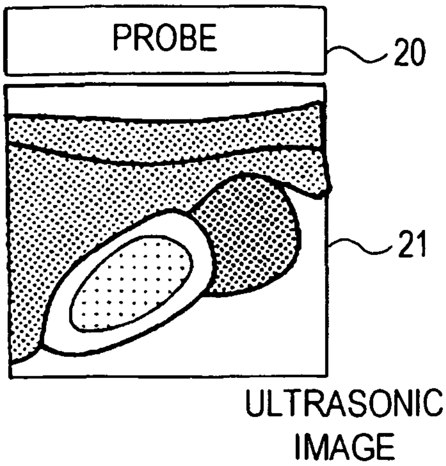


Fig. 9b

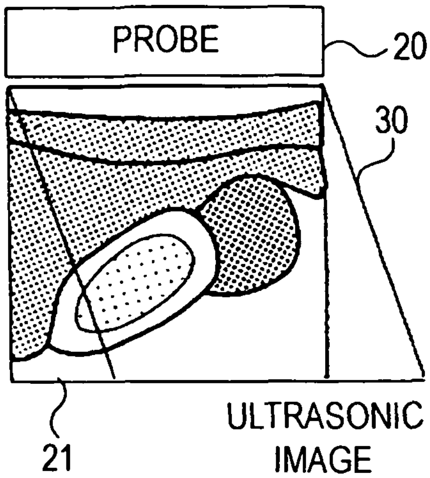


Fig. 9c

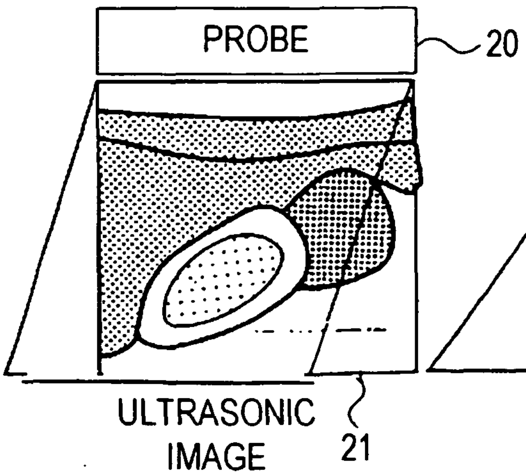
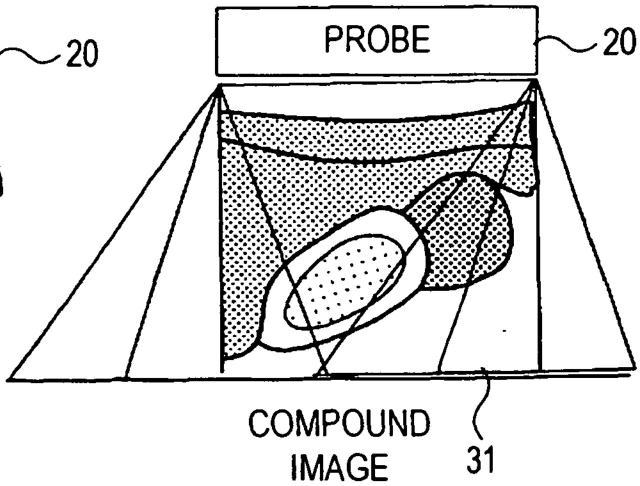


Fig. 9d



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6462133 A **[0005]**
- JP 5285146 A **[0005]**
- JP 2001104312 A **[0007]**
- US 4252025 A **[0011]**

专利名称(译)	超声波设备，超声波数据处理方法和超声波数据处理程序		
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当前申请(专利权)人(译)	日立医疗器械股份有限公司		
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发明人	BABA, HIROTAKA SATO, YUTAKA SHINOMURA, RYUICHI KUBOTA, JUN		
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外部链接	Espacenet		

摘要(译)

一种改善复合图像的S / N比的超声波设备。该装置包括用于组合来自设置在与样本不同位置的探针的多个接收束信号的装置，用于将组合的超声波束转换成亮度信号的装置，以及用于显示转换的亮度信号的装置。