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(54) **ULTRASONIC IMAGING DEVICE**

VORRICHTUNG EINER ULTRASCHALLBILDGEBUNG

DISPOSITIF D'IMAGERIE A ULTRASONS

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to an ultrasonic imaging apparatus for examining internal structure of a living body and goods, such as an ultrasonic diagnosis apparatus used for medical diagnosis, and a non-destructive examination apparatus used for non-destructive examination of goods. More particularly, it relates to an ultrasonic imaging apparatus that can obtain images of high quality even when the internal structure of a living body and goods are different in their propagation velocity of ultrasonic wave.

BACKGROUND OF THE INVENTION

[0002] In a linear scanning type ultrasonic imaging apparatus, ultrasound is received and transmitted by simultaneously driving the elements of an arrayed transducer group forming an aperture, which are selected by a aperture-selecting switch to form the aperture for a plurality of ultrasonic array transducers. Then, by shifting the aperture successively, the inside of the living body or goods is linear-scanned by an ultrasonic beam. Also, in a sector scanning type ultrasonic imaging apparatus, the inside of the living body or goods is scanned by inclining the ultrasonic beam, not shifting the aperture. In both the linear method and the sector method, a focus point is set up in the living body or the goods, and then a driving pulse is provided to each transducer in a delay-controlled manner so that all the ultrasonic waves transmitted from ultrasonic transducer group in the aperture can arrive at the focus point simultaneously.

[0003] For performing the delay control, a transmission delay circuit is provided. Output of the driving pulse generated from a transmitting circuit is delayed, said driving pulse is supplied to each transducer in the selected aperture through the transmission delay circuit, and ultrasonic beam is transmitted.

[0004] Reflection echoes from the object are received by a plurality of the ultrasonic transducers in the receiving aperture selected, and said reflection echoes are input to a receiving circuit connected to this plurality of ultrasonic transducers through an transmitting/receiving separation circuit. Said echoes are turned into signals having a good amplified dynamic range, and then, said signals are converted into digital signals by a plurality of analog digital converters. These signals are time-converted so that all received echoes arrive at the same time and then added up and output with a phase adjustment unit, which is comprised of a digital delay unit and an adder circuit. This output is used as receiving beam signals. Logarithm compression, filtering and γ correction are performed on this output by a signal processing unit, and the output is displayed after performing conversion of the data, such as coordinate transformation, or interpolation.

[0005] Delay data for delaying transmission and reception of signals described above is calculated by dividing the distance from each transducer to the focus point by propagation velocity of ultrasound in the object, thus deriving a time value. But, the structure of the medium to be examined is not uniform. Propagating velocity of ultrasound within a body is varied, depending for instance on whether the person is obese or muscular. Thus, in the present circumstance, delay data is set up in the apparatus by positing the average velocity of ultrasonic waves propagating in the living body.

[0006] When the actual ultrasonic propagation velocity is exceedingly different from posited velocity due to individual differences, a clear image cannot be obtained since ideal focusing is not performed.

[0007] As an example of method of estimating ultrasonic propagation velocity in living tissue, Japanese Patent Laid-open Publication No. Heisei 6-269447 can be referred. In this method, various coefficients of the medium being studied, including ultrasonic propagation velocity, are hypothesized, a hypothetical model of the transformation of a propagating waveform is calculated with a theoretical formula using those coefficients, by comparing the calculated waveform with measured waveform improved estimates of the above coefficients, including ultrasonic propagation velocity, are obtained.

[0008] As an example of an ultrasonic diagnostic apparatus performing optimum focusing by correcting the ultrasonic propagation velocity, Japanese Patent Laid-open Publication No. Heisei 2-274235 can be referred. In the apparatus of said example, an operator sets the ultrasonic propagation velocity of the medium from the console and then modifies the focus. Also, as an example of an ultrasonic diagnostic apparatus that can perform focusing automatically in a region where the focus is not made on a sectional image, Japanese Patent Laid-open Publication No. Heisei 8-317923 and No. Heisei 10-066694 can be referred. In the apparatus of this example, the human body is regarded as a non-uniform medium and the delay time is controlled in accordance with the living body, which is the object to be examined. According to this method, optimum focusing can be automatically obtained.

[0009] In the art disclosed in Japanese Patent Laid-open Publication No.Heisei6-269447, however, the medium composition has to be hypothesized and also the calculation method is complicated. Moreover, the long time it takes to do this calculation and compare it with the actual measured waveform is a drawback. The art disclosed in Japanese Patent Laid-open Publication No. Heisei 2-274235 does not contain a method of automatically estimating ultrasonic propagation velocity, it puts a great burden on the user, as well as lacking accuracy. Moreover, since the arts shown in Japanese Patent Laid-open Publication No Heisei 8-317923 and No. Heisei 10-066694 do not attempt the estimation of ultrasonic propagation velocity of the medium, good images cannot be obtained for the whole range of ultrasonic beam scanning object, which is a problem to be solved.

[0010] US-A-5 638 820 discloses an ultrasound system in line with the preamble of appended claim 1. Further, reference is made to US-A-5 415 173 and US-A-4 627 290.

DISCLOSURE OF THE INVENTION

[0011] The first object of the present invention is to provide an ultrasonic imaging apparatus that can calculate ultrasonic propagation velocity of the medium quickly and control delay time using this delay time.

[0012] The second object of the present invention is to provide an ultrasonic imaging apparatus having better operationality, which can automatically perform focusing with the ultrasonic propagation velocity suited to the medium, without an operator having to input this ultrasonic propagation velocity.

[0013] The third object of the present invention is to provide an ultrasonic imaging apparatus that can perform focusing uniformly and more sharply throughout the whole region which is subjected to ultrasonic beam scanning; that is, throughout the whole image.

[0014] Finally, the fourth object of the present invention is to provide an ultrasonic imaging apparatus that can provide the estimated ultrasonic propagation velocity to the operator in visible form.

[0015] The above objects are met by the present invention as defined in claim 1. The dependent claims relate to preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a block diagram showing an embodiment of the structure of a delay time controlling unit in an ultrasonic imaging apparatus of the present invention.

Fig.2 is a block diagram showing an embodiment of the structure of a delay time error-calculating unit of the present invention.

Fig.3 is a block diagram showing the outline structure of the ultrasonic imaging apparatus of the present invention.

Fig.4 is a graph representation of contents of the ultrasonic propagation velocity-derived delay time error relations storing unit.

Fig.5 is a diagram to explain the embodiment of displaying ultrasonic propagation velocity distribution.

BEST MODE FOR CARRYING OUT OF THE INVENTION

[0017] Hereinafter, an embodiment of the present invention is minutely described using diagrams. Fig.3 is a block diagram showing the structure of an ultrasonic imaging apparatus. In Fig.3, 1 is a transmission pulse circuit for generating pulse signals for driving ultrasonic transducers to transmit ultrasound. 2 is a transmission delay circuit for providing each ultrasonic transducer driven by the respective pulse signals output from the transmission pulse circuit 1 with the determined delay time corresponding to each driven transducer. 3 is a transmitting/receiving separation circuit for passing signals from the transmission pulse circuit to the ultrasonic transducer when transmitting ultrasonic waves, and from the ultrasonic transducer side to the receiving circuit side when receiving ultrasonic waves. 4 is a transducer selecting switch circuit for selecting from among the ultrasonic transducers that are arrayed on the ultrasonic probe a transducer group (an aperture) to transmit and receive. 5 is a ultrasonic probe having said array of ultrasonic transducers. 6 is a reception circuit for amplifying extremely weak echo signals, which are ultrasonic waves reflected from an object, which then have been converted into an electric signal by the transducer. 7 is an A/D converter (ADC) for converting analog echo signals into a digital signal, said analog echoes being output from the receiving circuit 6. 8 is a digital delay unit for delaying a digital echo signal that is output from the ADC 7. 9 is an adder circuit for forming an ultrasonic receiving beam signal by adding echo signals that are output from the digital delay unit 8. 10 is a signal processing unit for preprocessing said signals that are output from the adder circuit for conversion to images, that is, performing logarithmic compression, filtering and γ correction on this input signal. 11 is a display unit for successively storing the signals that are output from the signal processing unit 10 together with the position of the respective ultrasonic beam, as well as converting ultrasonic scanning into display scanning to output it, and displaying the image on a displaying device. 12 is a sampling signal generating unit for generating sampling signals at the ADC 7. 13 is a delay controlling unit for providing delay data to the transmission delay circuit 2 and the digital delay unit 8. 14 is a central processing unit (CPU) for collectively controlling said constituent features.

[0018] Next, the operation of the ultrasonic imaging apparatus that has the structure shown in Fig.3 will be described. First, an operator performs initial setting of the apparatus before beginning examination. At the initial setting, the operator identifies the part of the object to be examined, estimates the depth of said part to be examined from the body surface, and sets focusing depth of the transmitting wave. In the apparatus, transmission delay data (Dt) is calculated for this set focusing depth from the determined average value of ultrasonic propagation velocity of the organism by the CPU 14, and then said Dt is provided to the transmission delay circuit 2 through the delay control unit 13 when transmitting. Besides, in order to enable the operator to input ultrasonic propagation velocity manually to the apparatus, ultrasonic propagation velocity inputting device can be furnished in the console and the initial setting can be made with this inputted value of ultrasonic propagation velocity.

[0019] At least, after performing said initial setting, the operator applies the ultrasonic probe 5 to the surface of the examined part and inputs a command to begin ultrasonic scanning through the console. Then, the aperture of the probe to be used is selected and the transmission delay data (Dt) is set, and as well the reception delay data (Dr) of digital delay unit 8 at time of reception is set according to said average ultrasonic propagation velocity, and then the scanning begins. When the scanning begins, the driving pulse is output from the transmission circuit 1, and the delay time calculated for each ultrasonic transducer in the above aperture is applied to the driving pulse to be sent to that transducer by the transmission delay circuit 2. Then, the driving pulse is input to the transducer selecting switch circuit (a multiplexer circuit) 4 through the transmitting/receiving separation circuit 3. At the transducer selecting switch circuit 4, connection switchover is performed such that each inputted driving pulse is output to its assigned transducer with the delay time applied to that pulse. The probe is driven with the driving pulse that is output from the transducer selecting switch circuit 4.

[0020] The selected transducer group of the probe is driven in order of shortness of delay time of transmission of ultrasound. The ultrasound transmitted from the driven transducer group into the living body propagates within the living body such that every ultrasonic wave surface simultaneously arrives with the same phase at the transmission focus point that is set at the initial setting. Then, when a tissue having different acoustic impedance exists in the propagating course of the ultrasound, a part of ultrasound is reflected at the boundary surface of the tissue and the reflected wave (echo) returns towards the probe. The echoes return to the probe in turn according to the propagation of ultrasound that is transmitted from the shallow part to the deep part of the living body.

[0021] Said echoes are received by the transducers driven for transmitting, or by a transducer group of an aperture switched from smaller to larger aperture with the passage of time, and then it is transformed into an electric signal (echo signals). The amplifying process is separately performed at each transducer element line (channel) in the receiving circuit 6 to the echo signals that become electric signals at the transducer, through the transducer selecting switch circuit 4 and the transmitting/receiving separation circuit 3, and then, the amplified signals are inputted to the ADC 7 at each channel. The ADC 7 converts the echo signals of each channel into digital signals according to the timing of the sampling signals generated by the sampling signal generating means 12. Then, the digitalized echo signals are input to the digital delay unit 8.

[0022] The digital delay unit 8 is composed of digital delay circuits for each channel. It performs delay control on inputted echo signals by using said reception delay data that is provided from the delay control unit 13 controlled by the CPU 14, and the echo signals reflected from a certain point in the object (a point along the beam which is received) are outputted to the adder circuit 9 after adjusting the time phase of each channel so that these echo signals are all output at the same time.

[0023] The adder circuit 9 adds the echo signals of each channel, which have been outputted from the digital delay unit, forms ultrasonic received beam signals, and outputs them. As a result of said digital delay control and addition, there are formed echo beams that are received by the dynamic focus method well known in this field of the invention. Then, preprocessing such as logarithmic compression, filtering process, or γ correction are performed to the received beam signals, and then the signals are outputted to the display unit 11. The display unit 11 stores inputted beam signals in the memory for a time.

[0024] Transmission and reception of said ultrasound and its signal processing are repeated with each selection switchover of the ultrasonic transducer or direction change of ultrasonic beam. The received signals are taken into the display unit in turn, and beam signals inputted by each cycle of said transmission and reception form an image.

[0025] And, said stored contents in the memory that have become an image are read out while synchronizing with the scanning of the CRT display. In this manner, the inside of the living body is imaged and displayed.

[0026] By using the data obtained by said transmission and reception of ultrasound, the delay control unit 13 calculates the delay data for focusing at the next ultrasonic scanning. The structure and the operation of said delay control unit 13 will be described below.

[0027] Fig. 1 is a block diagram showing the detailed structure of the delay control unit 13 connected to the digital delay unit 8 of the ultrasonic imaging apparatus shown in Fig.3. In Fig.1, 82 is a digital delay data generating unit for providing delay data to the digital delay unit 8, and 131 is a delay time error calculating unit to calculate the delay error from a plurality of outputted echo signals, on which delay control has been performed by the digital delay unit 8.

[0028] Delay accuracy is improved and a good image can be obtained by adopting the above structure when the calculation result of the delay time error calculating unit 131 is fed back to the digital delay data generating unit 82 to perform delay control for the next ultrasonic transmission and reception. But as for calculation in the delay time error-calculating unit 131, if unexpected signal data is mixed with the data obtained with a tentative scanning, it becomes difficult to calculate accurate correction value. Therefore, an output of the delay time error calculating unit 131 must be regarded merely as a provisional standard.

[0029] Accordingly, an ultrasonic imaging apparatus of the embodiment of the present invention further comprises an ultrasonic propagation velocity-derived delay time error data storing unit 132 that is composed of, for example, ROM for storing in advance a group of delay time error data corresponding to the ultrasonic propagation velocities of various mediums, the delay time comparing unit 133 for comparing the stored value of delay time error data obtained in the delay time error calculating unit 131 with stored values of the ultrasonic propagation velocity-derived delay time error data storing unit 132, and outputting the delay time error data corresponding to the ultrasonic propagation velocity closest to that of the object, the ultrasonic propagation velocity data storing unit 134 for storing which ultrasonic propagation velocity results in which delay time group stored in the ultrasonic propagation velocity-derived delay time error data storing unit 132, and the ultrasonic propagation velocity/medium selecting unit 135 for selecting ultrasonic propagation velocity based on delay time error data, stored in the delay time error data storing unit, that had been output by the delay time comparing unit 133.

[0030] As is shown in Fig.2, the delay time error calculating unit comprises (M-1) delay time error detecting circuits 131a for detecting delay time errors by inputting the output of the digital delay circuits of two adjoining channels 8-1 to 8-M, and the delay time error distribution data forming circuit 131b for expressing output data of this delay time error detecting circuit as distribution data.

[0031] Here, for the ultrasonic propagation velocity-derived delay time error data storing unit 132, it is preferable to calculate in advance the delay time error data in the case of changing the ultrasonic propagation velocity by predetermined ultrasonic propagation velocity increments or decrements from a certain standard ultrasonic propagation velocity determined, for example, from the delay time error at each channel for said average ultrasonic propagation velocity, and store the data as a table. Then, stored data of this time is made into a graph in order to be visually understood is shown in Fig.4. In Fig. 4, the horizontal axis indicates the number of the channel and the vertical axis indicates delay time error, and the plurality of lines in the graph indicates the relation between the channels and the delay time error, for a plurality of respective ultrasonic propagation velocities as the parameter. The number of channels of ultrasonic transducers carrying out transmission and reception is M. Incidentally, Fig.4 is an example of linear scanning. In Fig. 4, ultrasonic propagation velocity Vo is chosen to be that velocity in which the delay time error is the constant value of zero at each channel. This is the reason that the present invention adopts the method of performing a tentative scanning by using the standard ultrasonic propagation velocity Vo, and calculating delay time errors that occur. Referring to Fig.4, when the velocity is faster than the standard velocity Vo, the delay time error line is convex downward with the lowest point at the center of the group of transducers (M/2). And, when velocity is slower than the standard velocity, the delay time error line is convex upward with the highest point at the center of the group of transducers (M/2). Data stored in the velocity-derived delay time error data storing unit 132 in this manner, as data for the standard ultrasonic propagation velocity and for velocities deviating from this, contributes to lowering the storage capacity needed in the memory unit.

[0032] Thus, by adding the ultrasonic propagation velocity-derived delay time error data storing unit 132, the delay time comparing unit 133, the ultrasonic propagation velocity storing unit 134 and the ultrasonic propagation velocity/medium selecting unit 135, an ultrasonic imaging apparatus of the embodiment of the present invention enables not only delay time correction for an adaptive imaging method which is generally called, but also estimation of ultrasonic propagation velocity of ultrasonic propagating medium.

[0033] Hereinafter, the principle and the operation of the part of an ultrasonic imaging apparatus containing an embodiment of the present invention concerning the present invention will be described. First, the ultrasonic propagation velocity of the medium is provisionally set to be the average ultrasonic propagation velocity of a living body in the digital delay unit 8 and the transmission delay data based on this average ultrasonic propagation velocity is set in the transmission delay circuit 2, and then ultrasonic scanning of said tentative scanning is performed. The reception delay data (Dr) corresponding to said average ultrasonic propagation velocity is supplied from the digital delay control unit 82 to the digital delay unit 8 so as to receive the echo signals which will be formed into a received beam by the digital delay unit 8, and then the echo signals are input to each channel of the delay time error calculating unit 131. The delay time error calculating unit 131 calculates delay time error (Dn) for each channel after the echo signals of adjoining channels such as 1CH and 2CH, 2CH and 3CH, ..., (M-1)CH and MCH are input in the delay time detecting circuit, using for example the correlation method disclosed in said Japanese Patent Laid-open Publications No. Heisei 8-317923 and 10-066694, and then calculates a delay time error data group consisting of D1, D2, ..., Dm as a distribution data. The purpose of calculating the delay time error data as a distribution is to prevent errors due to said unexpected noise or the like. Incidentally, calculation of the delay time error by the delay error calculating unit 131 can be done for the received beam in all scanning region in case of scanning in the living body while changing the position or the direction of a ultrasonic beam by a probe. It can be also done by setting a region of interest where an organ to be examined exists, and calculating the delay time error of the received beam only in said region.

[0034] Next, the ultrasonic propagation velocity in the living body is calculated from said distribution of delay time errors. In the ultrasonic propagation velocity-derived delay time error data storing unit 132, delay time error data corresponding to plausible ultrasonic propagation velocities is stored in a form making ultrasonic propagation velocity a parameter. Stored contents of said ultrasonic propagation velocity-derived delay time error data storing unit 132 are also stored as delay time distribution data for each channel in the cases of various ultrasonic propagation velocities. Then, stored contents of the ultrasonic propagation velocity-derived delay time error data storing unit 132 and the delay time calculating unit 131 are inputted to the delay time comparing unit 133 to be compared, and the delay time distribution in the ultrasonic propagation velocity-derived delay time error data storing unit 132 which is closest to the distribution of output data from the delay time error calculating unit 131 is selected. At this time, the delay time distributions in the ultrasonic propagation velocity-derived delay time error data storing unit 132, which are the subject with which comparison is made, is stored as delay time distributions for discrete ultrasonic propagation velocity values. Then, if the assumed ultrasonic propagation velocity values are few in number so that there are large gaps, the distribution of output data from the delay error calculating unit 131 does not often match well with the delay time distribution stored in the ultrasonic propagation velocity-derived delay time error data storing unit 132, and the most closely matching value might be the mean between two of them.

[0035] Assuming such a case, it is preferable to add a calculation circuit for selecting two values close to the output from the delay time error calculating unit 131 within the delay time error data stored in the ultrasonic propagation velocity-derived delay time error data storing unit 132, and for performing correction calculation based on an interpolation method or an extrapolation method by using said two values at the latter part of the comparing unit in the delay time comparing unit 133, and use this calculation result for determining ultrasonic propagation velocity. Incidentally, such correction calculation is not necessary when ultrasonic propagation velocity of the medium is estimated to a sufficient degree of accuracy, and this is stored in the ultrasonic propagation velocity-derived delay time error data storing unit 132. To be able to perform the comparison in the delay time comparing unit 133 simply, it is useful to use a method utilizing the fact that the delay time distribution to the input of a plurality of ultrasound signals can be approximated as a quadratic concave surface to reduce the information to be dealt with. Moreover, calculating the delay time distribution at discrete interval and applying a linear line to the array of delay time discrete value is useful because the information to be dealt with is further reduced.

[0036] Next, the stored delay time data for the delay time values matching the output from delay time error calculating unit 131 is inputted to the ultrasonic propagation velocity/medium selecting unit 134 and the ultrasonic propagation velocity is calculated referring to the delay time distribution in the ultrasonic propagation velocity storing unit 135.

[0037] To improve accuracy of the ultrasonic propagation velocity thus calculated, the received ultrasonic signal must have enough intensity. But in the structure of an apparatus dealing with fundamental waves with the same frequency as the transmitting frequency and harmonic waves generated from an ultrasonic medium, intensity of the harmonic wave is generally weaker than that of the fundamental wave. Thus, it is useful for accurate ultrasonic propagation velocity estimation to make the signal amplification factor of the harmonic wave larger than that of the fundamental wave to compensate for the signal reduction. Similarly, if it is known that the reduction degree of ultrasonic medium is different depending on transmitting frequency and path length, it is effective to amplify the signal by using a correction value that can be calculated in advance.

[0038] The ultrasonic propagation velocity data selected by the ultrasonic propagation velocity selecting unit 134 is fed back to the CPU 14 to form the delay data in the digital delay unit 8 for the ultrasonic scanning of the next examination. Also, the ultrasonic propagation velocity data is provided to the display unit 12 through the CPU 14 as a numerical value on the image of the display unit 12, as shown in Fig.5, where in the area labeled with the number 2 the ultrasonic propagation velocity is shown as V=1,5000.

[0039] In calculating the delay time error at the delay time error calculating unit 131, a plurality of delay time error data can be obtained by using the data obtained by scanning the broad region extending both in the depth direction and in the lateral direction. In this method, obtained ultrasonic propagation velocities are outputted as different values in a plurality of regions. It is possible to use all these data for scanning in an examination. But there are many cases that it is more useful to use only one ultrasonic propagation velocity representative of the whole region or of the region of interest (ROI). For example, calculating a typical ultrasonic propagation velocity in the whole region and using correction data based on it, an image of average sharpness over the whole region can be obtained. Alternatively, by calculating the ultrasonic propagation velocity only of the ROI and using the correction data based on this only an image in which only the ROI is sharply focused can be obtained. It is possible to use one of these methods selectively or two of them jointly, according to the purpose.

[0040] To calculate the ultrasonic propagation velocity that is typical in the whole region, it is useful to add a circuit structure for estimating and selecting from among the sub-regions in this region the sub-region that sends back the most reliable values to the medium/ ultrasonic propagation velocity selecting unit 134. For example, if the delay time error distribution outputted from the delay time error calculating unit 131 is tilted, it would appear that the beam would pass through this object in a direction different from the original beam direction, because the beam is made to perform focusing on an object having high level echo. It is difficult to determine the ultrasonic propagation velocity of a region sending back such delay time error values. It also is more difficult to determine ultrasonic propagation velocity as the absolute difference d between the delay time error distribution stored in the ultrasonic propagation velocity-derived delay time error data storing unit 132 and delay time D' corresponding to said medium becomes larger. Thus it is preferable to select only a region where the intensity A of the received signal is large for calculating the typical ultrasonic propagation velocity.

[0041] In other words, an estimated coefficient K for selecting one typical ultrasonic propagation velocity out of ultrasonic propagation velocities calculated in a plurality of regions is preferably calculated with the formula $K = A/\alpha + \beta/d + \gamma/\theta$ and then the ultrasonic propagation velocity in the region where K is maximum is selected. Here, α, β, γ are values freely chosen for performing suitable weighting to each estimated item.

[0042] Also, when calculating the ultrasonic propagation velocity in a specific region, if there is an element moving in the ROI (for example, bodily movement due to heartbeat in a human body) it is effective to continuously transmit ultrasound a number of times to one part and estimate the ultrasonic propagation velocity by averaging the delay time error information of each received signal because the ultrasonic propagation velocity is not so affected by the bodily movement and is stable. Further, as for the elements like cardiac valves that move especially fast, it is possible to calculate the ultrasonic propagation velocity accurately by obtaining the delay time error information synchronized with the electrocardiogram in addition to the above. And, when the ROI is changed from moving organs to other non-moving organs, it is efficient to switch from the mode of repeated ultrasound transmission at one place to the mode of transmission only one time.

[0043] As said delay time error measuring calculation methods, there are:

a method of detecting phase difference between adjoining channels by correlation processing;
a method of performing complex multiplication of signals of adjoining channels which have been phased with the main received frequency to isolate the frequency difference component, and then calculating $\tan\theta$ by dividing its real part by the imaginary part to calculate the phase difference; and
a method of varying the delay time of each channel so that they converge in order to set the noticed region in displayed to have the maximum histogram height and signal intensity.

[0044] Since the delay time error calculating unit 131 of the above embodiment is known in said reference, detailed explanation is here omitted. Any of the known methods above can be applied.

[0045] The present invention can be modified in various ways. For example, in said embodiment, the ultrasonic propagation velocity is calculated and delay time data is modified for imaging. But, because the output from the delay time error detecting circuit in the latter part of the digital delay unit includes the delay time error information, it can be input without modification as the delay time error of each channel in the CPU 14, where it is transformed into delay time data, input to the digital delay control unit 82 for imaging, corrected with the average ultrasonic propagation velocity of the whole imaging region to improve the image, and then perform ultrasonic propagation velocity correction only for the ROI according to said embodiment. By this process, the image quality of the whole image can be improved, and the image of the ROI becomes still clearer.

[0046] Also, as a method of displaying calculated ultrasonic propagation velocity, the example of displaying the ultrasonic propagation velocity as a numerical value in said embodiment has been explained. However, by scanning ultrasonic beam both in the depth direction and in the lateral direction, the ultrasonic propagation velocity can be calculated in a plurality of regions. If the distribution of all these calculated ultrasonic propagation velocities is made visible in the display, it is possible to observe that the organ is in the process of pathological change even when there is no change of the shape in the living body yet. Various embodiments for displaying it can be considered, display as a sonic velocity map may be the useful method.

[0047] Some examples of displaying methods of the ultrasonic propagation velocity map are as follows:

a method of making a ultrasonic propagation velocity map image such as the one shown in Fig.5(b) and displaying this and an ultrasonic image (cross sectional image) shown in Fig.5(a) side by side;
a method of selecting either the ultrasonic image or the ultrasonic propagation velocity map image for display on a screen of the displaying device;
a method of displaying the ultrasonic image and the ultrasonic propagation velocity map image overlapped,
a method of displaying the ultrasonic image by applying to the brightness value of each point on the image a brightness modulation corresponding to the ultrasonic propagation velocity of that point;
a method of displaying the monochromatic ultrasonic image after adding to each pixel a color modulation corresponding to that pixel of the ultrasonic propagation velocity map image;
a method of displaying the ultrasonic image superposed on the ultrasonic propagation velocity map where the ultrasonic propagation velocity values are offset from the correspondent pixel of the ultrasonic image.

[0048] It is possible to use one of these or a combination depending on the purpose. Of course, it is also useful to display a plurality of the ultrasonic propagation velocities as numerals or to display a typical ultrasonic propagation velocity value selected out of a plurality of ultrasonic propagation velocities by one of the above methods. Incidentally, when displaying the ultrasonic propagation velocity map image, it is helpful to display a scale (300 in Fig.5) that indicates contrast or color of map image near the map image to help a doctor read it.

[0049] Also, when the present invention not only to a

B-mode monochromatic image used in an ultrasonic image diagnostic apparatus but also a colored image (a color flow mapping image) is applied, it is possible to accurately display the positional relation of the monochromatic image and the colored image. When applied to the monochromatic image and the Doppler image, it is possible to improve accuracy of the positioning of Doppler signal reception region. Further, when applied to an M-mode image, it is possible to improve the distance accuracy. In another method, the degree of improvement of image quality can be indicated by first displaying the image with weak contrast and then displaying the part of the image whose image quality has been improved by lightly displaying it with usual contrast. And when constructing a phase adjustment circuit such that has two lines or shifts among a plurality of lines by time-sharing, the degree of improvement of image quality can be compared because images provided by the usual focus and provided by modified focus can be simultaneously obtained.

[0050] And furthermore, complicatedly alternating transmission wave forms are used in the coded transmission and reception, a technique to measure good reflection signals which does not increase the momentary transmission energy but increases the total energy. Thus, it can be inferred that the conventional delay error estimation method described above might easily make a wrong estimate. In this case, after performing usual transmission and reception and improving focusing accuracy by performing said ultrasonic propagation velocity estimation, then, the coded transmission and reception are performed. By this process, the accuracy of the delay time error estimation method can be improved similarly to the usual transmission and reception.

[0051] In this embodiment, the case of obtaining two-dimensional sectional images with a one-dimensional array of transducers is described. But also, the same process can be done and the same effect can be obtained in measuring and displaying a two-dimensional or a three-dimensional image by using a ring array or a two-dimensional array of transducers.

[0052] As described above, according to the present invention the ultrasonic propagation velocity of the medium can be quickly calculated with a simple calculation without making any assumption about the medium, and ultrasonic imaging can be performed by using the delay time data based on this ultrasonic propagation velocity. Also, the apparatus can automatically calculate a suitable ultrasonic propagation velocity without an operator inputting the ultrasonic propagation velocity of the medium. Thus, the operationality of the apparatus is improved.

[0053] Furthermore, according to the present invention, a uniform and clearer image can be obtained throughout the whole region of ultrasonic scanning

[0054] Furthermore, because the apparatus displays the calculated ultrasonic propagation velocity data automatically, the operator can find not only ultrasonic propagation velocity, but also distribution of ultrasonic propagation velocity in the living body.

Claims

1. An ultrasonic imaging apparatus comprising:

   an ultrasonic probe (5) having a plurality of built-in transducers for transmitting ultrasonic waves towards an object to be examined and receiving echo signals from it;
   means (7) for converting each echo signal tha is output from the plurality of transducers in said ultrasonic probe (5) into digital signals;
   a digital delay unit (8) for delaying digital echo signals that are output from said converting means (7) by applying predetermined delay time data;
   means (13) for calculating said delay time data using the output signals from said digital delay unit (8);
   an adder circuit (9) for forming received beam signals by adding the echo signals that are output from the digital delay unit (8); and
   means (10) for displaying an image on a display unit (11) by image-processing the received beam signals formed by said adder circuit (9),
   characterised in that said delay time data calculating means (13) comprises:

      means (131) for calculating delay time errors for each channel from a plurality of echo signals of adjoining channels output from said digital delay unit (8);
      means (132) for storing delay time error data corresponding to a plurality of ultrasonic propagation velocities; and
      a selecting unit (135) for selecting an ultrasonic propagation velocity by comparing the delay time errors output from said delay time error calculating means (131) with the delay time error data stored in said delay time error data storing means (132).

2. The apparatus of claim 1, wherein said delay time error data storing means (132) is adapted to store delay time error data corresponding to a plurality of ultrasonic transducer channels as a plurality of delay time distributions using the ultrasonic propagation velocity as a parameter.

3. The apparatus of claim 1, wherein said delay time error calculating means (131) is adapted to calculate the delay time errors by using a certain number of output signals of said digital delay unit (8) along a scanline in the depth direction.

4. The apparatus of claim 1, wherein said delay time

error calculating means (131) is adapted to calculate the delay time errors by using output data of said digital delay unit (8) in all regions along scanlines in the depth direction, wherein this calculation is performed throughout a predetermined ultrasonic scanning region that is formed by a plurality of received beams.

5. The apparatus of claim 1, wherein
a sonic velocity storing means (134) is provided for storing an ultrasonic propagation velocity corresponding to a plurality of delay time distributions that are stored in said delay time error data storing means (132), and
said selecting unit (135) is adapted to calculate an ultrasonic propagation velocity by comparing a selected delay time error data with the contents stored in said sonic velocity data storing means (134).

6. The apparatus of claim 5, further comprising means for displaying the ultrasonic propagation velocity data being calculated at said selecting unit (135) on the screen of said display unit (11).

7. The apparatus of claim 1, further comprising:

means for setting an ultrasonic propagation velocity estimated from the physical constitution of the object to be examined; and
means for calculating errors in this propagation velocity using the ultrasonic propagation velocity being set at said setting means and an ultrasonic propagation velocity in the object that is calculated by using the output signal of said digital delay unit (8),
wherein said adder circuit (9) is adapted to produce received beam signals by adding propagation velocity errors calculated by said error calculating means and an ultrasonic propagation velocity being set at said setting means to output signals of said digital delay unit (8).

8. The apparatus of claim 7, further comprising means for transforming delay time errors calculated by using data of a plurality of output signals of said digital delay unit (8) on all regions along scanlines in the depth direction into an ultrasonic propagation velocity data distribution, and then displaying it as an ultrasonic propagation velocity distribution image on the screen of said display unit (11).

9. The apparatus of claim 8, wherein the ultrasonic propagation velocity distribution image is displayed with hues varied in accordance with the difference of the ultrasonic propagation velocity.

10. The apparatus of claim 8, wherein said displaying means is adapted to display the ultrasonic propagation velocity distribution image and the ultrasonic cross sectional image simultaneously.

11. The apparatus of claim 10, wherein the ultrasonic cross sectional image is displayed superimposed on the ultrasonic propagation velocity distribution image.

Patentansprüche

1. Ultraschall-Bildgebungsgerät mit:

einer Ultraschallsonde (5) mit mehreren eingebauten Wandlern zum Übertragen von Ultraschallwellen zu einem zu untersuchenden Objekt und zum Empfangen von Echosignalen von diesem;
einer Einrichtung (7) zum Konvertieren jedes Echosignals, das von den mehreren Wandlern in der Ultraschallsonde (5) ausgegeben wird, in digitale Signale;
einer digitalen Verzögerungseinheit (8) zum Verzögern von digitalen Echosignalen, die von der Konvertierungseinrichtung (7) ausgegeben werden, indem vorbestimmte Verzögerungszeitdaten angewendet werden;
einer Einrichtung (13) zum Berechnen der Verzögerungszeitdaten unter Verwendung der Ausgabesignale von der digitalen Verzögerungseinheit (8);
einer Addierschaltung (9) zum Bilden empfangener Strahlsignale durch Addieren der Echosignale, die von der digitalen Verzögerungseinheit (8) ausgegeben werden; und
einer Einrichtung (10) zum Anzeigen eines Bildes auf einer Anzeigeeinheit (11), indem die durch die Addierschaltung (9) gebildeten empfangenen Strahlsignale bildverarbeitet werden,
dadurch gekennzeichnet, dass die Einrichtung (13) zur Berechnung der Verzögerungszeitdaten aufweist:

eine Einrichtung (131) zum Berechnen von Verzögerungszeitfehlern für jeden Kanal aus mehreren Echosignalen von benachbarten Kanälen, die von der digitalen Verzögerungseinheit (8) ausgegeben werden;
eine Einrichtung (132) zum Speichern von Verzögerungszeitfehlerdaten, die mehreren Ultraschall-Ausbreitungsgeschwindigkeiten entsprechen; und
eine Auswahleinheit (135) zum Auswählen einer Ultraschall-Ausbreitungsgeschwindigkeit, indem die von der Verzögerungszeitfehlerberechnungseinrichtung (131) ausgegebenen Verzögerungszeitfehler mit den in der

Verzögerungszeitfehlerdatenspeichereinrichtung (132) gespeicherten Verzögerungszeitfehlerdaten verglichen werden.

2. Gerät nach Anspruch 1, wobei die Verzögerungszeitfehlerdatenspeichereinrichtung (132) dazu ausgelegt ist, Verzögerungszeitfehlerdaten, die zu mehreren Ultraschall-Wandlerkanälen gehören, als mehrere Verzögerungszeitverteilungen zu speichern, indem die Ultraschall-Ausbreitungsgeschwindigkeit als ein Parameter verwendet wird.

3. Gerät nach Anspruch 1, wobei die Verzögerungszeitfehlerberechnungseinrichtung (131) dazu ausgelegt ist, die Verzögerungszeitfehler zu berechnen, indem eine bestimmte Anzahl von Ausgabesignalen der digitalen Verzögerungseinheit (8) längs einer Abtastlinie in der Tiefenrichtung verwendet werden.

4. Gerät nach Anspruch 1, wobei die Verzögerungszeitfehlerberechnungseinrichtung (131) dazu ausgelegt ist, die Verzögerungszeitfehler zu berechnen, indem Ausgabedaten der digitalen Verzögerungseinheit (8) in allen Bereichen längs Abtastlinien in der Tiefenrichtung verwendet werden, wobei diese Berechnung über einen gesamten vorbestimmten Ultraschallabtastbereich durchgeführt wird, der durch mehrere empfangene Strahlen gebildet ist.

5. Gerät nach Anspruch 1, wobei
eine Schallgeschwindigkeitsspeichereinrichtung (134) vorgesehen ist, um eine Ultraschall-Ausbreitungsgeschwindigkeit entsprechend mehreren Verzögerungszeitverteilungen zu speichern, die in der Verzögerungszeitfehlerdatenspeichereinrichtung (132) gespeichert sind, und
die Auswahleinheit (135) dazu ausgelegt ist, eine Ultraschall-Ausbreitungsgeschwindigkeit zu berechnen, indem ausgewählte Verzögerungszeitfehlerdaten mit den in der Schallgeschwindigkeitsdatenspeichereinrichtung (134) gespeicherten Inhalten verglichen werden.

6. Gerät nach Anspruch 5, ferner mit einer Einrichtung zum Anzeigen der Ultraschall-Ausbreitungsgeschwindigkeitsdaten, die an der Auswahleinheit (135) berechnet werden, auf dem Schirm der Anzeigeeinheit (11).

7. Gerät nach Anspruch 1, ferner mit:

einer Einrichtung zum Einstellen einer Ultraschall-Ausbreitungsgeschwindigkeit, die anhand des physikalischen Zustands des zu untersuchenden Objekts geschätzt wurde; und

einer Einrichtung zum Berechnen von Fehlern in dieser Ausbreitungsgeschwindigkeit unter Verwendung der Ultraschall-Ausbreitungsgeschwindigkeit, die an der Einstelleinrichtung eingestellt wurde, und einer Ultraschall-Ausbreitungsgeschwindigkeit in dem Objekt, die durch Verwendung des Ausgabesignals von der digitalen Verzögerungseinheit (8) berechnet wurde, wobei die Addierschaltung (9) dazu ausgelegt ist, empfangene Strahlsignale zu erzeugen, indem die Ausbreitungsgeschwindigkeitsfehler, die durch die Fehlerberechnungseinrichtung berechnet wurden, und eine Ultraschall-Ausbreitungsgeschwindigkeit, die an der Einstelleinrichtung eingestellt wurde, zu Ausgabesignalen der digitalen Verzögerungseinheit (8) addiert werden.

8. Gerät nach Anspruch 7, ferner mit einer Einrichtung zum Umformen von Verzögerungszeitfehlern, die unter Verwendung von Daten von mehreren Ausgabesignalen der digitalen Verzögerungseinheit (8) in allen Bereichen längs Abtastlinien in der Tiefenrichtung berechnet wurden, in eine Ultraschall-Ausbreitungsgeschwindigkeitsdatenverteilung, und zum anschließenden Anzeigen derselben als ein Ultraschall- Ausbreitungsgeschwindigkeitsverteilungsbild auf dem Schirm der Anzeigeeinheit (11).

9. Gerät nach Anspruch 8, wobei das Ultraschall-Ausbreitungsgeschwindigkeitsverteilungsbild mit Farbtönen angezeigt wird, die gemäß dem Unterschied der Ultraschall-Ausbreitungsgeschwindigkeit variieren.

10. Gerät nach Anspruch 8, wobei die Anzeigeeinrichtung dazu ausgelegt ist, das Ultraschall-Ausbreitungsgeschwindigkeitsverteilungsbild und das Ultraschall-Querschnittsbild gleichzeitig anzuzeigen.

11. Gerät nach Anspruch 10, wobei das Ultraschall-Querschnittsbild überlagert über dem Ultraschall-Ausbreitungsgeschwindigkeitsverteilungsbild angezeigt wird.

Revendications

1. Appareil d'imagerie à ultrasons comprenant :

une sonde à ultrasons (5) comportant une pluralité de transducteurs incorporés pour émettre des ondes ultrasonores vers un objet à examiner et recevoir des signaux d'écho de ce dernier ;
un moyen (7) pour convertir chaque signal d'écho qui est délivré par la pluralité de transducteurs dans ladite sonde à ultrasons (5) en

signaux numériques ;
une unité de retard numérique (8) pour retarder les signaux d'écho numériques qui sont délivrés par ledit moyen de conversion (7) en appliquant des données de temps de retard prédéterminées ;
un moyen (13) pour calculer lesdites données de temps de retard en utilisant les signaux de sortie de ladite unité de retard numérique (8) ;
un circuit additionneur (9) pour former des signaux de faisceaux reçus en additionnant les signaux d'écho qui sont délivrés par l'unité de retard numérique (8) ; et
un moyen (10) pour afficher une image sur une unité d'affichage (11) par traitement d'image des signaux de faisceaux reçus formés par ledit circuit additionneur (9),
caractérisé en ce que ledit moyen de calcul de données de temps de retard (13) comprend :

un moyen (131) pour calculer des erreurs de temps de retard pour chaque canal à partir d'une pluralité de signaux d'écho de canaux contigus délivrés par ladite unité de retard numérique (8) ;
un moyen (132) pour mémoriser des données d'erreurs de temps de retard correspondant à une pluralité de vitesses de propagation ultrasonores ; et
une unité de sélection (135) pour sélectionner une vitesse de propagation ultrasonore en comparant les erreurs de temps de retard délivrées par ledit moyen de calcul d'erreurs de temps de retard (131) avec les données d'erreurs de temps de retard mémorisées dans ledit moyen de mémorisation de données d'erreurs de temps de retard (132).

2. Appareil selon la revendication 1, dans lequel ledit moyen de mémorisation de données d'erreurs de temps de retard (132) est adapté pour mémoriser les données d'erreurs de temps de retard correspondant à une pluralité de canaux de transducteurs ultrasonores sous la forme d'une pluralité de distributions de temps de retard en utilisant la vitesse de propagation ultrasonore comme paramètre.

3. Appareil selon la revendication 1, dans lequel ledit moyen de calcul d'erreurs de temps de retard (131) est adapté pour calculer les erreurs de temps de retard en utilisant un certain nombre de signaux de sortie de ladite unité de retard numérique (8) le long d'une ligne de balayage dans la direction de la profondeur.

4. Appareil selon la revendication 1, dans lequel ledit moyen de calcul d'erreurs de temps de retard (131) est adapté pour calculer les erreurs de temps de retard en utilisant les données de sortie de ladite unité de retard numérique (8) dans toutes les régions le long de lignes de balayage dans la direction de la profondeur, dans lequel ce calcul est effectué sur toute une région de balayage ultrasonore prédéterminée qui est formée par une pluralité de faisceaux reçus.

5. Appareil selon la revendication 1, dans lequel :

un moyen de mémorisation de vitesse sonique (134) est prévu pour mémoriser une vitesse de propagation ultrasonore correspondant à une pluralité de distributions de temps de retard qui sont mémorisées dans ledit moyen de mémorisation de données d'erreurs de temps de retard (132), et
ladite unité de sélection (135) est adaptée pour calculer une vitesse de propagation ultrasonore en comparant une donnée d'erreur de temps de retard sélectionnée avec le contenu mémorisé dans ledit moyen de mémorisation de données de vitesse sonique (134).

6. Appareil selon la revendication 5, comprenant en outre un moyen pour afficher les données de vitesse de propagation ultrasonore calculées dans ladite unité de sélection (135) sur l'écran de ladite unité d'affichage (11).

7. Appareil selon la revendication 1, comprenant en outre :

un moyen pour établir une vitesse de propagation ultrasonore estimée à partir de la constitution physique de l'objet à examiner ; et
un moyen pour calculer les erreurs dans cette vitesse de propagation en utilisant la vitesse de propagation ultrasonore établie par ledit moyen de réglage et une vitesse de propagation ultrasonore dans l'objet qui est calculée en utilisant le signal de sortie de ladite unité de retard numérique (8),
dans lequel ledit circuit additionneur (9) est adapté pour produire des signaux de faisceaux reçus en additionnant les erreurs de vitesse de propagation calculées par ledit moyen de calcul d'erreur et une vitesse de propagation ultrasonore étant établie dans ledit moyen de réglage pour délivrer les signaux de ladite unité de retard numérique (8).

8. Appareil selon la revendication 7, comprenant en outre un moyen pour transformer les erreurs de temps de retard calculées en utilisant les données d'une pluralité de signaux de sortie de ladite unité de retard numérique (8) sur toutes les régions le long de lignes de balayage dans la direction de la profondeur en une distribution de données de vitesse de propagation ultrasonore, puis pour l'afficher comme image de distribution de vitesse de propagation ultrasonore sur l'écran de ladite unité d'affichage (11).

9. Appareil selon la revendication 8, dans lequel l'image de distribution de vitesse de propagation ultrasonore est affichée avec des teintes qui varient en fonction de la différence de la vitesse de propagation ultrasonore.

10. Appareil selon la revendication 8, dans lequel ledit moyen d'affichage est adapté pour afficher simultanément l'image de distribution de vitesse de propagation ultrasonore et l'image de coupe transversale ultrasonore.

11. Appareil selon la revendication 10, dans lequel l'image de coupe transversale ultrasonore est affichée en superposition sur l'image de distribution de vitesse de propagation ultrasonore.

Fig. 1

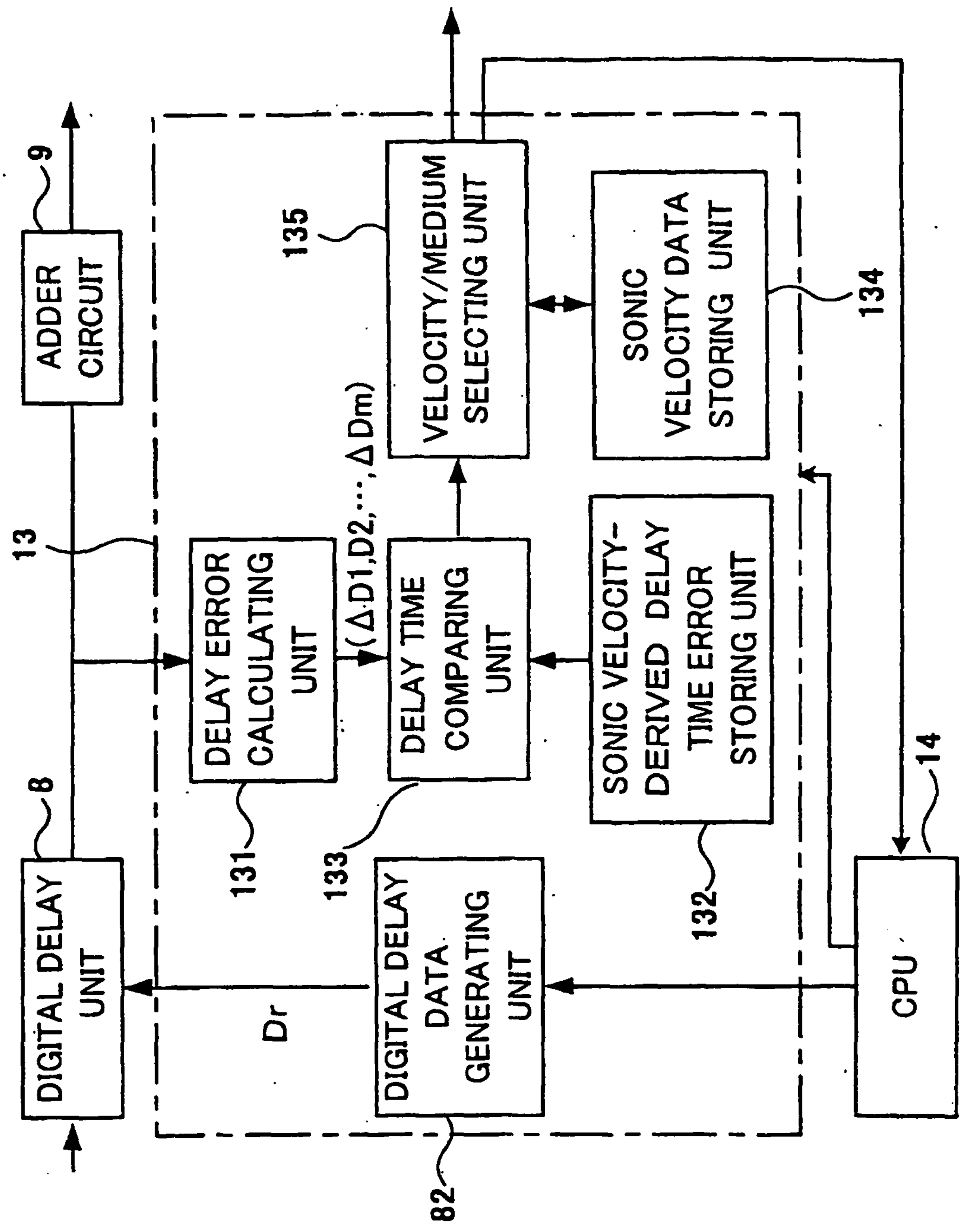

DIGITAL DELAY UNIT
8
ADDER CIRCUIT
9
13
DELAY ERROR CALCULATING UNIT
131
(ΔD1,D2,···,ΔDm)
DELAY TIME COMPARING UNIT
133
VELOCITY/MEDIUM SELECTING UNIT
135
SONIC VELOCITY-DERIVED DELAY TIME ERROR STORING UNIT
132
SONIC VELOCITY DATA STORING UNIT
134
DIGITAL DELAY DATA GENERATING UNIT
82
Dr
CPU
14

Fig. 2

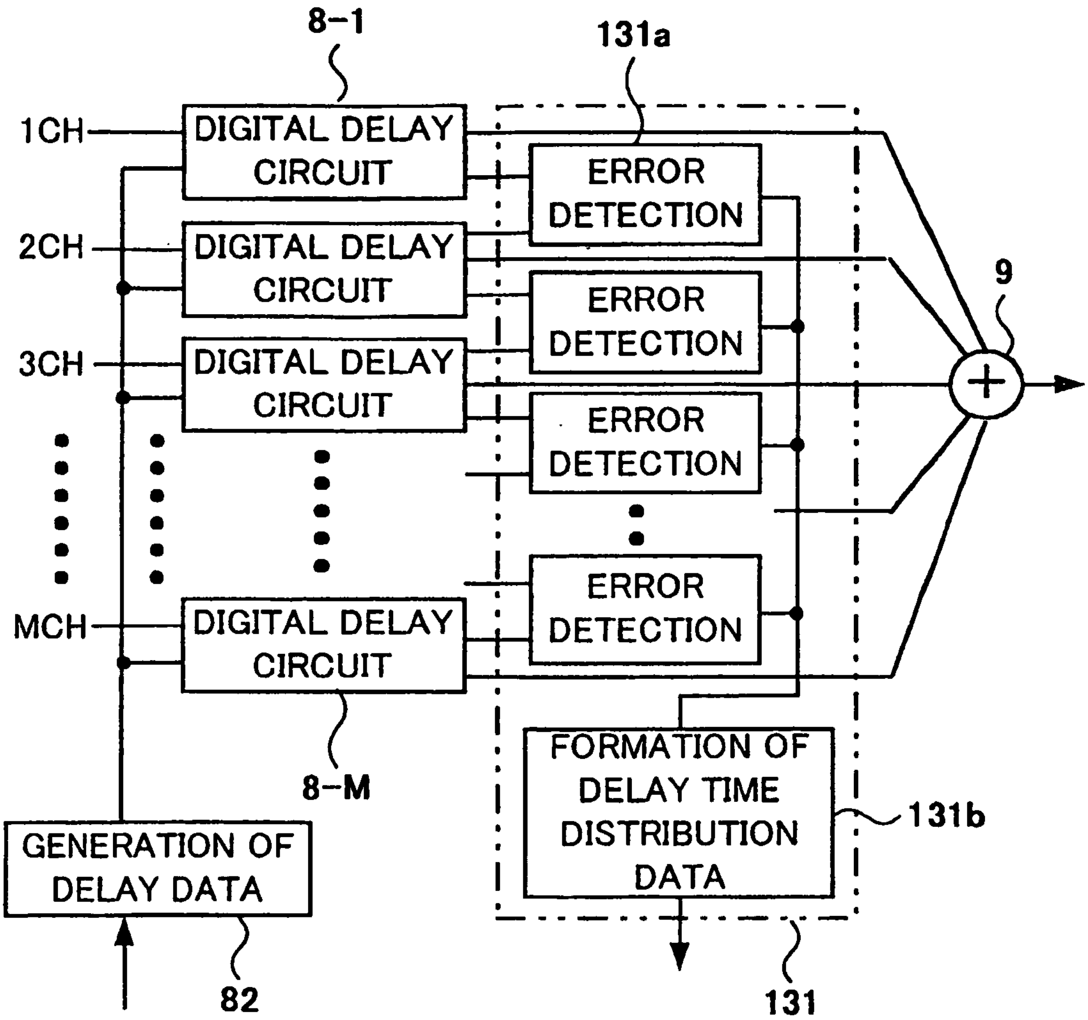

8-1
131a
1CH
DIGITAL DELAY CIRCUIT
ERROR DETECTION
2CH
DIGITAL DELAY CIRCUIT
ERROR DETECTION
9
3CH
DIGITAL DELAY CIRCUIT
ERROR DETECTION
ERROR DETECTION
MCH
DIGITAL DELAY CIRCUIT
8-M
FORMATION OF DELAY TIME DISTRIBUTION DATA
131b
GENERATION OF DELAY DATA
82
131

Fig. 3

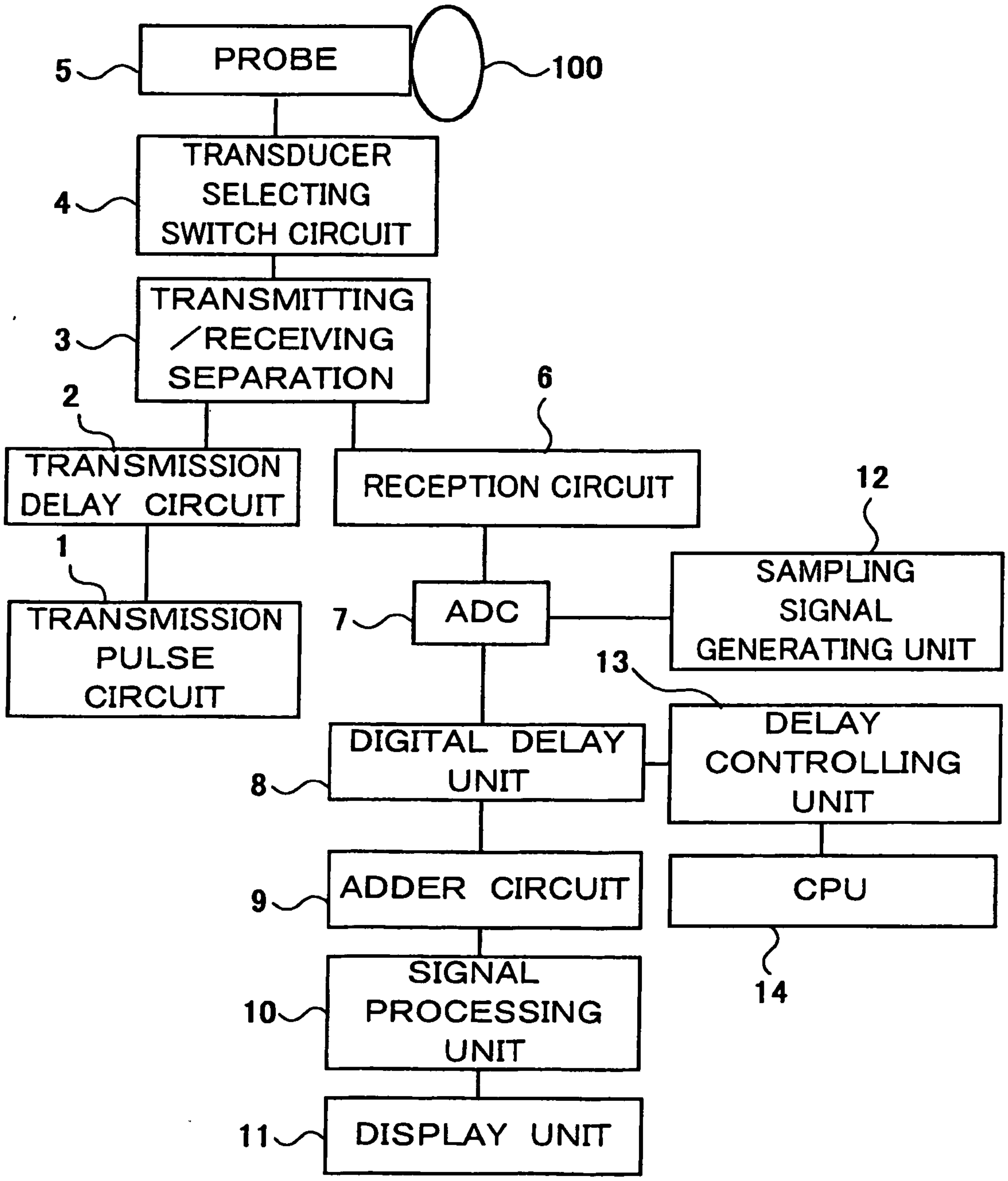

PROBE
5
100
TRANSDUCER SELECTING SWITCH CIRCUIT
4
TRANSMITTING /RECEIVING SEPARATION
3
2
6
TRANSMISSION DELAY CIRCUIT
RECEPTION CIRCUIT
12
1
TRANSMISSION PULSE CIRCUIT
7
ADC
SAMPLING SIGNAL GENERATING UNIT
13
DIGITAL DELAY UNIT
8
DELAY CONTROLLING UNIT
ADDER CIRCUIT
9
CPU
SIGNAL PROCESSING UNIT
10
14
DISPLAY UNIT
11

Fig. 4

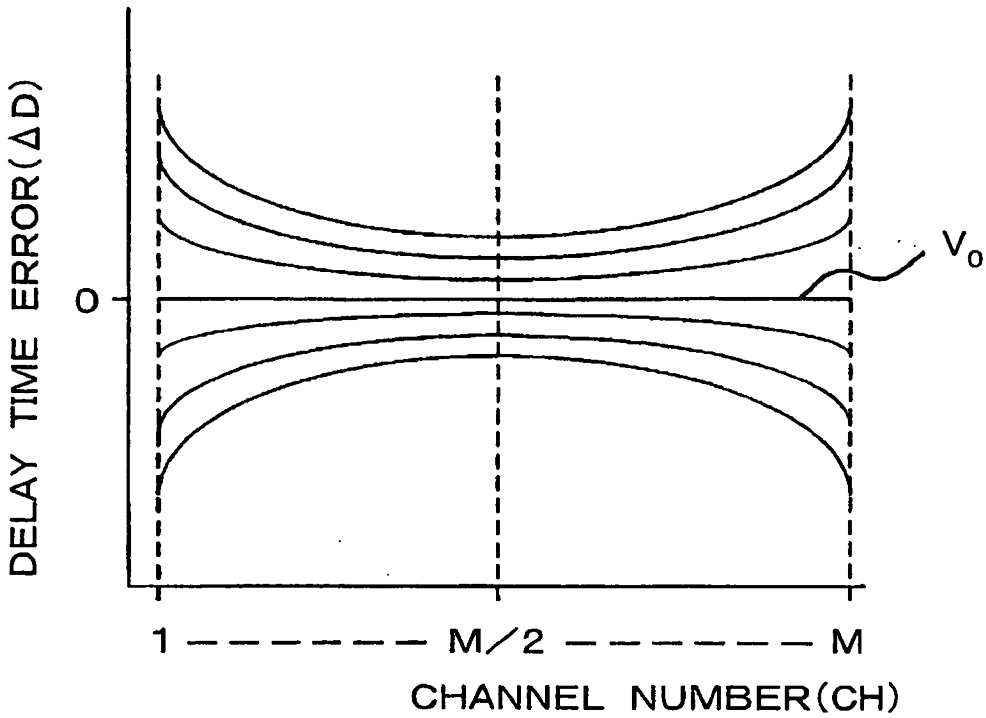
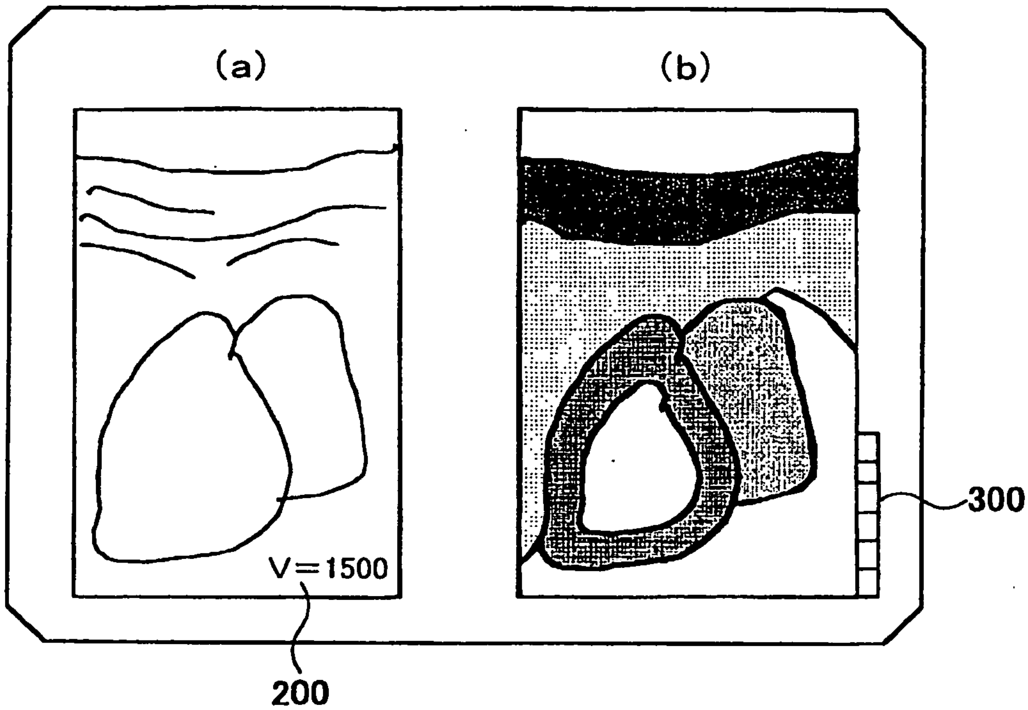


Fig. 5



REFERENCES CITED IN THE DESCRIPTION

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- US 5638820 A **[0010]**
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- JP 10066694 A **[0033]**

专利名称(译)	超声波成像装置		
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[标]申请(专利权)人(译)	株式会社日立医药		
申请(专利权)人(译)	日立医疗器械股份有限公司		
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优先权	2000066764 2000-03-10 JP		
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外部链接	Espacenet		

摘要(译)

本发明的超声波成像装置利用与平均声速相对应的延迟时间对生物体内部进行超声波的临时扫描，通过使用来自每个通道的接收信号计算延迟时间误差检测电路中的延迟时间误差。已经在数字延迟电路中执行了哪个延迟控制，在延迟时间比较单元中将所述计算数据与对应于各种声速的多个延迟时间误差数据进行比较，使用声速作为预先存储在声速导致的延迟中的参数时间误差存储单元，用声速选择单元在那些声速中选择与延迟时间误差数据匹配的声速，并计算生物体内的声速。然后，将所计算的声速反馈到CPU，并且在超声扫描中施加的延迟的延迟数据提供给延迟电路。以这种方式，可以通过简单的计算来计算在介质中传播的超声波速度，并且可以使用与超声波成像装置中的所述速度对应的延迟数据来进行成像。

Fig. 1