(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 652 475 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
31.08.2016 Bulletin 2016/35

(21) Application number: **04745943.3**

(22) Date of filing: **09.06.2004**

(51) Int Cl.:
A61B 8/00 *(2006.01)* ***G01S 15/89*** *(2006.01)*
G01S 7/52 *(2006.01)* ***A61B 8/08*** *(2006.01)*

(86) International application number:
PCT/JP2004/008391

(87) International publication number:
WO 2005/013829 (17.02.2005 Gazette 2005/07)

(54) **ULTRASONOGRAPHIC DEVICE AND ULTRASONOGRAPHIC METHOD**

ULTRASCHALLGERÄT UND ULTRASCHALLVERFAHREN

DISPOSITIF ULTRASONOGRAPHIQUE ET PROCEDE ULTRASONOGRAPHIQUE

(84) Designated Contracting States:
DE FR GB IT NL

(30) Priority: **06.08.2003 JP 2003206184**

(43) Date of publication of application:
03.05.2006 Bulletin 2006/18

(73) Proprietor: **HITACHI MEDICAL CORPORATION**
Tokyo 101-0047 (JP)

(72) Inventors:
- **AZUMA, Takashi,**
  c/o Hitachi, Ltd. Central Research
  Kokubunji-shi, Tokyo 185-8601 (JP)
- **UMEMURA, S.,**
  c/o Hitachi Ltd.,
  Central Research
  Kokubunji-shi, Tokyo 185-8601 (JP)
- **BABA, Hirotaka,**
  c/o Hitachi Medical Corporation
  Chiyoda-ku, Tokyo 101-0047 (JP)

(74) Representative: **Strehl Schübel-Hopf & Partner**
Maximilianstrasse 54
80538 München (DE)

(56) References cited:
WO-A1-03/022153
JP-A- 2002 526 226
JP-A- 2003 135 454
US-B1- 6 464 638
US-B1- 6 511 426

- **KARAMAN M ET AL: "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, DOI: DOI:10.1109/58.710591**
- **O'DONNELL M ET AL: "CORRELATION-BASED ABERRATION CORRECTION IN THE PRESENCE OF INOPERABLE ELEMENTS", IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS AND FREQUENCY CONTROL, IEEE, US, vol. 39, no. 6, 1 November 1992 (1992-11-01), pages 700-707, XP000329678, ISSN: 0885-3010, DOI: DOI:10.1109/58.165554**
- **SHIINA T. ET AL.: 'Strain imaging using combined RF and envelope autocorrelation processing' 1996 IEEE ULTRASONICS SYMPOSIUM 1996, pages 1331 - 1336, XP010217681**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 652 475 B1

Description

Field of the Invention

[0001] The present invention relates to an ultrasonic imaging device used for medical diagnosis or other purposes, and more specifically to a technique for obtaining a high quality tomographic image referred generally to as a compound scan image displayed as one image by synthesizing image signals obtained by scanning a scanned object from various angles.

Description of the Related Art

[0002] The ultrasonic imaging device brings an ultrasonic probe into contact with a surface of a scanned object, transmits ultrasonic waves to the object from the probe, receives reflected waves (echo signals) from the inside of the object, and displays tomographic images showing a state of various sections of the object based on the echo signals, which are used for medical diagnosis or other purposes.

[0003] FIG. 1(A) is a view illustrating the general configuration of an ultrasonic imaging device. Reference numeral 10 indicates an control unit such as a personal computer. Designated at reference numeral 11 is a CPU, at 12 a memory, at 13 a hard disk, at 21 an input device, and at 22 a display device. The devices are connected to each other through a bus 14 for delivery of various types of information between the devices. The hard disk 14 stores therein various types of programs and data required for operations of the ultrasonic imaging device, and the programs and data are read out according to the necessity and stored in the memory 12, and used for operations under control by the CPU 11. The input device is a keyboard, a mouse, or the like, and is used for receiving set-up information required by a user of the ultrasonic imaging device or for outputting operation signals. Various screens including necessary operation screens or a screen showing the results of imaging are displayed on the display device 13.

[0004] Reference numerals 23 and 24 indicate a transmission beam former and a receiving beam former respectively, which are connected to the bus 14 of the control unit 10. Moreover, the transmission beam former 23 and receiving beam former 24 are connected via a transmission/receiving separator 31 to a ultrasonic probe 32. The transmission beam former 23 generates an ultrasonic transmission signal corresponding to a digital signal delivered from the control unit 10 and sends the ultrasonic transmission signal via the transmission/receiving separator 31 to the ultrasonic probe 32 so that an ultrasonic signal corresponding to a program corresponding to the user's operation signal is transmitted from the ultrasonic probe 32. On the other hand, when an echo is received as a reflection wave from inside of the object by the ultrasonic probe 32, a signal corresponding to the received ultrasonic signal is transmitted via the transmission/receiving separator 31 to the receiving beam former 24. The receiving beam former 24 subjects the signal to required processing such as digitalization and sends the processed signal to the control unit 10. The control unit 10 processes the received signal with a program appropriate for the object of imaging, and displays a result of imaging on the display device 13.

[0005] FIG. 1(B) illustrates an example of the ultrasonic probe 32, and in this example, n sets of transducer elements 1-1, 1-2, and 1-3 are arrayed in a linear state in parallel to each other. Although not shown in the figure, wiring is provided for the transducer elements for transmitting a transmission signal from a transmission beam former 23 and also a signal corresponding to a reflected wave from the inside of the object detected by each transducer element to a receiving beam former 24. Furthermore, the ultrasonic probe 32 is an acoustic matching layer 5 made of, for instance, a mixture of metal powder and polymeric materials and an acoustic lens also made of polymeric materials for effectively bringing the transducer elements into contact with the scanned object for efficient transaction of ultrasonic signals with the scanned body. By controlling amplitude of a signal given to each transducer element and timing for transmitting the signal, the focus depth, direction of irradiation and amplitude of the ultrasound irradiated from the ultrasonic probe 32 can be controlled freely, that is, the depth and direction can be controlled as indicated by F_1 - F_1 and F_2 - F_2. Furthermore, to synthesize B mode image data of the object imaged from a plurality of angular directions as described below, for instance, control can be provided so that the beam is oriented to the direction A, B, or C on the focus line F_1 - F_1. Although not shown in the figure, the ultrasonic probe 32 has a handle to be grasped by a user.

[0006] The configuration of the ultrasonic probe 32 is not limited to the example shown in FIG. 1(B), and for any purpose of imaging, the ultrasonic probe 32 may have various forms, for example, in which a plurality of transducer elements are arranged at equal intervals in a linear, curved or planar manner. For instance, a linear scan type of ultrasonic imaging device forms an aperture by selecting a group of transducer elements driving simultaneously with the preset aperture selecting function, and moves the aperture by and by to scan the inside of a sample or an object with a ultrasonic beam. Also the convex scan type of ultrasonic imaging device works similarly.

[0007] In the case of imaging only from one direction, there arise the following defects. Due to the effect of angle-dependent reflectance, only sections vertical to a direction in which the ultrasonic wave propagates within a contour of a reflecting section of the scanned object are imaged with emphasized tone, while sections of a tissue border substantially

parallel to the direction in which the ultrasonic wave propagates are not images substantially at all. In addition, sections in the shadow of a highly reflective body are hardly imaged. In contrast, when there are a plurality of directions in which the ultrasonic waves propagate like in the case of compound imaging, a percentage of ultrasonic waves are introduced in the vertical direction to a border surface of the reflecting body. Therefore, the contour is imaged in a relatively continuous state and is clear with the shadowed sections reduced, which contributes to the improvement of the defects described above.

[0008] A second merit is to be largely effective in removing speckles causing degradation of the contrast resolution. Since images picked up from substantially different angular directions have different speckle patterns, the signal amplitude for a section corresponding to the reflecting section of the scanned object itself increases due to the effect of addition, while the speckle patterns increase only in proportion to a root of the sum. When it is assumed that a number of added factors is N, therefore the contrast resolution is improved in proportion to a root of N.

[0009] Improvement of the contrast resolution as described above can be realized since image synthesis is carried out by converting RF signals to envelope curve signals to make the signals incoherent and then adding the signals. To describe it from the contrary viewpoint, since the signals are made incoherent and then added, improvement of spatial resolution like in the case of addition of coherent signals cannot be expected.

[0010] As a method based on the concept of addition of coherent signals, namely a method of signal synthesis in the state of RF signals, also the synthetic aperture method as disclosed in non-patent document 1 is well known in the art. In the synthetic aperture method, signals from a plurality of different angular directions are added in the coherent state, which provides the effect equivalent to enlargement of the aperture and contributes to an improvement in the spatial resolution.

[0011] In both of the compound imaging method and synthetic aperture method as described above, when the scanned object is a moving one such as a living body, movement of the body occurring between a plurality of times for imaging is troublesome. To solve the problem, in the two known examples, a method is disclosed in which positional displacement between images is estimated by means of correlation method prior to image synthesis to minimize blurring of the image due to movement of a scanned object.

[Patent document 1]

[0012] JP-A 2002-526225

[Non-patent document 1]

[0013] IEEE Transaction on Ultrasonics, Ferroelectrics, and Frequency Control, Volume 45, No. 4, pp. 1077 to 1087

[0014] WO 03/022153 A1 discloses an ultrasonographic apparatus and a corresponding method capable of increasing the S/M ratio of a compound image, since envelope detection is conducted after the echo signals of the ultrasonic transmissions have been synthesized. US 6 464 638 B1 discloses a related ultrasound imaging system. US 6 511 426 B1 discloses an ultrasonic imaging device using compounding of ultrasonic data of a number of two-dimensional image frames each having a different elevation in order to reduces speckles of ultrasound images.

Disclosure of the Invention

[0015] An internal organ of a human body as an object for ultrasonic imaging is not a solid body, and deforms differently from place to place. Therefore, it is difficult to perform idealistic correction for the entire image. Furthermore, influence of positional displacement between synthesized images in the synthetic aperture method is different from that in the compound imaging.

[0016] In the aperture synthesis, there occurs interference between signals to be synthesized, and if there occurs positional displacement larger than a quarter of a wavelength, the signal is degraded after synthesis. On the other hand, in the case of compound imaging, there occurs no interference between signals to be synthesized, so that positional displacement smaller than the width of an envelop of an envelop signal does not cause any signal degradation. Generally in the currently available ultrasonic imaging devices, the width of an envelope is only several times larger than the wavelength.

[0017] Since there are two image synthesis methods currently available, namely the compound imaging method and synthetic aperture method, and the two methods have different merits respectively, there has been a desire for development of an imaging method having the merits provided by the two conventional methods as described above. In other words, the desire is to realize improvement of contrast resolution and improvement of spatial resolution at the same time and also to realize an imaging method in which an image is little degraded due to movement of a scanned object.

[0018] In the currently available ultrasonic imaging devices, a transfer function of the ultrasonic probe 32 is equivalent to a width of several waves on the time axis because the width is limited in the frequency space. In ultrasonic imaging,

influence by a transfer function of the ultrasonic probe 32 occurs twice because of transmission of ultrasonic signal waves from the ultrasonic probe 32 and receiving of ultrasonic waves reflected by a scanned body with the ultrasonic probe 32, and therefore a width of the envelope is in the range from about 2 to 4 waves. In other words, influence caused by movement of a scanned object in the coherent case is around 10 times larger than that in the incoherent case. If a displacement range between synthesized images can idealistically be corrected pixel by pixel, the influence caused by movement of an scanned object could be corrected by any of the two known methods. However, since the corrected value is not always precise because of influences by noises, and there is displacement also in a direction perpendicular to the tomographic image, it is difficult to accurately estimate a local displacement.

[0019] The present invention provides the ultrasonic imaging device according to claim 1 and the ultrasonic imaging method according to claim 2. It is not aimed to perfectly correct a local displacement, and correction is carried out based on the large scale displacement rate. That is to say, when a displacement is small (for instance, smaller than a quarter of a wavelength), signal synthesis is executed based on RF data, and when the displacement is larger, the signal synthesis is carried out based on the envelope detection signals. A degree of each displacement can be determined on recognition of correlation of RF data between images in different frames. Furthermore, any of signal synthesis based on RF data and signal synthesis of envelope detection signals can be selected freely by controlling a reference frequency for heterodyne detection.

Brief Description of the Drawings

[0020]

FIG. 1(A) illustrates a general configuration of a ultrasonic imaging device;
FIG. 1(B) illustrates an example of an ultrasonic probe;
FIG. 2 is a flow chart illustrating a signal processing flow in an ultrasonic imaging device according to a first example of the present invention;
FIG. 3 is a flow chart illustrating a signal processing flow in an ultrasonic imaging device according to an embodiment of the present invention;
FIG. 4 is a flow chart illustrating a signal processing flow in an ultrasonic imaging device according to a second example of the present invention;
FIG. 5(A) is a schematic diagram illustrating three beam propagating directions A, B and C different from each other received by the transmitting/receiving transducer;
FIG. 5(B) is a diagram showing beam patterns of RF signals in the beam propagating directions received by the transmitting/receiving transducer;
FIG. 5(C) is a diagram illustrating beam patterns after envelope detections for RF signals received by the transmitting/receiving transducer;
FIG. 6(A) is a diagram plotted with the horizontal axis indicating a displacement between images in different frames and also with the vertical axis indicating envelope detection carried out according to the displacement and addition based on RF data;
FIG. 6(B) is a diagram illustrating an example of setup curve for setting a reference frequency ω_1 for heterodyne detection;
FIG. 7 is a diagram illustrating distribution of ultrasonic wave signal intensities when the beams in three different directions A, B, and C shown in FIG. 5(B) are subjected to envelope detection to obtain the beam patterns after the envelope detection shown in FIG. 5(C) and then the signals are synthesized;
FIGS. 8(A), 8(B), 8(C), and 8(D) are diagrams illustrating examples of beam patterns showing results of heterodyne detection with the reference frequency ω_1 of the reference wave set to 2 MHz, 1 MHz, 0 MHz, and -1 MHz respectively and also with the central frequency of ultrasonic wave signals ω_0 set to 2 MHz;
FIG. 9(A) is a diagram showing a result of simulation for an image obtained through steps 115, 117 shown in FIG. 2;
FIG. 9(B) is a view showing a result of simulation for an image obtained through steps 119, 120 shown in FIG, 2;
FIGS. 10(A), 10(B), 10(C), and 10(D) are views showing example of images corresponding to those shown in FIGS. 8(A), 8(B), 8(C), and 8(D), respectively; and
FIG. 11 illustrates an appearance of an input device operated by a user to set a frequency of a reference wave in the ultrasonic imaging device according to the second example of the present invention.

Best Mode for Carrying out the Invention

[0021] Preferred embodiments of the present invention and examples useful for its understanding will be described in detail below with reference to the drawings. Each embodiment of the present invention is realized by an ultrasonic imaging device having a control unit as shown in FIGS. 1(A) and 1(B).

(First Example)

[0022] FIG. 2 is a flow chart illustrating a signal processing flow in the ultrasonic imaging device according to a first example of the present invention.

[0023] Reference numeral 101 indicates a preparation step, in which data such as a type of an ultrasonic probe to be used and codes indicating objective portions of an object to be imaged is inputted through an input device 21. Reference numeral 103 indicates a step of specifying the number of image frames to be synthesized for the target portions of the scanned object, in which the data is inputted through the input device 21. The number of frames to be synthesized is at least 3 or more. The number of frames may be in the range from 7 to around 15. As the number of frames to be synthesized increases, effects of image synthesis and defects caused by synthesis increase, and therefore the number of frames should preferably be determined according to an object to be imaged (movement of the object to be imaged).

[0024] Reference numeral 105 indicates a step for setting a direction in which ultrasonic waves are to be transmitted toward a target portion for imaging, in which the data is inputted via the input device 21. The data corresponds to the number of frames to be synthesized, specified in step 103, and the data may automatically be set by a program in response to the number of frames already imaged. Referring to FIG. 1(B), the direction of transmitting ultrasonic waves as used herein indicates each of the different directions A, B, and C transmitted on the plane of the focus F_1 - F_1. In FIG. 5(A), the directions are shown as a square A schematically shown with a solid line, a square B shown with a dot and chain line, and a square C shown with a broken line. That is to say, the squares A, B, and C schematically show the state in which a scanned object is linearly scanned by transmitting ultrasonic beams at the same focus depth and at different angles.

[0025] The reference numeral 107 indicates a step of transmitting and receiving ultrasonic waves for one frame and storing RF data. When the number of imaged frames is specified (step 103) and a direction of transmitting ultrasonic waves is set (step 105), an ultrasonic wave pulse signal corresponding to a program for the target portion to be imaged is generated by the CPU 11. The signal is converted by the transmission beam former 23 to a signal given to transducer elements in the ultrasonic probe 32. The converted signal is then given via the transmission/receiving separator 31 to the transducer elements in the ultrasonic probe 32. The ultrasonic signal reflected from the target portion for imaging is received and converted to an electric signal by transducer elements in the ultrasonic probe 32, and the electric signal is given to the receiving beam former 24 via the transmission/receiving separator 31. In the receiving beam former 24, the electric signal is converted to a digital signal and subjected to phase-aligned addition between channels, and is stored as RF data in the memory 12. Reference numeral 109 indicates a step of evaluating the number of frames already imaged, in which a check is made as to whether or not RF data for transmitted/received signals has been stored by the number of frames specified in step 103. When it is determined that RF data has not been stored by the number of frames specified in step 103, the processing returns to step 105, in which the RF data for transmitted and received ultrasonic signals for one frame in the next signal transmitting direction is stored. When it is determined in step 108 that the number of frames already imaged has been stored by the number specified in step 103, the processing proceeds to data assessment.

[0026] Reference numeral 111 indicates a step of computing correlation of RF data between images for different frames. In this step, image data for the respective frames stored in the memory 12 are sequentially read out to compute the correlation. In other words, an amount of displacement and an amount of deformation are computed by especially checking a specified reflecting portion of a scanned object in each ultrasonic wave transmitting direction on the basis of image data for each frame.

[0027] Reference numeral 113 indicates a step of checking whether or not a deformation rate between images for different frames is greater than a preset value. That is to say, when it is determined that the correlation of RF data between images for different frames computed in step 111 is smaller than the preset value, the RF data for each frame stored in the memory 12 is subjected to envelope detection (step 115), and data synthesis is carried out between images of the different frames based on the data after the envelope detection (step 117). When the correlation value of RF data between images for different frames is greater than the preset value, data synthesis is carried out between images for different frames based on the RF data for each frame stored in the memory 12 (step 121), and the synthesized RF data is subjected to envelope detection (step S121).

[0028] Reference numeral 123 indicates an image display step, in which an image satisfying requirements of a particular program is displayed on the display device 22 based on either one of the data obtained in step 117 or data in step 121. Reference numeral 125 indicates a step of determining whether or not adjustment of the image quality is required. For instance, in the image display step 123, the question of "data re-acquisition required?" and "YES", "NO" switches are displayed at a portion of the screen. When the user is not satisfied with the image displayed on the display device 22 and selects "YES", the processing returns to step 103, and the processing flow is again executed from the necessary setup process. When the user selects "NO", imaging is finished. When imaging is to be carried out again, the conditions for acquiring RF data of transmitted and received ultrasonic signals are changed, for instance, by increasing the number of synthesized images, or by making a change rate of a signal transmitting direction minuter. In the ultrasonic diagnostic

unit, imaging is continued and the screen is continuously updated unless the imaging stop button is pressed. Because of the feature, even when a screen display of inquiring the necessity of data acquisition is not provided, the user can change the setup according to each image or reflect the changed conditions to imaging next time.

[0029] As described above, influence of displacement of target portions included in a scanned object over synthesized signals largely varies between a case of coherent signals such as RF signals and a case of incoherent signals such as envelope detection signals. In the case of incoherent signals, when the displacement is equal to a half of the wavelength or more, the signals cancel each other completely, and the influence can be ignored only when the displacement is not greater than a quarter of the wavelength. In the case of coherent signals, canceling never occurs, and therefore the influence is small when the displacement is not greater than a width of the envelop.

[0030] In the first example of the present invention, in recognition of the point described above, correlation of RF data between images for different frames is computed in step 111, and whether a deformation between images for different frames is larger than a preset value or not is determined in step 113. When a displacement of a target position of a scanned object between images for different frames is larger than the preset value, the signal processing is carried out based on incoherent signals giving smaller influence due to displacement between images for different frames. When displacement of a target position of a scanned object between images for different frames is smaller than the preset value, the signal processing is carried out based on coherent signals.

[0031] A method of computing a deformation based on correlation is described in detail below. In the following descriptions, symbol M indicates the number of data in the depth direction in one frame, and N indicates the number of data in the horizontal direction. Further, it is assumed in the following descriptions that the coordinate values for the depth direction become larger from the shallower positions to the deeper positions, and the coordinate values along the horizontal axis become larger according to a sequential order of a scanned luster. It is also assumed in the following directions that scanning is carried out sequentially in the horizontal direction. In the following descriptions, $I^k_{i,j}$ indicates brightness of a pixel located at the i-th position in the depth direction and j-th position in the horizontal direction in the frame number k, and $A^k_{i,j}$ indicates an amplitude of an RF signal at the same position.

[0032] Assuming that w indicates a size of a window for which correlation is to be computed, the deformation vector $V^k_{i,j}$ based on correlation between two frames at the pixel ij is computed through equations (1) and (2) below. The correlation Cr(k, K+1) is computed through equation (1) below:

$$C_r(k,k+1)=\left(A^k_{i-\frac{w-1}{2},j}\cdots A^k_{i+\frac{w-1}{2},j}\right)*\left(A^{k+1}_{i-\frac{w-1}{2},j}\cdots A^{k+1}_{i+\frac{w-1}{2},j}\right)\text{---}(1)$$

$$C_r(k,k)=\left(A^k_{i-\frac{w-1}{2},j}\cdots A^k_{i+\frac{w-1}{2},j}\right)*\left(A^k_{i-\frac{w-1}{2},j}\cdots A^k_{i+\frac{w-1}{2},j}\right)\text{---}(2)$$

[0033] On the other hand the self correlation Cr(k, k) is computed through equation (2) above.

[0034] The difference between the pixel number imax1 where the correlation Cr (k, K+1) is maximized and the pixel number imax0 where the self correlation cr (k, k) (V = imax0 - imax1) indicates a deformation in the depth direction between a frame k and frame k+1. In the equations above symbol * indicates convolution. In the above descriptions, it is assumed that w is an odd number, but also when w is an even number, computing can be executed similarly by replacing i-(w-1)/2 with i-(w-2)/2 and i+(w-1)/2 with i+w/2.

[0035] In the descriptions above, a local deformation is treated as a one-dimensional program only in the depth direction although the local deformation relates to a two-dimensional vector. The reason is that, because point responses based on transmitted and received ultrasonic pulses are distributed in a narrow area along the depth direction and in a wide direction along the azimuth direction, sampling is executed more finely as compared to the Nyquist frequency of the RF signal wave along the depth direction and more roughly along the azimuth direction. When compared quantitatively, in a case where the sonic velocity is 1500 m/s and the sampling frequency in the depth direction is 50 MHz, the sampling interval in the depth direction is 15 μm. On the other hand, the sampling interval in the azimuth direction is generally equivalent to the element pitch or around a half of the element pitch. Therefore, assuming that the element width is around a half of the central frequency, when the central frequency is 3 MHz, the sampling pitch is around 125 μm, which is about 10 times larger than that in the depth direction. Because of it, when the frame rate is fully higher as compared with a velocity of the scanned object, the deformation may be measured only in the depth direction.

[0036] A window is set for computing correlation for the following two reasons. The first reason is that, when all of data for one luster is used out all at once, it is disadvantageous for scanning an object such as a living thing which can not be treated as a solid object, because the deformation varies according to the depth. Secondly, in the present invention,

correlation is computed between images picked up from different angular directions, and therefore, when a luster is compared to another luster, places can not be matched with each other in the depth direction. However, when a limit is introduced for a window width, it is possible to prevent a luster from being overlapped on another luster within a range of the window. For instance, when a deformation is computed between frames imaged from beam directions different by 5 degrees from each other, if the luster interval is 125 μm and the sampling interval in he depth direction is 15 μm, 125 μm /tan (5 degrees) /15 μm = 95, and therefore when the window width is not more than 95 sampling points, it can be recognized that also the deformation in the azimuth direction is computed based on data acquired at the same position. Needless to say, in this case, the number of a luster as a partner for correlation changes in association with movement of the window.

[0037] After a deformation at the pixel ij is computed as described above, when influence by noises is small, the obtained data may be used as a deformation rate as it is. When the influence by noises is large, however, it is also possible to execute the processing by replacing the value with an average value with, for instance, a low-pass spatial filter.

[0038] When movement of a scanned object is faster as compared to the frame rate, the two-dimensional deformation may be computed by computing a two-dimensional deformation based on the two-dimensional correlation including the azimuth direction, or by integrating the values luster by luster in the depth direction, computing the deformation in the azimuth direction based on correlation of integrated patterns for different frames, and combining the deformation with that in the depth direction described before.

[0039] FIG. 6(A) is a diagram plotted with a displacement between images for frames along the horizontal axis and selection between addition of RF data and envelope detection executed according to the displacement along the vertical axis. In this example, the threshold value for a displacement between images for different frames is a quarter of a wavelength of the ultrasonic wave with the central frequency ω_0. When the displacement between images for different frames is larger than a quarter of the wavelength of the ultrasonic wave with the central frequency ω_0, the signal processing is executed by envelope detection, namely based on the incoherent signals. When the displacement between images for different frames is smaller than a quarter of the wavelength of the ultrasonic wave with the central frequency ω_0, the signal processing is carried out by executing addition based on the RF data and then by envelope detection, namely based on the coherent signals.

[0040] As described above, by selecting signals for image generation in response to a displacement of target portions to be imaged between images for different frames, it is possible to realize the improvements of the contrast resolution and the spatial resolution at the same time for providing an imaging method with low image degradation due to movement of a scanned object.

(Embodiment)

[0041] FIG. 3 is a flow chart illustrating a signal processing flow in an ultrasonic imaging device according to the embodiment of the present invention. In FIG. 3, the same reference numbers are assigned to the corresponding steps in FIG. 2.

[0042] Also in the embodiment, like in the first example, a type of a ultrasonic probe to be used and a target portion of a scanned object are set (step 101), the number of frames to be imaged for image synthesis is specified (step 103), a ultrasonic signal wave transmission direction toward each target portion to be imaged is set (step 105), RF data for transmitted and received ultrasonic signal waves for one frame is stored (step 107), the number of imaged frames is checked (step 109), and the processing sequence is repeated until the number of imaged frames reaches the number of frames specified in step 103. Then correlation of RF data between images for different frames in step 111 is computed.

[0043] Reference numeral 114 indicates a step of setting the reference frequency ω_1 for heterodyne detection, and reference numeral 116 indicates a step of executing the heterodyne direction corresponding to the set reference frequency ω_1. Reference numeral 118 indicates a step of receiving a result of detection in step 116 and synthesizing data after detection of images for different frames. The image display in step 123 and image quality adjustment in step 125 are the same as those described in the first example.

[0044] FIG. 6(B) illustrates an example of setup curve for setting the reference frequency ω_1 for heterodyne detection in step 114. This diagram is plotted with the horizontal axis indicating a displacement between images for different frames with respect to a wavelength of ultrasonic wave with the central frequency ω_0 of the ultrasonic wave and also with the vertical axis indicating a ratio of a frequency after mixing corresponding to the reference frequency determined in response to each displacement to the central frequency ω_0 of the ultrasonic wave. Also in the embodiment, like in the first example, a quarter of a wavelength of ultrasonic wave with the central frequency ω_0 is used as a threshold value for the displacement between images for different frames. In other words, when the displacement between images for different frames is a quarter of the wavelength of ultrasonic wave with the central frequency ω_0, the reference frequency for heterodyne detection is the same as the central frequency ω_0 of the ultrasonic wave. When the displacement between images for different frames is different from a quarter of the wavelength of ultrasonic wave with the central frequency ω_0, the reference frequency is set to the frequency after mixing shown in FIG. 6(B). As a result, only when the displacement

between images for different frames is equal to a quarter of the wavelength of ultrasonic wave with the central frequency ω_0, the signal processing is carried out by envelope detection, namely based on the incoherent signals. On the other hand, when the displacement between images for different frames is different from a quarter of the wavelength of ultrasonic wave with the central frequency ω_0, the reference frequency is selected according to the degree of difference. In addition, heterodyne detection based on the RF data is carried out, and then the signal processing is executed by envelope detection, namely based on the coherent signals.

[0045] In the embodiment, only when the correlation of RF data between images for different frames computed in step 111 is equal to a prespecified threshold value, the reference frequency ω_1 is set to a value equal to the central frequency ω_0 of the ultrasonic wave to execute homodyne detection. In other words, RF data for the received ultrasonic waves is transformed into incoherent signals, and imaging is carried out by envelop detection. When the correlation of RF data between images for different frames is different from the threshold value, the reference frequency ω_1 is set to a value different from the central frequency ω_0 of the ultrasonic wave to execute heterodyne detection.

[0046] The method of executing switching between coherent signals and incoherent signals by means of heterodyne detection in the embodiment is described in more details below.

[0047] FIG. 5(A) is a schematic diagram illustrating three beam propagating directions A, B and C different from each other received by the transmitting/receiving transducer 32. FIG. 5(B) is a diagram showing beam patterns of RF signals in the beam propagating directions received by the transmitting/receiving transducer 32. FIG. 5(C) is a diagram illustrating beam patterns after envelop detections for RF signals received by the transmitting/receiving transducer 32. As clearly understood when FIG. 5(B) is compared to FIG. 5(C), only the intensity signals are strongly displayed and the phase signals are hard to be recognized visually in the beam patterns after envelope detection.

[0048] FIG. 7 illustrates distribution of ultrasonic signal intensities after beam patterns are obtained by executing envelope detection for the beams in the different three directions A, B, and C as shown in FIG. 5(B) and then synthesizing the beam patterns shown in FIG. 5(C). That is, the horizontal direction indicates a spread of ultrasonic signal waves, and the vertical direction indicates the focus depth. FIG. 7 illustrates a case in which the transmitting/receiving transducer 32 is focused to a position with the depth of 50 mm and the spread is $\pm$ 2 degrees at the focus position. The lines extending along the vertical axis indicate a contour of ultrasonic signal intensities.

[0049] The RF signal as shown in FIG. 5(B) can be expressed as a time function F(t) by equation (3) below:

$$F(t) = A(t)\sin(\omega_0) \quad \text{----- (3)}$$

wherein ω_0 indicates a central frequency of the ultrasonic wave signal, and A(t) indicates the envelope.

[0050] There is the homodyne detection as a specific variant of the heterodyne detection for detecting the envelope expressed by F(t).

[0051] Assuming that G(t) indicates a signal obtained by multiplying F(t) by the reference wave sin (ω_1t), the following equation is obtained:

$$G(t) = (1/2)A(t)[\sin\{(\omega_0-\omega_1)t\} + \sin\{(\omega_0+\omega_1)t\}] \quad \text{----- (4)}$$

[0052] Assuming that the frequency ω_1 of the reference wave is equal to the central frequency ω_0 of the ultrasonic signal, when the homodyne detection is executed, the following equation is obtained:

$$G(t) = (1/2)A(t)\sin\{2\omega_0 t\} \quad \text{----- (5)}$$

and therefore, by removing the double harmonic component with the low band pass filter, an envelope signal can be obtained.

[0053] In other words, by executing the homodyne detection as a particular variant of the heterodyne detection executed with the reference signal wave sin(ω_0t) with the frequency which is equal to the central frequency ω_0 of the ultrasonic signal, image synthesis can be executed with the incoherent signals obtained after the envelop detection described in the first example. Specifically, as shown in FIG. 6(B), image synthesis is executed based on the RF signals, namely coherent signals only when a displacement between images for different frames is a specific value (a quarter of a wavelength of the ultrasonic signal with the central frequency in the figure). When the displacement is different from the specific value, the reference frequency ω_1 after heterodyne detection is set to a value different from the central frequency ω_0 of the ultrasonic signal as shown in the figure based on the correlation between RF data as a parameter. With this operation, the coherent signals can be changed successively to incoherent signals, and image synthesis based on both

the incoherent signals and coherent signals can be realized.

[0054] FIG. 8 illustrates how the distribution of ultrasonic wave intensities shown in FIG. 7 changes with reference to the cases in which the central frequency ω_0 of ultrasonic wave is set to 2 MHz and the frequency ω_1 of the reference wave is set to 2 MHz, 1 MHz, 0 MHz, and -1 MHz.

[0055] FIG. 8(A), FIG. 8(B), FIG. 8(C), and FIG. 8(D) show examples of beam patterns indicating the results of heterodyne detection when the frequency ω_1 of the reference wave is set to 2 MHz, 1 MHz, 0 MHz, and -1 MHz. As the beam pattern is thinner (with small spread), the spatial resolution in the azimuth direction is higher, and as the side lobe is stronger, speckle patterns are generated more strongly with the contrast resolution degraded.

[0056] FIG. 8(A) shows a case where the frequency ω_1 of the reference wave is 2 MHz, that is, the frequency after mixing with the reference wave and passing through the low pass filter (a frequency after heterodyne detection) is 0 MHz, and this case corresponds to the envelope detection described in relation to step 115 in the first example. In this example, the contrast resolution is the highest, and the spatial resolution is the lowest. FIG. 8(C) shows a case where the frequency ω_1 of the reference wave is 0 MHz, that is, the frequency after heterodyne detection is 2 MHz, and therefore this case corresponds to detection of received RF signals, in other words to the envelope detection after synthesis of RF data in step 119 in the first example. FIG. 8(B) shows a case where the frequency ω_1 of the reference wave is 1 MHz, that is, the frequency after heterodyne detection is 1 MHz, and therefore an intermediate state between those shown in FIGS. 8(A) and 8(C) is obtained. FIG. 8(D) shows a case where the frequency ω_1 of the reference wave is -1 MHz, that is, the frequency after heterodyne detection is 3 MHz (the reference wave has a phase reverse to that shown in FIG. 8(B)), and in this case, the spatial resolution is highest, and the contrast resolution is low.

[0057] In other words, it can be understood also from the forms of the beam patterns that coherent signals can successively be changed to incoherent signals, and FIGS. 9 and 10 show examples of screens displaying the image after synthesis.

[0058] FIG. 9(A) shows an example of a result of simulation for an image obtained through steps 115 and 117 shown in FIG. 2, while FIG. 9(B) shows an example of a result of simulation for an image obtained through steps 119 and 120 shown in FIG. 2. This case shows an example of a result of simulation for imaging a portion of a human body in which a blood vessel not reflecting ultrasonic waves is present with the size of 5 cm x 5 cm. A black portion at a central lower section corresponds to the blood vessel, while the peripheral portion corresponds to the body. White dots on the left side and in the upper edge section are images of dot-like reflecting bodies. As understood from comparison of FIG. 9(A) to FIG. 9(B), the image obtained by synthesis in the state of RF signals in FIG. 9(B) shows the higher spatial resolution.

[0059] FIGS. 10(A) to 10(D) show examples of images corresponding to those shown in FIGS. 8(A) to (D), respectively, which are results of simulation executed in the same way as shown in FIGS. 9(A) and 9(B). FIG. 10(A) shows a case in which the frequency ω_1 of the reference wave is 2 MHz as with the case shown in FIG. 9(A) corresponding to the envelope detection described above. FIG. 10(C) shows a case in which the frequency of the reference wave is 0 MHz, and this case corresponds to detection of received RF signal which is the same as the envelope detection shown in FIG. 9(B) after synthesis of RF data in step 119 in the first example. FIG. 10(B) shows case in which, as with the case shown in FIG. 8(B), the frequency ω_1 of the reference wave is 1 MHz, and therefore a result indicating an intermediate state between those shown in FIGS. 10(A) and 10(C) is obtained. FIG. 10(D) shows a case in which, as with the case shown in FIG. 8(D), the frequency ω_1 of the reference wave is -1 MHz (the reference wave has a phase reverse to that shown in FIG. 7(B)), and therefore the spatial resolution is the most excellent, while the contrast resolution is low.

(Second Example)

[0060] FIG. 4 is a flow chart illustrating a signal processing flow in an ultrasonic imaging device according to a second example of the present invention. In FIG. 4, the same reference numerals are assigned to the steps of executing the same processing steps shown in FIG. 2 or 3.

[0061] In the embodiment, a reference frequency for heterodyne detection is automatically selected according to correlation of RF data between images for different frames (step 114). In the second example, however, a user can change the reference frequency for heterodyne detection based on the user's policy in step 104, which is the only difference from the second embodiment. Other processing steps are the same as those shown in the processing flow shown in FIG. 3.

[0062] FIG. 11 shows an appearance of an input device operated by a user in step 104 in the second example. Reference numeral 51 indicates an operation button, which can be moved in the horizontal direction along a travel guide 52. Reference numeral 53 indicates a display section. In this example, a volume type of operation button which can linearly be moved is shown. For instance, the displays 0 - 3 indicate positions for specifying the reference frequencies for obtaining images corresponding to FIGS. 10 (A) to (D), respectively. In other words, operation of the operation button 51 indicates setting of the reference frequency ω_1 for heterodyne detection corresponding to FIG. 6(B). In this case, the user can accumulate knowledge as to how the obtained image changes according to an object or a disease to be checked through experiences, so that the user can determine which of the contrast resolution and spatial resolution should come

first case by case.

[0063] In the descriptions above, the number of images to be synthesized is three, but the number may be made larger. In this case, it is possible to synthesize a coherent image using a portion of the images and synthesize an incoherent image using the remaining images, and also to obtain an image by mixing the coherent and incoherent images.

[0064] The present invention enables an improvement in spatial resolution by synthesis when an object for scanning moves only a little, and also enables an improvement in contrast resolution even when the object largely moves. In other words, the present invention makes it possible to obtain an image with a good balance between the contrast resolution and spatial resolution according to a positional displacement between images to be synthesized. Further the present invention makes it possible to acquire an image with a good balance between the contrast resolution and spatial resolution according to an object to be imaged, or according to selection by the user.

Claims

1. An ultrasonic imaging device comprising:

a control unit (10) adapted to sequentially send digital control signals to a transmission beam former (23) for forming ultrasonic transmission beams one after another to irradiate a plane of an object from plural angular directions via an ultrasonic probe (32) and to receive processed signals from a receiving beam former (24); wherein
the transmission beam former (23) is adapted to form a set of ultrasonic transmission signals in response to the digital control signals;
the ultrasonic probe (32) is adapted to receive the ultrasonic transmission signals from the transmission beam former (23) via a transmission/receiving separator (31), to irradiate the ultrasonic transmission beams to the object; and to detect echo signals of the irradiation of each of the ultrasonic transmission beams;
the receiving beam former (24) is adapted to align phases of the echo signals and to form sets of processed signals;
wherein the control unit (10) is adapted to

store a first set of processed signals as RF data of a first frame which represents the plane of the object irradiated with ultrasonic transmission beams from a first angular direction;
change the angular direction of ultrasonic transmission beams to a second angular direction to receive a second set of processed signals;
store the second set of processed signals as RF data of a second frame which represents the plane of the object irradiated with the ultrasonic transmission beams from the second angular direction;
compute correlation of RF data between the first frame and the second frame which indicates a degree of displacement of the object;
mix each of the first and second set of the processed signals with a reference signal having a frequency, which is selected from a first frequency equal to the center frequency of the transmission signals, a second frequency equal to zero, and a third frequency different to the first and the second frequency according to a result of the computation for the correlation;
perform a synthesis of the mixed data derived from the first set of the processed signals and the mixed data from the second set of the processed signals to obtain image data representing a synthesised B-mode image, the synthesis being an incoherent synthesis when the reference frequency is equal to the center frequency of the transmission signals, a coherent synthesis when the reference frequency is zero or a synthesis, which lies between the incoherent and the coherent one, when the reference frequency is different to the first and the second frequency; and
display the synthesised B-mode image data on a display device (22).

2. An ultrasonic imaging method comprising the steps of:

transmitting ultrasonic beams from an ultrasonic probe (32) to a plane of an object from a first angular direction by driving the ultrasonic probe (32) with a set of ultrasonic transmission signals;
receiving echo signals reflected from the object and forming a first set of processed signals;
storing the first set of processed signals as RF data of a first frame which represents the plane of the object irradiated with ultrasonic transmission beams from the first angular direction;
changing the angular direction of irradiation to a second angular direction;
transmitting ultrasonic beams from the ultrasonic probe (32) to the plane of the object from the second angular

direction;
receiving the ultrasonic signals reflected from the object and forming a second set of processed signals;
storing the second set of processed signals as RF data of a second frame which represents the plane of the object irradiated with ultrasonic transmission beams from the second angular direction;
computing correlation of RF data between the first frame and the second frame which indicates a degree of displacement of the object;
mixing each of the first and the second set of the processed signals with a reference signal having a frequency which is selected from a first frequency equal to the center frequency of the transmission signals, a second frequency equal to zero, and a third frequency different to the first and the second frequency according to a result of the computation for the correlation;
synthesising the mixed data derived from the first set of the processed signals and the mixed data derived from the second set of the processed signals to obtain image data representing a synthesised B-mode image, wherein the synthesising performs an incoherent synthesis when the reference frequency is equal to the center frequency of the transmission signals, a coherent synthesis when the reference frequency is zero or a synthesis, which lies between the incoherent and the coherent one when the reference frequency is different to the first and the second frequency; and
displaying the synthesised B-mode image on a display device.

Patentansprüche

1. Ultraschall-Bildgebungsgerät, umfassend:

eine Steuereinheit (10), die dazu ausgelegt ist, sequentiell digitale Steuersignale an eine Transmissionsstrahlbildungseinrichtung (23) zum Bilden von aufeinanderfolgenden Ultraschalltransmissionsstrahlen zum Bestrahlen einer Ebene eines Objekts aus mehreren Winkelrichtungen über eine Ultraschallsonde (32) zu senden und verarbeitete Signale von einer Empfangsstrahlbildungseinrichtung (24) zu empfangen; wobei
die Transmissionsstrahlbildungseinrichtung (23) dazu ausgelegt ist, einen Satz von Ultraschalltransmissionssignalen auf die digitalen Steuersignale hin zu bilden;
die Ultraschallsonde (32) dazu ausgelegt ist, die Ultraschalltransmissionssignale von der Transmissionsstrahlbildungseinrichtung (23) über eine Transmissions-/Empfangstrennungseinrichtung (31) zu empfangen, das Objekt mit den Ultraschalltransmissionsstrahlen zu bestrahlen und Echosignale der Bestrahlung mit jedem der Ultraschalltransmissionsstrahlen zu detektieren;
die Empfangsstrahlbildungseinrichtung (24) dazu ausgelegt ist, Phasen der Echosignale aneinander auszurichten und Sätze verarbeiteter Signale zu bilden;

wobei die Steuereinheit (10) zu Folgendem ausgelegt ist:

einen ersten Satz verarbeiteter Signale als Hochfrequenzdaten eines ersten Frames, der die Ebene des mit Ultraschalltransmissionsstrahlen bestrahlten Objekts aus einer ersten Winkelrichtung darstellt, zu speichern;
die Winkelrichtung der Ultraschalltransmissionsstrahlen auf eine zweite Winkelrichtung zum Empfangen eines zweiten Satzes verarbeiteter Signale zu ändern;
den zweiten Satz verarbeiteter Signale als Hochfrequenzdaten eines zweiten Frames, der die Ebene des mit den Ultraschalltransmissionsstrahlen bestrahlten Objekts aus der zweiten Winkelrichtung darstellt, zu speichern;
Korrelation von Hochfrequenzdaten zwischen dem ersten und dem zweiten Frame, die einen Verschiebungsgrad des Objekts angibt, zu berechnen;
sowohl den ersten als auch den zweiten Satz der verarbeiteten Signale mit einem Referenzsignal mit einer Frequenz, die aus einer der zentralen Frequenz der Transmissionssignale gleichen ersten Frequenz, einer zweiten Frequenz, die gleich Null ist, und einer von der ersten und der zweiten Frequenz verschiedenen dritten Frequenz gemäß einem Berechnungsergebnis der Korrelation ausgewählt ist, zu mischen;
eine Synthese der vom ersten Satz der verarbeiteten Signale stammenden gemischten Daten und der gemischten Daten vom zweiten Satz der verarbeiteten Signale durchzuführen, um Bilddaten zu erhalten, die ein synthetisiertes B-Mode-Bild darstellen, wobei die Synthese eine inkohärente Synthese ist, wenn die Referenzfrequenz gleich der zentralen Frequenz der Transmissionssignale ist, eine kohärente Synthese ist, wenn die Referenzfrequenz Null ist, oder eine Synthese ist, die zwischen der inkohärenten und der kohärenten liegt, wenn die Referenzfrequenz von der ersten und der zweiten Frequenz verschieden ist; und
die synthetisierten B-Mode-Bilddaten auf dem Anzeigegerät (22) anzuzeigen.

2. Ultraschallbildgebungsverfahren, umfassend die folgenden Schritte:

Transmittieren von Ultraschallstrahlen aus einer Ultraschallsonde (32) auf eine Ebene eines Objekts aus einer ersten Winkelrichtung durch Ansteuern der Ultraschallsonde (32) mit einem Satz von Ultraschalltransmissionssignalen;
Empfangen von vom Objekt reflektierten Echosignalen und Bilden eines ersten Satzes verarbeiteter Signale;
Speichern des ersten Satzes verarbeiteter Signale als Hochfrequenzdaten eines ersten Frames, der die Ebene des mit Ultraschalltransmissionsstrahlen bestrahlten Objekts aus der ersten Winkelrichtung darstellt;
Ändern der Winkelrichtung der Bestrahlung auf eine zweite Winkelrichtung;
Transmittieren von Ultraschallstrahlen aus der Ultraschallsonde (32) auf die Ebene des Objekts aus der zweiten Winkelrichtung;
Empfangen der vom Objekt reflektierten Ultraschallsignale und Bilden eines zweiten Satzes verarbeiteter Signale;
Speichern des zweiten Satzes verarbeiteter Signale als Hochfrequenzdaten eines zweiten Frames, der die Ebene des mit Ultraschalltransmissionsstrahlen bestrahlten Objekts aus der zweiten Winkelrichtung darstellt;
Berechnen von Korrelation von Hochfrequenzdaten zwischen dem ersten und dem zweiten Frame, die einen Verschiebungsgrad des Objekts angibt;
Mischen sowohl des ersten als auch des zweiten Satzes der verarbeiteten Signale mit einem Referenzsignal mit einer Frequenz, die aus einer der zentralen Frequenz der Transmissionssignale gleichen ersten Frequenz, einer zweiten Frequenz, die gleich Null ist, und einer von der ersten und der zweiten Frequenz verschiedenen dritten Frequenz gemäß einem Berechnungsergebnis für die Korrelation ausgewählt wird;
Synthetisieren der vom ersten Satz der verarbeiteten Signale stammenden gemischten Daten und der vom zweiten Satz der verarbeiteten Signale stammenden gemischten Daten, um Bilddaten zu erhalten, die ein synthetisiertes B-Mode-Bild darstellen, wobei bei der Synthetisierung eine inkohärente Synthese ausgeführt wird, wenn die Referenzfrequenz gleich der zentralen Frequenz der Transmissionssignale ist, eine kohärente Synthese ausgeführt wird, wenn die Referenzfrequenz Null ist, oder eine Synthese ausgeführt wird, die zwischen der inkohärenten und der kohärenten liegt, wenn die Referenzfrequenz von der ersten und der zweiten Frequenz verschieden ist; und
Anzeigen des synthetisierten B-Mode-Bildes auf dem Anzeigegerät.

Revendications

1. Dispositif d'imagerie échographique, comportant :

une unité de commande (10) conçue pour envoyer séquentiellement des signaux numériques de commande à un conformateur (23) de faisceaux d'émission pour former l'un après l'autre des faisceaux d'ultrasons d'émission afin d'irradier un plan d'un sujet depuis plusieurs directions via une sonde échographique (32) et de recevoir des signaux traités issus d'un conformateur (24) de faisceaux de réception ; dans lequel
le conformateur (23) de faisceaux d'émission est conçu pour former une série de signaux échographiques d'émission en réponse aux signaux numériques de commande ;
la sonde échographique (32) est conçue pour recevoir les signaux échographiques d'émission issus du conformateur (23) de faisceaux d'émission via un séparateur d'émission/réception (31) afin d'irradier le sujet avec les faisceaux d'ultrasons d'émission ; et pour détecter des signaux d'échos de l'irradiation par chacun des signaux échographiques d'émission ;
le conformateur (24) de faisceaux de réception est conçu pour aligner des phases des signaux d'échos et former des séries de signaux traités ;
l'unité de commande (10) étant conçue pour

stocker une première série de signaux traités en tant que données RF d'une première trame qui représente le plan du sujet irradié depuis une première direction angulaire par les faisceaux échographiques d'émission ;
modifier la direction angulaire de faisceaux échographiques d'émission pour leur donner une seconde direction angulaire afin de recevoir une seconde série de signaux traités ;
stocker la seconde série de signaux traités en tant que données RF d'une seconde trame qui représente le plan du sujet irradié depuis la seconde direction angulaire par les faisceaux échographiques d'émission ;
calculer une corrélation de données RF entre la première trame et la seconde trame, qui indique un degré de déplacement du sujet ;

mélanger chacune des première et seconde séries des signaux traités avec un signal de référence ayant une fréquence, laquelle est choisie parmi une première fréquence égale à la fréquence centrale des signaux d'émission, une deuxième fréquence égale à zéro et une troisième fréquence différente de la première et de la deuxième fréquences en fonction d'un résultat du calcul pour la corrélation ;
réaliser une synthèse des données mélangées dérivées de la première série des signaux traités et des données mélangées de la seconde série des signaux traités afin d'obtenir des données d'image représentant une image de synthèse en mode B, la synthèse étant une synthèse non-cohérente si la fréquence de référence est égale à la fréquence centrale des signaux d'émission, une synthèse cohérente si la fréquence de référence est nulle, ou une synthèse intermédiaire entre les formes non-cohérente et cohérente si la fréquence de référence est différente des première et seconde fréquences ; et
afficher sur un dispositif d'affichage (22) les données de l'image de synthèse en mode B.

2. Procédé d'échographie comportant les étapes de :

émission de faisceaux d'ultrasons depuis une sonde échographique (32) jusqu'à un plan d'un sujet depuis une première direction angulaire en entraînant la sonde échographique (32) avec une série de signaux échographiques d'émission ;
réception de signaux d'échos réfléchis par le sujet et formation d'une première série de signaux traités ;
stockage de la première série de signaux traités en tant que données RF d'une première trame qui représente le plan du sujet irradié depuis la première direction angulaire par les faisceaux échographiques d'émission :

modification de la direction angulaire d'irradiation pour en faire une seconde direction angulaire ;
émission de faisceaux d'ultrasons depuis la sonde échographique (32) jusqu'au plan du sujet depuis la seconde direction angulaire ;
réception des signaux échographiques réfléchis par le sujet et formation d'une seconde série de signaux traités ;
stockage de la seconde série de signaux traités en tant que données RF d'une seconde trame qui représente le plan du sujet irradié depuis la seconde direction angulaire par les faisceaux échographiques d'émission ;
calcul d'une corrélation de données RF entre la première trame et la seconde trame, qui indique un degré de déplacement du sujet ;
mélange de chacune des première et seconde séries des signaux traités avec un signal de référence ayant une fréquence, laquelle est choisie parmi une première fréquence égale à la fréquence centrale des signaux d'émission, une deuxième fréquence égale à zéro et une troisième fréquence différente de la première et de la deuxième fréquences en fonction d'un résultat du calcul pour la corrélation ;
réalisation d'une synthèse des données mélangées dérivées de la première série des signaux traités et des données mélangées dérivées de la seconde série des signaux traités afin d'obtenir des données d'image représentant une image de synthèse en mode B, la réalisation de la synthèse aboutissant à une synthèse non-cohérente si la fréquence de référence est égale à la fréquence centrale des signaux d'émission, à une synthèse cohérente si la fréquence de référence est nulle, ou à une synthèse intermédiaire entre les formes non-cohérente et cohérente si la fréquence de référence est différente des première et seconde fréquences ; et
l'affichage, sur un dispositif d'affichage, des données de l'image de synthèse en mode B.

FIG. 1

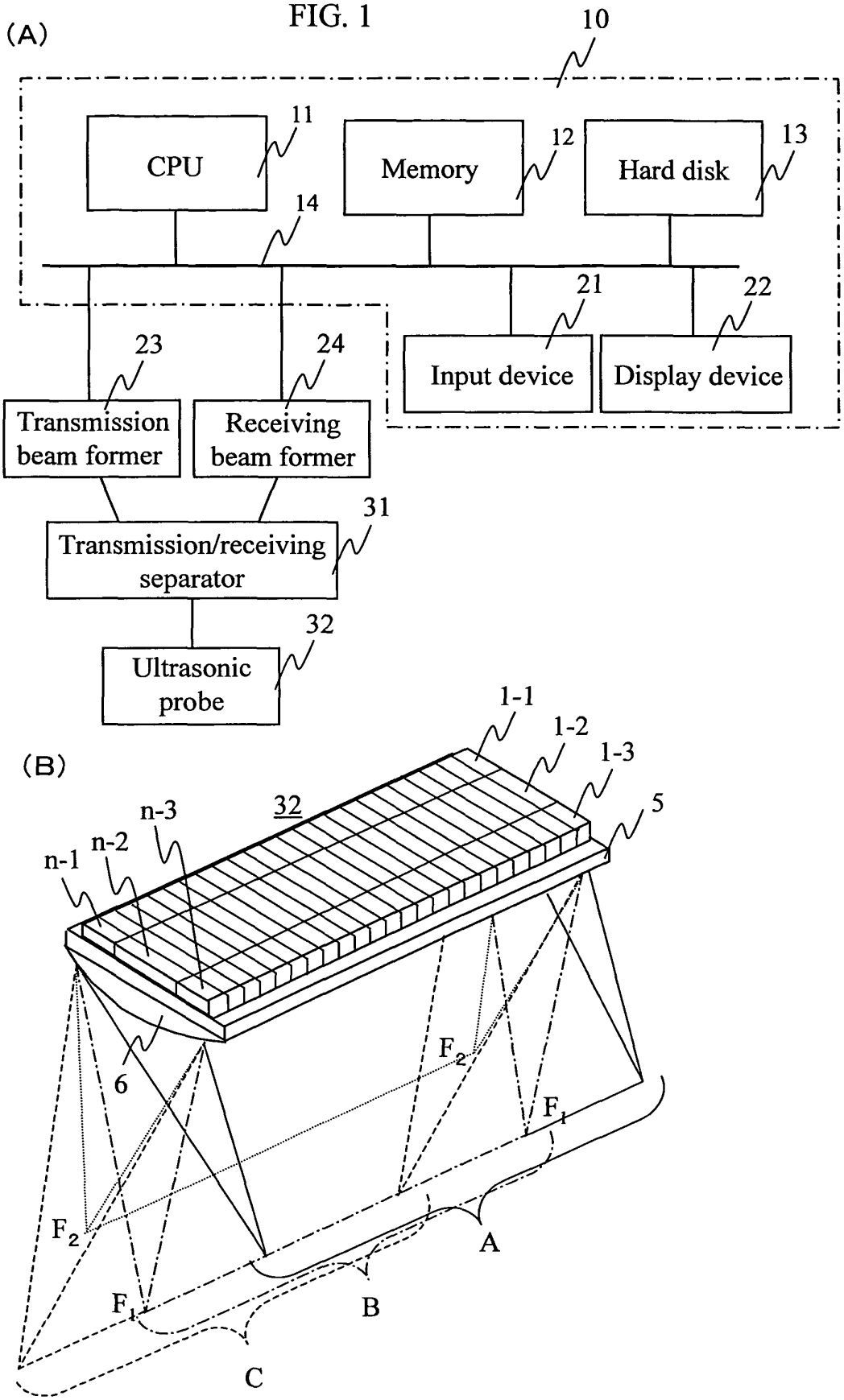

(A)
10
CPU
11
Memory
12
Hard disk
13
14
21
22
23
24
Input device
Display device
Transmission beam former
Receiving beam former
31
Transmission/receiving separator
32
Ultrasonic probe
(B)
1-1
1-2
1-3
5
n-3
32
n-2
n-1
6
F2
F1
A
B
C

FIG. 2

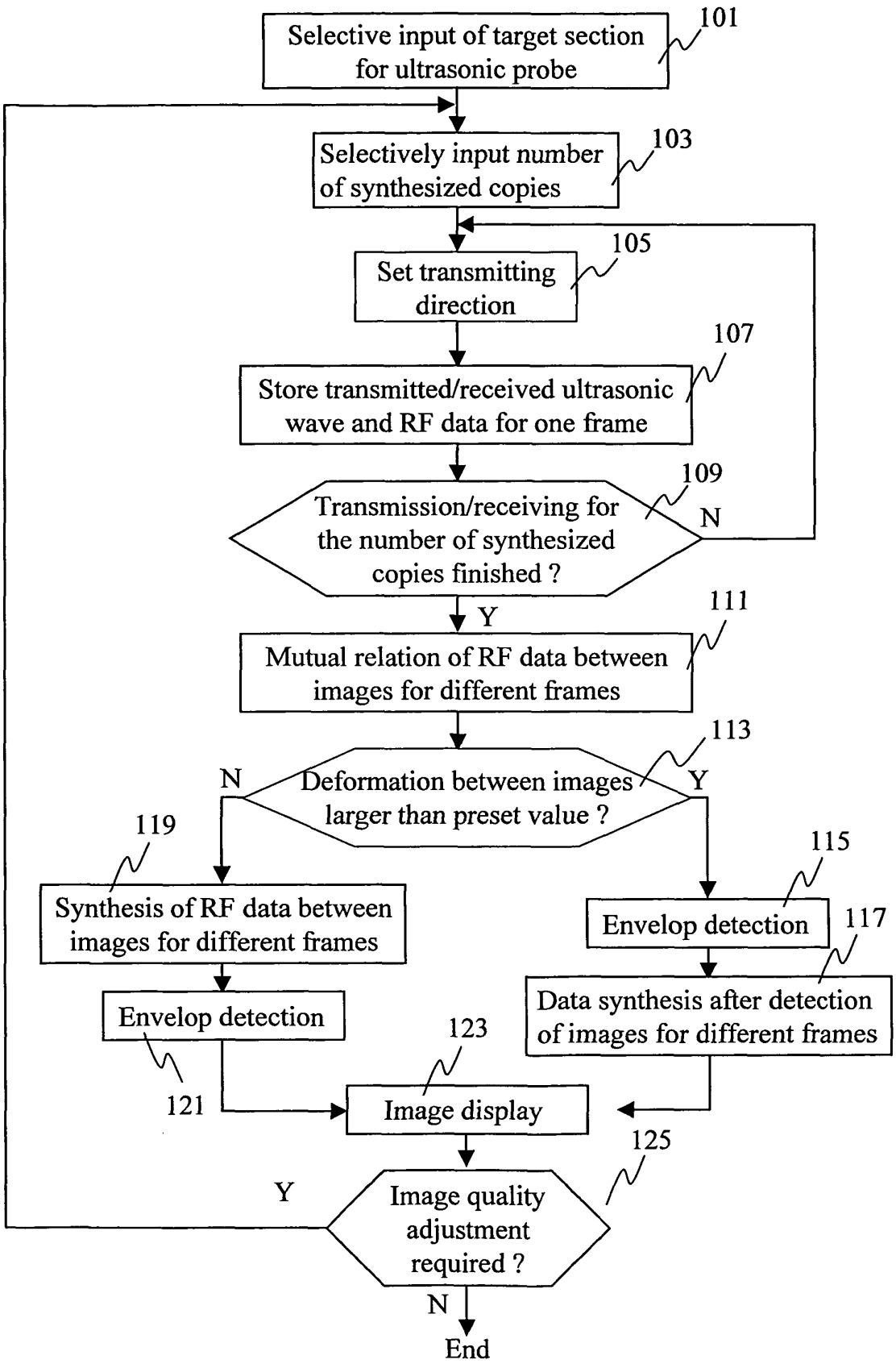

Selective input of target section for ultrasonic probe
101
Selectively input number of synthesized copies
103
Set transmitting direction
105
Store transmitted/received ultrasonic wave and RF data for one frame
107
Transmission/receiving for the number of synthesized copies finished ?
109
N
Y
Mutual relation of RF data between images for different frames
111
Deformation between images larger than preset value ?
113
N
Y
Synthesis of RF data between images for different frames
119
Envelop detection
121
Envelop detection
115
Data synthesis after detection of images for different frames
117
Image display
123
Image quality adjustment required ?
125
Y
N
End

FIG. 3

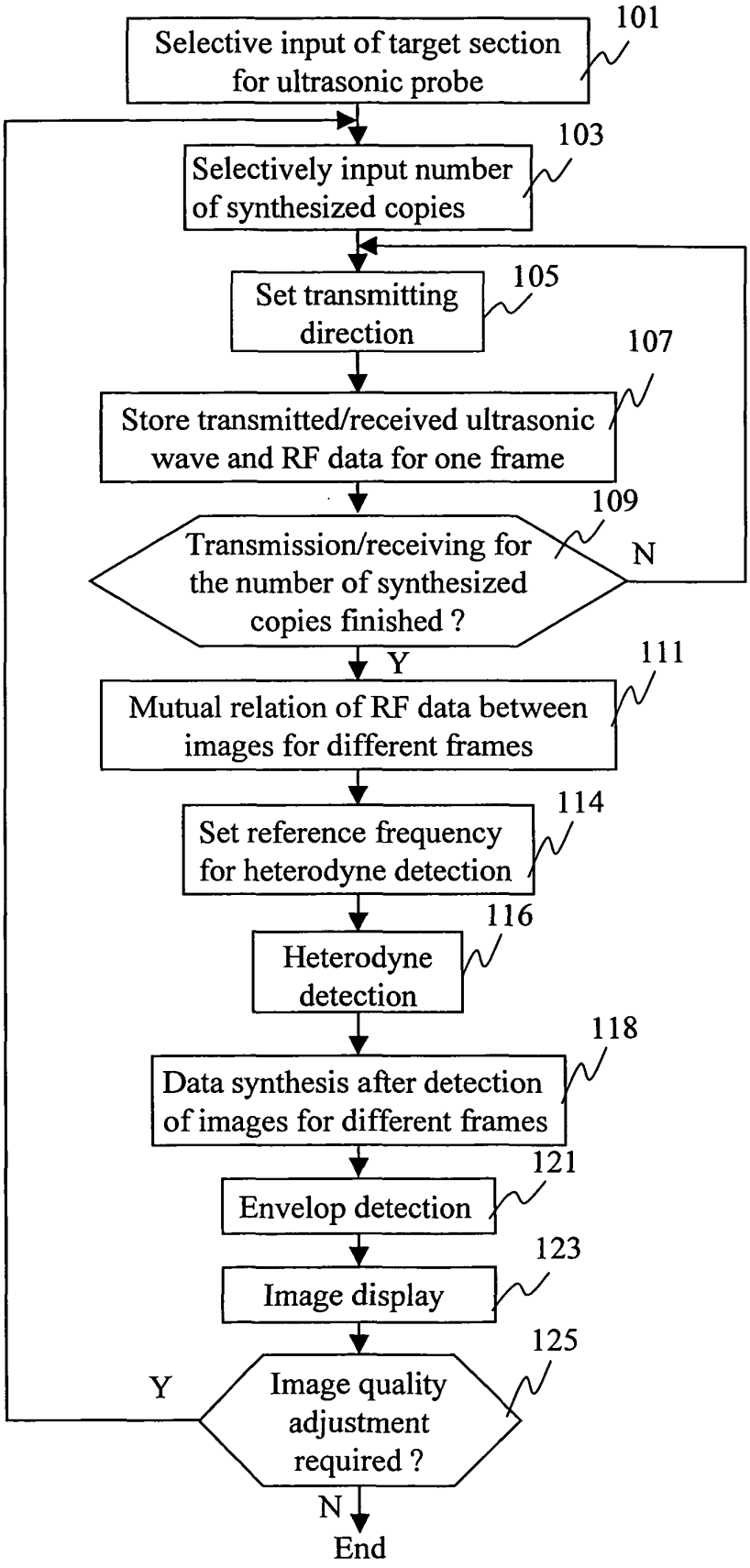

Selective input of target section for ultrasonic probe
101
Selectively input number of synthesized copies
103
Set transmitting direction
105
Store transmitted/received ultrasonic wave and RF data for one frame
107
Transmission/receiving for the number of synthesized copies finished ?
109
N
Y
Mutual relation of RF data between images for different frames
111
Set reference frequency for heterodyne detection
114
Heterodyne detection
116
Data synthesis after detection of images for different frames
118
Envelop detection
121
Image display
123
Image quality adjustment required ?
125
Y
N
End

FIG. 4

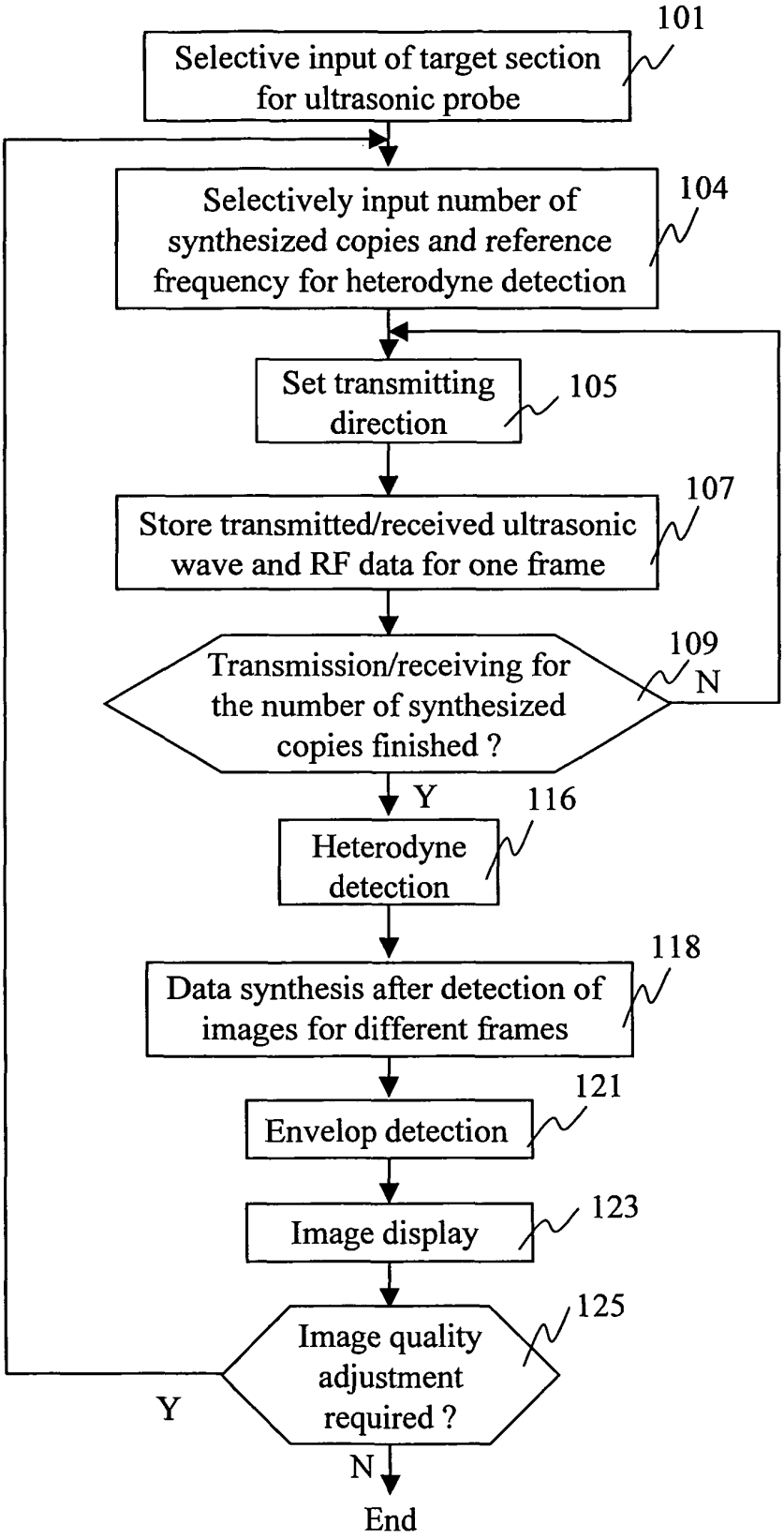

101
Selective input of target section for ultrasonic probe
104
Selectively input number of synthesized copies and reference frequency for heterodyne detection
Set transmitting direction
105
107
Store transmitted/received ultrasonic wave and RF data for one frame
109
Transmission/receiving for the number of synthesized copies finished ?
N
Y
116
Heterodyne detection
118
Data synthesis after detection of images for different frames
121
Envelop detection
123
Image display
125
Image quality adjustment required ?
Y
N
End

FIG. 5

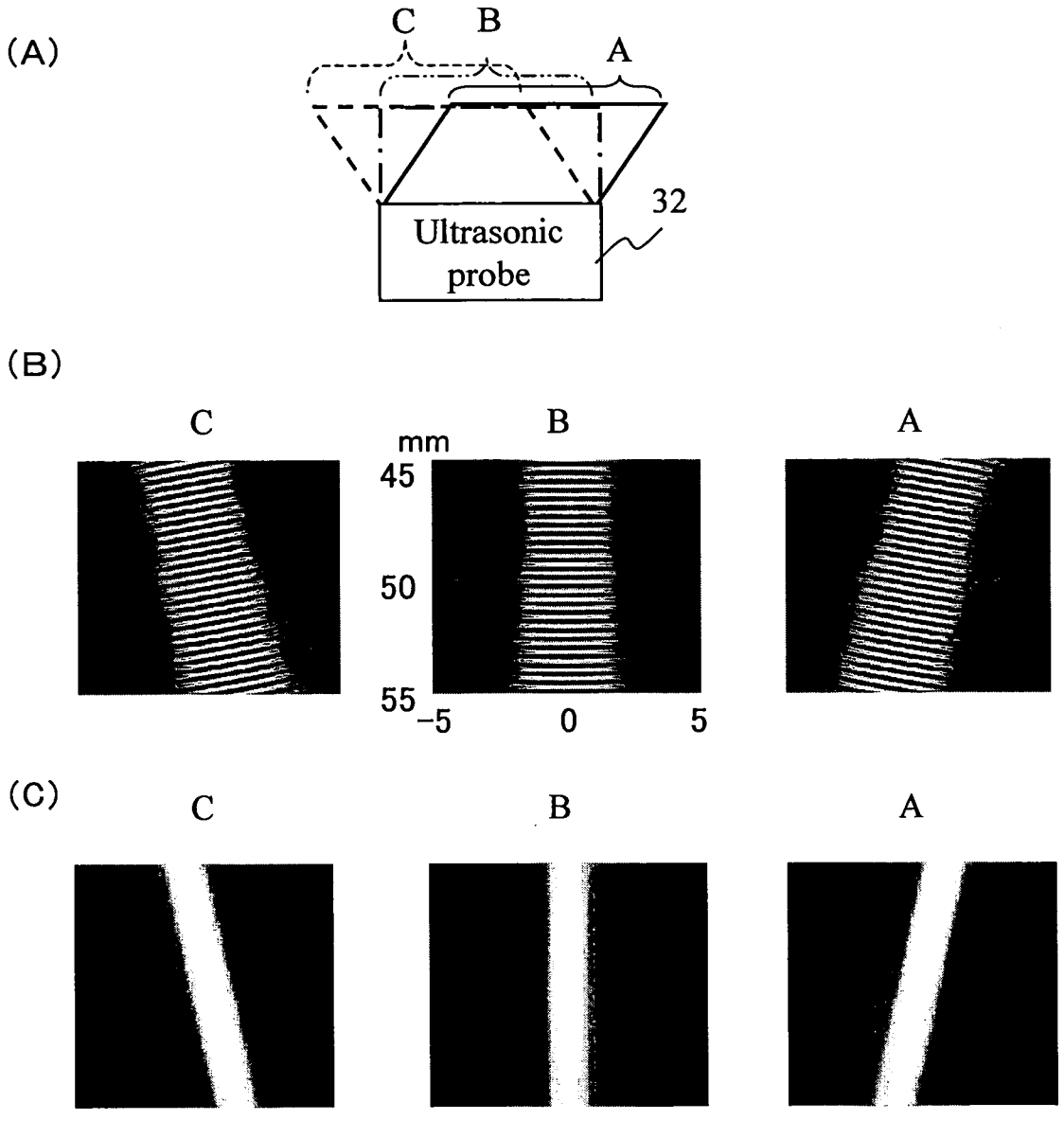


FIG. 6

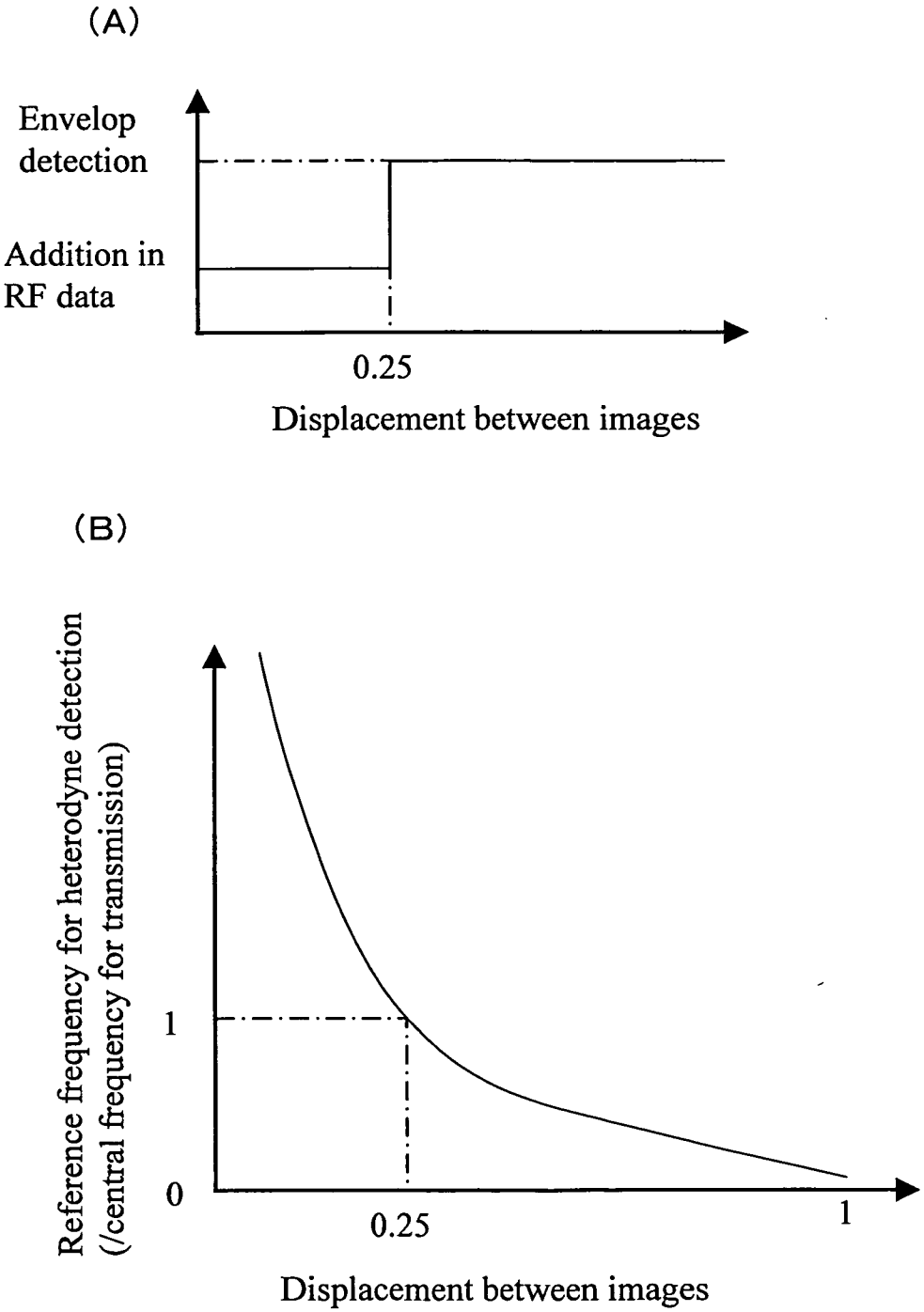

(A)
Envelop detection
Addition in RF data
0.25
Displacement between images
(B)
Reference frequency for heterodyne detection (/central frequency for transmission)
1
0
0.25
1
Displacement between images

FIG. 7

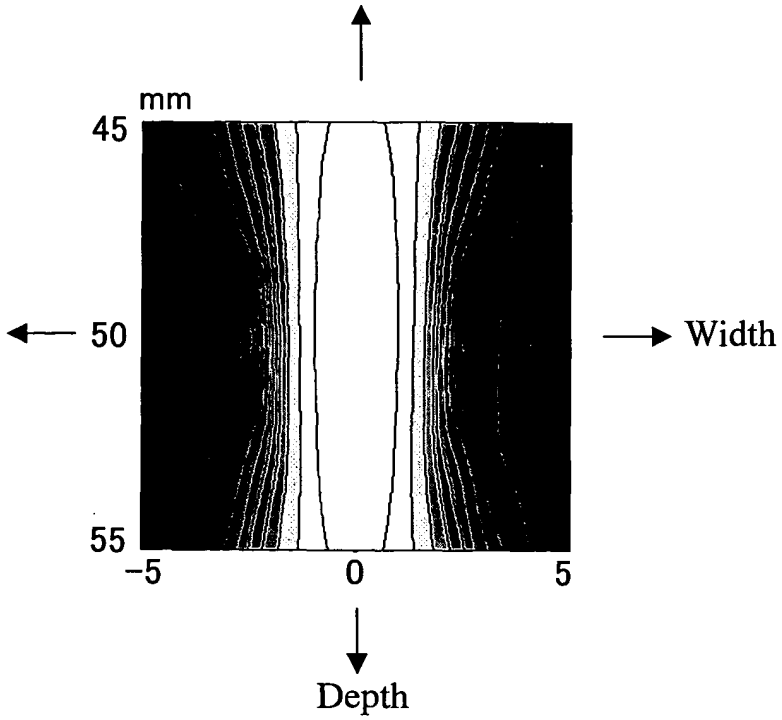

mm
45
50
55
−5
0
5
Width
Depth

FIG. 8

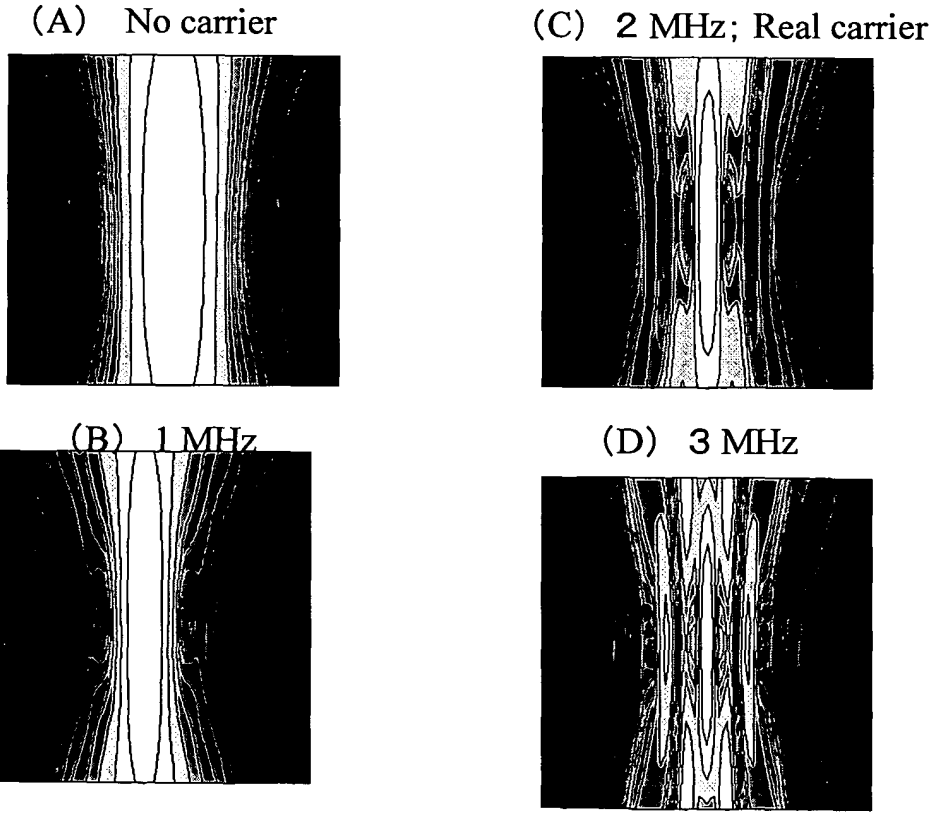
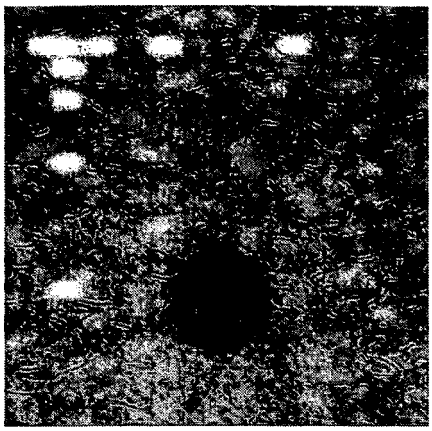

(A) No carrier
(C) 2 MHz; Real carrier
(B) 1 MHz
(D) 3 MHz

FIG. 9

(A) Addition after envelop detection



(B) Addition in RF data

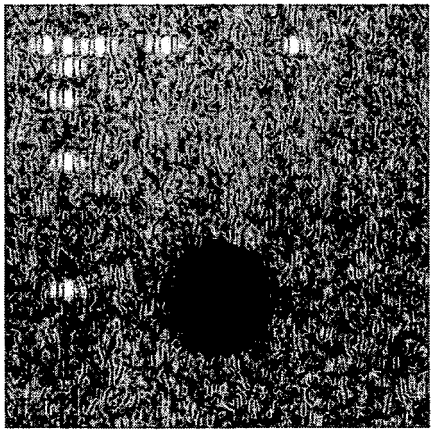
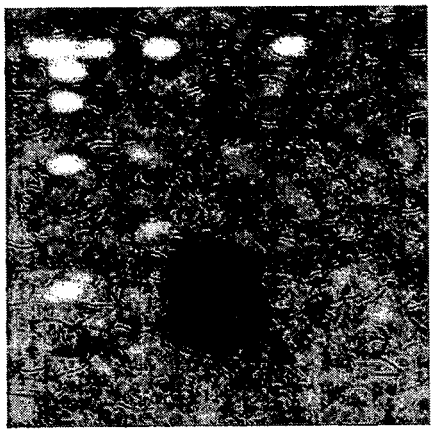
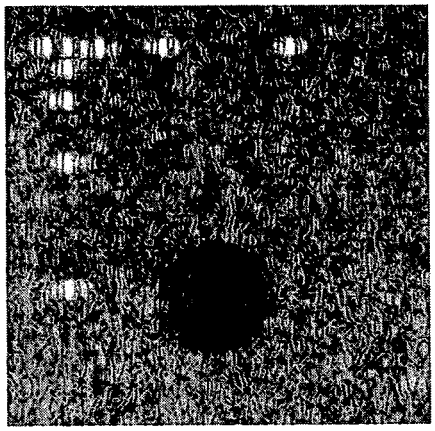


FIG. 10

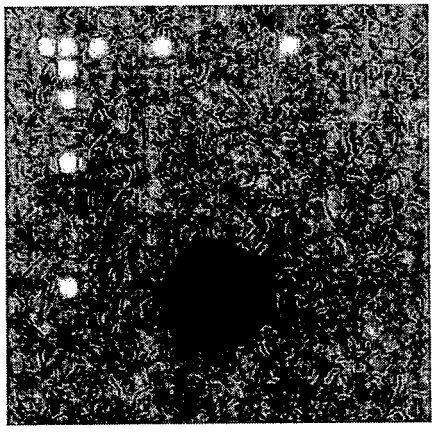
(A) No carrier



(C) 2 MHz; Real carrier



(B) 1 MHz



(D) 3 MHz

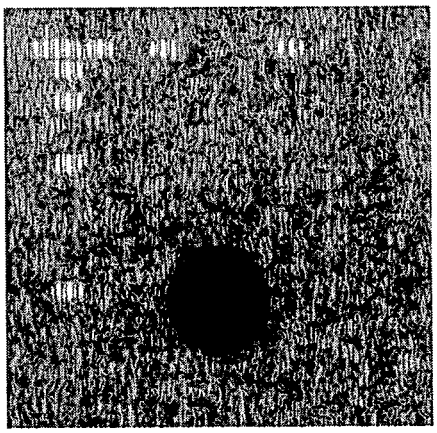
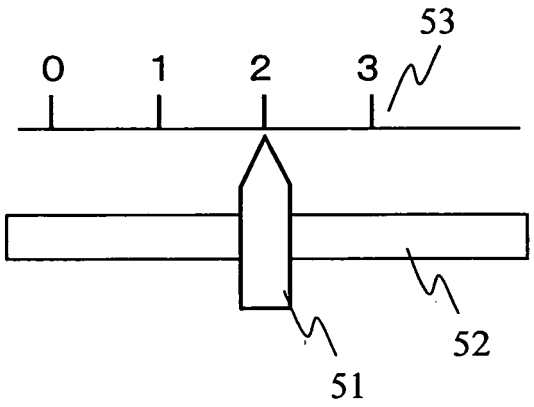


FIG. 11



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

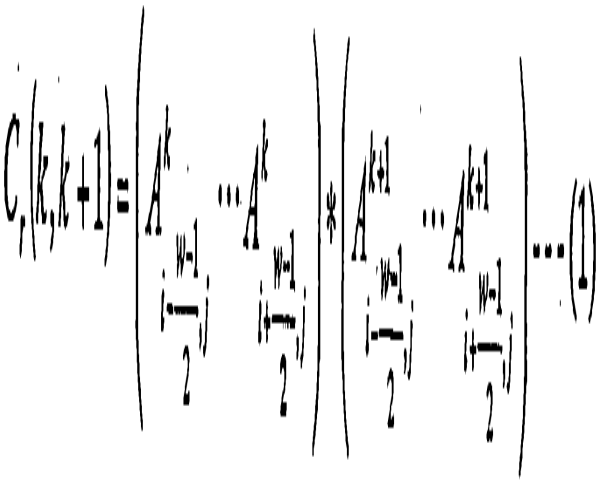
Patent documents cited in the description

- JP 2002526225 A **[0012]**
- WO 03022153 A1 **[0014]**
- US 6464638 B1 **[0014]**
- US 6511426 B1 **[0014]**

Non-patent literature cited in the description

- *IEEE Transaction on Ultrasonics, Ferroelectrics, and Frequency Control,* vol. 45 (4), 1077-1087 **[0013]**

专利名称(译)	超声波装置和超声波检查法		
公开(公告)号	EP1652475B1	公开(公告)日	2016-08-31
申请号	EP2004745943	申请日	2004-06-09
[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		
当前申请(专利权)人(译)	HITACHI，LTD.		
发明人	AZUMA, TAKASHI, C/O HITACHI, LTD. CENTRAL RESEARCH UMEMURA, S., C/O HITACHI LTD., CENTRAL RESEARCH BABA, HIROTAKA, C/O HITACHI MEDICAL CORPORATION		
IPC分类号	A61B8/00 G01S15/89 G01S7/52 A61B8/08		
CPC分类号	A61B8/00 G01S7/52077 G01S15/8995		
优先权	2003206184 2003-08-06 JP		
其他公开文献	EP1652475A1 EP1652475A4		
外部链接	Espacenet		

摘要(译)

在具有图像合成单元的超声波成像装置中，计算要合成的图像之间的相关性，以在对比度分辨率的提高和空间分辨率的提高之间进行平衡，并计算图像之间的位移量。当位移量大时，合成包络检测后的信号。当位移量小时，合成RF信号。或者，混合频率可以根据位移量而变化，并且根据位置位移的程度实现空间分辨率的提高和合同分辨率的改善之间的平衡。