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(54) **RF DATA BASED ULTRASONIC IMAGING METHOD**

AUF RF-DATEN BASIERENDES ULTRASCHALLBILDGEBUNGSVERFAHREN

PROCÉDÉ D’IMAGERIE ULTRASONORE EN FONCTION DE DONNÉES RF

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Description

FIELD OF THE INVENTION

[0001] The present application relates to a field of ultrasound diagnostic imaging, more particularly to an ultrasonic imaging processing method and an ultrasonic imaging processing system based on RF (radio frequency) data.

BACKGROUND OF THE INVENTION

[0002] With the development of related fields such as electronics, computers and material science, the function of ultrasound diagnostic apparatus has been greatly improved in recent years. At the same time, medical ultrasound diagnosis technology occurred several revolutionary leaps. Now, it has become a preferred method for various clinical disease diagnosis and a necessary tool of ultrasound diagnosis during ultrasound imaging. Correspondingly, B mode ultrasound imaging, CF mode ultrasound imaging and PW mode ultrasound imaging etc., are those most basic and most widely used technologies in ultrasound imaging systems. There are many clinical applications of various modes of ultrasound imaging, i.e., to monitor the fetus status in obstetrics, or for valvular heart disease diagnosis in internal medicine. Ultrasound imaging technology has been widely studied and applied globally. But because of constant update of ultrasound devices, application demands of ultrasonic inspection and clinical diagnoses etc., continuously increased. As a result, new content and new technologies emerge in endlessly. The existing study is unable to meet the demand for ultrasound imaging applications.

[0003] Traditional modes of ultrasound imaging include a front-end processing, a middle processing and a back-end processing, wherein the front-end processing is used to get focused RF signals, the middle processing is used to get the baseband signals and the back-end processing is used to display signals after being scanned and converted. Since the back-end processing technology is only in a preliminary development stage, and also considering the computer processing capacity, in the existing technology, the echo signals are divided into two I\Q signals in the middle processing, and the echo signals are treated by desampling and dropping bit in order to match the computer processing capacity. As a result, the whole processing needs large hardware support, especially for the middle processing, it usually needs dedicated chip or digital signal processor, which makes the processing chain extremely complex. For example, FIG. 1 shows a flowchart of an existing processing method in the ultrasound imaging technology. The method includes the following steps: P1, receiving echo signals which are obtained by sending ultrasound signals; P2, beamforming the echo signals; P3, obtaining the RF data of the echo signals; P4, orthogonally demodulating or Hibert transforming the RF data in order to divide the RF data into two I/O orthogonal signals; P5, treating the two I/O orthogonal signals obtained from the step P4 via baseband filtering or low-pass filtering in order to desample and drop bit of the two I/O orthogonal signals; P6, treating the two I/O orthogonal signals processed after the step P5 via ultrasound imaging in order to obtain a target image. US2013/231563A1, CARLOS FRITSCH ET AL, "A Digital Envelope Detection Filter for Real-Time Operation", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, (19991201), vol. 48, no. 6, ISSN 0018-9456, XP011024874, LEVESQUE P ET AL, "Real-Time Hand-Held Ultrasound Medical-Imaging Device Based on a New Digital Quadrature Demodulation Processor", IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS AND FREQUENCY CONTROL, IEEE, US, (20090801), vol. 56, no. 8, doi:10.1109/TUFFC.2009.1230, ISSN 0885-3010, pages 1654 - 1665, XP011271286, CN103454640A and CN191175A disclose a method for ultrasonic imaging processing according to the preamble of claim 1.

SUMMARY

[0004] In order to solve the above problems, the present application provides an ultrasonic imaging processing method and an ultrasonic imaging processing system based on RF data, with simple structure but without loss of data information.

[0005] In order to achieve one of the above objects, the present invention is defined by the features of claim 1. It provides an ultrasonic imaging processing method based on RF data. The method comprises the following steps:

S1, receiving echo signals which are obtained by sending ultrasound signals;
S2, beamforming the echo signals;
S3, obtaining RF data of the echo signals;
S4, directly conducting an ultrasonic imaging process based on the obtained RF data in order to obtain a target image.

[0006] Correspondingly, in order to achieve one of the above objects, the present application provides an ultrasonic imaging processing system based on RF data. The system comprises:

an ultrasonic probe module for sending and receiving ultrasound signals;

an ultrasound echo receiving module for receiving echo signals obtained by sending the ultrasound signals;
a beam synthesis module for beamforming the echo signals;
a RF data transmitting and storage module for getting the RF data of the echo signals;
an image processing module for directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0007] The ultrasonic imaging processing method and the ultrasonic imaging processing system based on RF data of the present application are capable of directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image, after getting the RF data of the echo signals. Compared with the existing technology, the system structure is simple, but without loss of data information, which improves real-time performance and image quality of ultrasonic diagnose, makes diagnostic information and axial resolution in more detail and clearer, and also lowers the cost of manufacture and usage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a flowchart of an existing ultrasound imaging processing method.

FIG. 2 is a flowchart of an ultrasonic imaging processing method based on RF data in accordance with a first embodiment of the present application.

FIG. 3 is a flowchart of an ultrasonic imaging processing method based on RF data in accordance with a second embodiment of the present application.

FIG. 4 is a module schematic diagram of an ultrasonic imaging processing system based on RF data in accordance with a first embodiment of the present application.

FIG. 5 is a module schematic diagram of an ultrasonic imaging processing system based on RF data in accordance with a second embodiment of the present application.

FIG. 6 is a flowchart of adopting EI mode processing based on RF data in order to obtain the target image.

FIG. 7 is a simplified structure diagram of FIG. 6.

FIGS. 8A and 8B are zero-phase linear diagrams in the process of adopting EI mode processing based on RF data in order to obtain the target image of FIG. 6.

FIG. 9 is a schematic diagram showing initial delay of multiple places of a fame signal in the process of adopting EI mode processing based on RF data in order to obtain the target image of FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] Detailed description of the present application will be depicted in combination with embodiments shown in figures.
[0010] Referring to FIG. 2 which is a flowchart of an ultrasonic imaging processing method based on RF data in accordance with an embodiment of the present invention. Correspondingly, the method includes the following steps:

S1, receiving echo signals which are obtained by sending ultrasound signal;
S2, beamforming the echo signals;
S3, obtaining RF data of the echo signals;
S4, directly conducting an ultrasonic imaging process based on the obtained RF data in order to obtain a target image.

[0011] In the above description of the ultrasonic imaging processing method based on RF data, the steps S1, S2 and S3 are similar to the existing technology shown in FIG. 1, detailed description thereof will be omitted herein. The difference between the present invention and the existing technology is that the present application is capable of directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image. Even though the system structure for achieving the method is simple, there is no loss of data information. Besides, real-time performance and image quality of ultrasonic diagnose using the ultrasonic imaging processing method and the ultrasonic imaging processing system are improved, which makes diagnostic information and axial resolution in more detail and clearer, and also lowers the cost of manufacture and usage at the same time.

[0012] The "RF" of the RF data is an abbreviation of radio frequency.

[0013] The present invention will be depicted in more detail hereinafter.

[0014] Based on the obtained RF data, the step S4 specifically includes adopting B mode processing, CF mode processing, PW mode processing and EI mode processing in order to obtain the target image.

[0015] The "CF" of the CF mode processing is an abbreviation of color flow which means blood flow imaging in Chinese. The "PW" of the PW mode processing is an abbreviation of pulsed wave doppler. The "EI" of the EI mode processing is an abbreviation of elastography which means tissue elasticity imaging in Chinese.

[0016] According to the present invention, adopting B mode processing to obtain the target image includes conducting gray scale map imaging of the obtained RF data. Accordingly, there are two ways to use the B mode to obtain the target image.

[0017] The first way, which is not part of the invention: assuming the RF signal data output by the beam synthesis is I, the absolute value of the RF signal data $|I|$ is took for gray map imaging.

[0018] The second way according to the present invention: assuming the RF signal data output by the beam synthesis is I and then constructing I' using the following formulas: $I = A \times Cos\omega t$,

$$I' = A \times Cos(\omega t + \emptyset),$$

Then, we can achieve the following formulas:

$$\begin{cases} I + I' = 2ACos\left(\omega t + \frac{\emptyset}{2}\right) Cos\left(\frac{\emptyset}{2}\right) \\ I - I' = 2ASin\left(\omega t + \frac{\emptyset}{2}\right) Sin\left(\frac{\emptyset}{2}\right) \end{cases}$$

And then, we can achieve the following formula from the above one:

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{I - I'}{I + I'} ctg\left(\frac{\emptyset}{2}\right),$$

In combination with the formula: $tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{tg(\omega t) + tg(\emptyset/2)}{1 - tg(\omega t) tg(\emptyset/2)}$, we can achieve $tg(\omega t)$. Under this condition, the mode $|A|$ of the RF signal data will be took for gray map imaging using the following formula:

$$|A| = |I/Cos\omega t|.$$

[0019] According to a preferred embodiment, which is not part of the invention, adopting CF mode processing to obtain the target image includes adopting ButterflySearch algorithm or CrossCorrelation algorithm directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0020] The ButterflySearch algorithm of the CF mode processing is carried out by searching along dimensions of depth and time of the objective reflection ultrasonic signals. The slope of butter line with maximum matching rate is corresponding to the target axial movement speed.

[0021] The CrossCorrelation algorithm applied in the CF mode processing is achieved by cross-correlation operating the objective reflection ultrasonic signals along a depth direction. The peak position of the cross-correlation coefficient is corresponding to shift caused by movement. Then the target axial movement speed can be calculated. This algorithm is mainly based on the signal time shift generated by the target movement. In actual calculation, a cross-correlation operation will be done between two adjacent RF data within a sampling volume in order to caculate a speed, and then the total calculated speeds are averaged to get a final speed for the sampling volume.

[0022] In a preferred embodiment, which is not part of the invention, an improved CrossCorrelation algorithm is adopted to directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0023] In detail, traditional CrossCorrelation algorithm can only obtain time shift with integer times of sampling interval, which requires interpolation in order to achieve the precise shift. There are two kinds of interpolation methods. The first method is interpolation on RF signal in order to upsampling. But it can not meet the real-time requirement because of high computation complexity. The second method is parabolic, sine or cosine interpolation on crosscorrelation coefficient. Although this method can meet real-time requirements, it is necessary to ensure that true cross-correlation peak is indeed contained in the interpolation curve, which is easily matched the wrong peak.

[0024] In a preferred embodiment, which is not part of the invention, if the CrossCorrelation algorithm is adopted to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image, based on the conventional CrossCorrelation algorithm, a limited searching scope will be defined through prior value in order to avoid matching error peak cross-correlation coefficient. This will simplify the computation complexity of CrossCorrelation algorithm, and meet the real-time requirements.

[0025] Time shift (or displacement) of traditional RF signal is continuous along the axial direction and the lateral direction. So, the prior value is calculated as the shift of previous point which is in line with the current point, or the shift of same location of an adjacent line corresponding to the current point. For example, if the shift of previous point in the same line is 2, then the shift of the current point is around 2, and cross-correlation search scope can be set between [1, 3].

[0026] In another preferred embodiment, which is not part of the invention, CrossCorrelation algorithm can be adopted to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image. Besides, it is also feasible to combine the CrossCorrelation algorithm with AutoCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0027] Firstly, a rough shift value can be calculated by using the CrossCorrelation algorithm. RF signal can be intercepted based on the rough shift value. Then, a precise shift value can be calculated by using the AutoCorrelation algorithm. The final accurate shift value can be achieved by adding these two shift value.

[0028] In combination with the above description, before adopting the CrossCorrelation algorithm, by limiting the cross-correlation search scope through priori values, the shift value of previous point or adjacent point can be directly used as rough shift value of current point. Then, the AutoCorrelation algorithm is used to calculate a precise shift value. By using this method, it is possible to minimize the calculation complexity of the CrossCorrelation algorithm, and avoid aliasing of precise shift value calculated by AutoCorrelation algorithm.

[0029] In the process of calculating the precise shift value by using the AutoCorrelation algorithm, it only needs temporarily Hilbert demodulation of the RF signal. Such process can be implemented at the algorithm layer, which simplify the system structure without data loss.

[0030] In a preferred embodiment, which is not part of the invention, adopting PW mode processing to obtain the target image includes adopting a ButterflySearch algorithm or CrossCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0031] The ButterflySearch algorithm for achieving the target image of the PW mode processing is to obtain data of each rate component along a depth direction of the RF signal in the sampling box and also along a slope of the velocity. The size of the corresponding data is then calculated for spectrum display.

[0032] In an embodiment of the present application, the step S4 also includes adopting EI mode processing to obtain the target image based on the obtained RF data.

[0033] It is noted that, in existing technologies, there are multiple ways to obtain a target image by adopting the EI mode, among which it is particularly noticeable as to time delay estimation in the process of obtaining the target image of the EI mode.

[0034] Currently, there are a lot of time delay estimation methods commonly used in the EI mode processing, including CrossCorrelation method, AutoCorrelation method, a method combining the CrossCorrelation method and the AutoCorrelation method, zero-phase iterative method, maximum likelihood method, and frequency domain processing method etc. The methods mentioned above have their own advantages and disadvantages.

[0035] Among them, the most classic time delay estimation algorithm is the CrossCorrelation method. The time delay is determined by calculating the cross-correlation coefficient between adjacent ultrasonic RF signals. It is the place where the cross-correlation coefficient has the maximum value corresponds to the time delay of the signals. In using the CrossCorrelation method, it is only feasible to get the integer multiple time delay of the sampling period through the place where the cross-correlation coefficient has the maximum value, because the ultrasonic signals have limited sample rate. However, in some applications (such as shear wave elasticity imaging or temperature monitoring), the time delay of the ultrasonic signals is even less than one sampling period. In order to get sub-sample time delay estimation, it is typical in the CrossCorrelation method by using interpolation of the ultrasonic RF signals or CrossCorrelation coefficients. It will tend to much additional calculation by using interpolation of the ultrasonic RF signals. So, it is necessary to exhaustively search the signals in a given range in the CrossCorrelation method, which is an extreme big calculation load. And, when the signal delay is less than one sampling period, the sub-sample time delay estimation obtained by the interpolation method will have big error.

[0036] Further, in order to reduce the calculation load of the CrossCorrelation algorithm, some simplified methods such as sum of absolute difference (SAD) and sum of squared differences (SSD) have been proposed. Although these methods have small calculation load, they are less accurate than the CrossCorrelation method.

[0037] Further, the AutoCorrelation method is classic delay or phase-shift estimation algorithm which has been widely used in the field of ultrasonic doppler, usually calculating in the complex field. Comparing with the interpolation operation of the CrossCorrelation method, the AutoCorrelation method does not need exhaustive search so that the calculation load is small, and it can get the precise sub-sample time delay estimation. However, the inherent flaw of the AutoCorrelation method is, when the signal delay is large (greater than half period signal), it will cause phase winding, also called aliasing. In addition, for accuracy consideration, the AutoCorrelation method is more suitable to narrow-band signals rather than wide-band signals.

[0038] Further, when the AutoCorrelation method based on the parsing signal is used for time delay estimation of the ultrasound signal, the method firstly applies Hilbert change to the ultrasound RF signal in order to get plural domain parsing signal. Then AutoCorrelation operation takes place regarding the parsing signal in a given range. The maximum place of the model of the auto-correlation coefficient corresponds to integer time delay of the sampling period. And then, sub-sample time delay can be calculated using the phase of the maximum place of the auto-correlation coefficient and the phase of an adjacent front point or an adjacent rear point. The eventual time delay can be achieved by adding them. This method resolves the aliasing of the AutoCorrelation operation and is suitable for any bandwidth signal. But the method needs to process the plural domain parsing signal (including the real part and the imaginary part), and still requires exhaustive search of the signals within a certain range. As a result, the calculation load is greater than the CrossCorrelation method. The robust capability is not good because in order to get the precise sub-sample time delay, it is necessary to precisely calculate the integer time delay of the sampling period.

[0039] Further, regarding the method combining the CrossCorrelation method and the AutoCorrelation method applied for time delay estimation of ultrasonic signals, firstly, a "rough time delay" of the method is got via a cross-correlation operation, using signal half wavelength (half cycle) as a step. Then, the AutoCorrelation operation is adopted based on the signal reference point of the "rough time delay" in order to get a "precise time delay". Then the final time delay will be obtained by adding the "rough time delay" and the "precise time delay". This method greatly reduces the calculation load of the CrossCorrelation operation. At the same time, this method ensures precise estimation of the sub-sample time delay by using AutoCorrelation operation. As a result, this method is a practical method. However, in actual application, orthogonal base band signal is normally given a down-sampling, if step length of the CrossCorrelation operation is too big, mutual related coefficient may miss the real peak and then generate a pseudo peak, which means that the value of the "rough time delay" could be totally wrong and may eventually led to singular value of delay estimation. In addition, ultrasound signal in human organization will constantly attenuate. Signal center frequency f_0 will actually get gradually reduced with depth going deeply, which will also result in estimation error of "precise time delay".

[0040] Further, regarding the zero phase iterative method for time delay estimation of ultrasonic signals, its principle is to get an initial phase by AutoCorrelation calculation of orthogonal base signal S_r and S_d, and get a new S'_d using interpolation method according to the S_d according to the initial phase. Then a calculation between S_d and S'_d will be conducted to get the phase therebetween. Then, a new S'_d will be obtained by using interpolation method according to the previously accumulated phase of S_d. The above iteration process will be repeated until the phase between S_r and S'_d tends to near zero, which is so called zero phase iterative method. It is possible to set maximum iteration time or phase threshold. When the iteration time reaches the maximum value or is less than the threshold value, the iterative process will be over. The final phase shift will be obtained by accumulating all the iteration phases. Zero phase iterative method solves the aliasing problem in AutoCorrelation method, but the method raises an error calculation when the signal central frequency f0 gets gradually reduced with depth going deeply.

[0041] In addition, some other time delay estimation methods of ultrasonic signals, such as maximum likelihood method and frequency domain processing method etc., which are rarely used in the prior art because of big defects. Detailed description of them is omitted herein.

[0042] Referring to FIGS. 6 and 7, in a preferred embodiment of the present application, the method adopting EI mode processing to achieve target image includes the following step:
to get ultrasonic RF signals of the same scan sample in different scan time. The ultrasonic RF signals include a reference signal S_r and a delay signal S_d.

[0043] In the current embodiment, the ultrasonic RF signals are RF data.

[0044] The target image is obtained by directly proceeding based on the obtained RF data. So, it simplifies the time delay estimation method of ultrasonic signals and is without data information loss. As a result, real-time performance and image quality of ultrasonic diagnose appliance by using the proceeding method are improved.

[0045] Further, in this embodiment, the method adopting EI mode processing to achieve target image includes selecting a section containing the current position of the reference signal S_r and the delay signal S_d for CrossCorrelation operation in order to get integer multiple initial delay of the current location sampling period.

[0046] It is understandable that, for easy calculation and low amount of calculation, a section containing the current position of the reference signal S_r and the delay signal S_d is usually selected for CrossCorrelation operation. Besides, in a preferred embodiment of the present application, the selected section could be a signal having the current position as its center, which will not be described in detail herein.

[0047] In the present embodiment, after conducting the CrossCorrelation operation as to the section containing the current position of the reference signal S_r and the delay signal S_d, the CrossCorrelation function will be expressed as follows:

$$R_{cc}(m,n,d)=\sum_{m'=-M}^{M}\sum_{n'=-N}^{N}S_r(m+m',n+n')S_d(m+m'+d,n+n')$$

[0048] Wherein, m represents signal axis location, n represents signal horizontal location. Value range of m' is between -M to M. Value range of n' is between -N to N. The range between -M and M represents 2M plus one points with the point (m, n) as a center, along the axis direction. The range between -N and N represents 2N plus one point with the point (m, n) as a center, along the horizontal direction. That is to say, the mutual window of the location (m, n) is [2M+1, 2N+1]. Wherein, d represents signal axial relative shift. R_{cc}(m, n, d) represents a CrossCorrelation coefficient, when the signal is located at the location (m, n) and the axial relative shift is d. If the maximum search range d belongs to [-D, D], after calculating all the CrossCorrelation coefficients of the range, assuming the maximum location of the CrossCorrelation coefficient is d_0, the d_0T_s is exactly the integer multiple initial delay of the current location sampling period.

[0049] In an exemplary embodiment of the present application, the method for obtaining integer multiple initial delay of the current location sampling period can also be applied to obtain integer multiple initial delay of the current location sampling period of adjacent locations, which will not be depicted in detail herein.

[0050] Normally, the CrossCorrelation operation only provides integer multiple initial delay of the current location sampling period and does not accompany the entire process. In order to avoid strange value of the integer multiple initial delay of the current location sampling period, usually CrossCorrelation operation is also applied to multiple adjacent locations in order to get integer multiple initial delay of the current location sampling period of the adjacent locations. Then, a filtering processing will be took regarding the obtained multiple initial delay in order to get a middle value as the initial time delay of the current location.

[0051] Further, in the present embodiment, the method adopting EI mode processing to achieve target image includes obtaining multiple domain analytic signal of the reference signal S_r and the delay signal S_d by Hilbert transformation.

[0052] In the present embodiment, using the CS_r and CS_d to represent the multiple domain analytic signals obtained by Hilbert transformation of the reference signal S_r and the delay signal S_d, respectively, the AutoCorrelation function will be expressed as follows:

$$R_{ac}(m,n,d)=\sum_{m'=-M}^{M}\sum_{n'=-N}^{N}CS_r(m+m',n+n')CS_d^{*}(m+m'+d,n+n')$$

[0053] Wherein, symbol * represents conjugate, m represents signal axis location, n represents signal horizontal location. Value range of m' is between -M to M. Value range of n' is between -N to N. The range between -M and M represents 2M plus one points with the point (m, n) as a center, along the axis direction. The range between -N and N represents 2N plus one point with the point (m, n) as a center, along the horizontal direction. That is to say, the mutual window of the location (m, n) is [2M+1, 2N+1]. Wherein, d represents signal axial relative shift. R_{ac}(m, n, d) represents a AutoCorrelation coefficient, when the signal is located at the location (m, n) and the axial relative shift is d.

[0054] Since the center frequency of the ultrasonic signals is slowly changing with depth going deeply, phase of partial signal keeps linearity.

[0055] Further, in the present embodiment, the method adopting EI mode processing to achieve target image further includes conducting AutoCorrelation operation of the multiple domain analytic signal of the present location based on a relative shift between the initial time delay and a second initial time delay in order to achieve the AutoCorrelation coefficient of at least two adjacent points. The second initial time delay is a time delay which has an adjacent value of the initial time delay, and is achieved by retaking an integer multiple sampling cycle with respect to the initial time delay.

[0056] Considered the continuity in space of the ultrasound signal delay, each calculated output time delay of the current location can be used as an initial time delay of a next location (axial) or an adjacent location (horizontal). As a result, follow-up calculation process does not need relying on the mutual related exhaustive search. It is only needed to calculate the AutoCorrelation coefficients of at least two points with respect to the initial time delay, which greatly reduces calculation load.

[0057] In the above example, the initial time delay of the determined location (m, n) is d_0T_s. In the present embodiment, AutoCorrelation coefficients of the relative shift d_0 and at least two adjacent points will be calculated. Take three points for example, AutoCorrelation coefficients will be calculated in turn and obtained as [R(m,n,d_0-1), R(m,n,d_0), R(m,n,d_0+1)].

[0058] Further, in the present embodiment, the method adopting EI mode processing to achieve target image further includes obtaining a phase based on the AutoCorrelation coefficients of at least two adjacent points, and a fine time delay by using zero-phase linear fitting method.

[0059] In a specific embodiment of the present application, referring to FIGS. 8A and 8B, the difference between the initial time delay and the actual time delay is less than one sampling period according to the zero-phase linear fitting shown in FIG. 8A. The difference between the initial time delay and the actual time delay is greater than one sampling period according to the zero-phase linear fitting shown in FIG. 8B.

[0060] Accordingly, the phase obtained based on the AutoCorrelation coefficients of at least two adjacent points, and the fine time delay obtained by using zero-phase linear fitting method specifically include:
calculating each phase according to the AutoCorrelation coefficients of at least two adjacent points; getting slope and intercept of the phases of the obtained at least two points by linear fitting operations; and taking the time delay corresponding to the fitted linear zero phase according to the calculated slope and the calculated intercept as the fine time delay.

[0061] Zero-phase linear fit ensures the accuracy of the sub sample delay so that the final time delay estimation precision is guaranteed. Specifically, based on phase linear characteristics of partial signal, it is possible to conduct linear fit of the above AutoCorrelation coefficients in order to obtain line y=kx+b. Wherein k represents the slope, b represents the intercept, the symbol ∠ represents achieving phase angle which means ∠ (x+jy) =arctan (y/x). As a result, the intersection of the line and the X axis represents the zero phase location, and the time delay corresponds to the intersection is $-\frac{b}{k}T_s$. Further, the fine time delay is actually the time delay $-\frac{b}{k}T_s$.

[0062] Further, in the present embodiment, the method adopting EI mode processing to achieve target image further includes adding the obtained initial time delay and the obtained fine time delay in order to get a high precision output delay of the current location.

[0063] According to the above example, the high precision output delay of the current location is $-\frac{b}{k}T_s+d_0T_s$.

[0064] It is understandable that in the present application, it is possible to use a least square method as a linear fit method, which will not be detailed herein.

[0065] Further, under normal circumstances, it is necessary to calculate time delays of all locations of a frame signal in an ultrasound scanning process. The frame signal usually includes multiple signals each of which includes time delays corresponding to multiple locations at different depths.

[0066] Further, in the present embodiment, the method adopting EI mode processing to achieve target image further includes taking integer value of the sampling period as an initial time delay of the next location based on the high precision output delay of the current location, and then calculating the time delay of the high precision output delay of the next location using the above method. The next location is a location corresponding to a next depth of a signal which is in the same column of the current signal, or the same depth of a signal of an adjacent column of the current signal.

[0067] Referring to FIG. 9, in a preferred embodiment of the present application that adopting EI mode processing method to achieve target image, the initial time delay of all locations of the column signal is obtained through CrossCorrelation operation. In order to remove strange values, a middle value filtering processing is further took to treat the initial time delay of all locations of the column signal. Then, high precision output delay of all the locations of the column signal will be calculated and obtained. As shown by the arrows of FIG. 9, the high precision output delay of the current location will be took as an initial time delay of a corresponding location of an adjacent signal. Following this rule in turn, calculations will be completed until both the left and the right reach the boundary.

[0068] Further, the high precision output delays of all the locations of the obtained frame signal are integrated in order to form an image or achieve a new image based on the image in subsequent processing. In a word, adopting the B mode proceeding, the CF mode proceeding, the PW proceeding and the EI mode processing to obtain the target image, in the process of directly calculating and searching the RF data, it directly conducts ultrasonic imaging based on the obtained RF data in order to obtain the target image. Comparing with existing technology, the present application obtains I/Q orthogonal signal based on the processing of the RF data, and gets the target image based on the I/Q orthogonal signal via ultrasound imaging processing. The sampling data obtained in such process is more accurate and the calculation result is more accurate as well. Besides, when using the EI mode processing to obtain target image, the EI mode has the advantages of low calculation load and excellent robustness capability, which has very high utility value.

[0069] Referring to FIG. 3, FIG. 3 shows a flowchart of an ultrasonic imaging processing method based on RF data in accordance with a second embodiment of the present application. Accordingly, the second embodiment of the present application is similar with the first embodiment, the main difference is that the method further comprises a following step after obtaining RF data of the echo signals shown in the step S3:
M1, pretreatment the acquired RF data and removal of system noise in the RF data.

[0070] Accordingly, there are a lot of ways to pretreat the acquired RF data and remove the system noise in the RF data. In a preferred embodiment of the present application, the following method is adopted for removing the system noise in the RF data.

[0071] Accordingly, noise RF signal data I_0 is removed when the collection system is under a silent status. By assuming that the RF signal data of the ultrasonic echo in practical application is I, it is possible to remove the background noise by using I minus I_0.

[0072] Comparing with existing technology, the present application, which is based on RF data ultrasound imaging processing, directly conducts ultrasonic imaging based on the obtained RF data of the echo signals in order to obtain the target image. Such method is simple and with no loss of data information. Besides, real-time performance and image quality of ultrasonic diagnose appliance using such method are improved, which makes diagnostic information and axial resolution in more detail and clearer, and also lowers the cost of manufacture and usage at the same time. Referring to FIG. 4, FIG. 4 is a module schematic diagram of an ultrasonic imaging processing system based on RF data in accordance with a first embodiment of the present application.

[0073] Accordingly, the ultrasonic imaging processing system based on the RF data in accordance with the first embodiment of the present application includes an ultrasonic probe module 100 for sending and receiving ultrasound signal; an ultrasound echo receiving module 200 for receiving echo signals obtained by sending the ultrasound signal; a beam synthesis module 300 for beamforming the echo signals; a RF data transmitting and storage module 400 for getting the RF data from the echo signals; and an image processing module 500 for directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0074] Based on the obtained RF data, the image processing module 500 is also used to directly obtain the target image by adopting B mode processing, CF mode processing, PW mode processing and EI mode processing.

[0075] Specifically, in an embodiment according to the invention, the image processing module 500 adopts the B mode processing to obtain the target image. The image processing module 500 is used for gray map imaging based on the obtained RF data. Accordingly, there are two ways which can be used to obtain the target image by adopting the B mode processing.

[0076] In a first way, which is not part of the invention, assuming the RF signal data output by the beam synthesis is *I*, the absolute value of the RF signal data |*I*| is took for gray map imaging.

[0077] In a second way: assuming the RF signal data output by the beam synthesis is *I* and then constructing *I*' using the following formulas:

$$I = A \times Cos\omega t,$$

$$I' = A \times Cos(\omega t + \emptyset),$$

Then, we can achieve the following formulas:

$$\begin{cases} I + I' = 2ACos\left(\omega t + \frac{\emptyset}{2}\right)Cos\left(\frac{\emptyset}{2}\right) \\ I - I' = 2ASin\left(\omega t + \frac{\emptyset}{2}\right)Sin\left(\frac{\emptyset}{2}\right) \end{cases}$$

And then, we can achieve the following formula from the above one:

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{I - I'}{I + I'}ctg\left(\frac{\emptyset}{2}\right),$$

In combination with the formula: $tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{tg(\omega t) + tg(\emptyset/2)}{1 - tg(\omega t)tg(\emptyset/2)}$, we can achieve $tg(\omega t)$. Under this condition, the mode |*A*| of the RF signal data will be took for gray map imaging using the following formula:

$$|A| = |I/Cos\omega t|.$$

[0078] Accordingly, in a preferred embodiment, which is not part of the invention, the image processing module 500 adopts the CF mode processing to obtain the target image. The image processing module 500 is specifically applied by adopting ButterflySearch algorithm or CrossCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0079] In detail, the ButterflySearch algorithm of the CF mode processing is by searching along dimensions of depth and time of the objective reflection ultrasonic signals. The slope of butter line with maximum matching rate is corresponding to the target axial movement speed.

[0080] The CrossCorrelation algorithm applied in the CF mode processing is achieved by cross-correlation operating the objective reflection ultrasonic signals along a depth direction. The peak position of the cross-correlation coefficient is corresponding to shift caused by movement. Then the target axial movement speed can be calculated. This algorithm is mainly based on the signal time shift generated by the target movement. In actual calculation, a cross-correlation operation will be done between two adjacent RF data within a sampling volume in order to calculate a speed, and then the total calculated speeds are averaged to get a final speed for the sampling volume.

[0081] Accordingly, in a preferred embodiment, which is not part of the invention, the image processing module 500 adopts the CF mode processing to obtain the target image. The image processing module 500 is specifically applied by adopting an improved CrossCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0082] In detail, traditional CrossCorrelation algorithm can only obtaintime shift with integer times of sampling interval , which requires interpolation in order to achieve the precise shift. There are two kinds of interpolation methods. The first method is to interpolation on RF signal in order to upsampling. But it can not meet the real-time requirement because of high computation complexity. The second method is parabolic, sine or cosine interpolation on crosscorrelation coefficient. Although this method can meet real-time requirements, it is necessary to ensure that true cross-correlation peak is indeed contained in the interpolation curve, which is easily matched the wrong peak.

[0083] In a preferred embodiment, which is not part of the invention, if the image processing module 500 adopts the CrossCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image, based on the conventional CrossCorrelation algorithm, a limited searching scope will be defined through prior value in order to avoid matching error peak cross-correlation coefficient. This will simplify the computation complexity of CrossCorrelation algorithm, and meet the real-time requirements.

[0084] In detail, time shift (or displacement) of traditional RF signal is continuous along the axial direction and the lateral direction. So, prior value is calculated as the shift of previous point which is in line with the current point, or the shift of same location of an adjacent line corresponding to the current point. For example, if the shift of previous point in the same line is 2, then the shift of the current point is around 2, and cross-correlation search scope can be set between [1, 3].

[0085] Accordingly, in another preferred embodiment, which is not part of the invention, if the image processing module 500 adopts the CrossCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image, it is also feasible to combine the CrossCorrelation algorithm with AutoCorrelation algorithm to directly conduct ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0086] In detail, firstly, the image processing module 500 adopts the CrossCorrelation algorithm to calculate a rough shift value based on which the RF signal can be intercepted. Then, a precise shift value can be calculated by using the AutoCorrelation algorithm. The final accurate shift value can be achieved by adding these two shift value.

[0087] Accordingly, in combination with the above description, before the image processing module 500 adopts the CrossCorrelation algorithm, by limiting the cross-correlation search scope through priori values, the shift value of previous point or adjacent point can be directly used as rough shift value of current point. Then, the AutoCorrelation algorithm is used to calculate a precise shift value. By using this method, it is possible to minimize the calculation complexity of the CrossCorrelation algorithm, and avoid aliasing of precise shift value calculated by AutoCorrelation algorithm.

[0088] In the process of calculating the precise shift value by using the AutoCorrelation algorithm, it only needs temporarily Hilbert demodulation of the RF signal. Such process can be implemented at the algorithm layer, which simplify the system structure, without data loss.

[0089] Accordingly, in a preferred embodiment, which is not part of the invention, the image processing module 500 adopting PW mode processing to obtain the target image includes adopting a ButterflySearch algorithm or CrossCorrelation algorithm directly conducting ultrasonic imaging based on the obtained RF data in order to obtain the target image.

[0090] The ButterflySearch algorithm for achieving the target image of the PW mode processing is to obtain data of each rate component along a depth direction of the RF signal in the sampling box and also along a slope of the velocity. The size of the corresponding data is then calculated for spectrum display.

[0091] Referring to FIGS. 6 and 7, in a preferred embodiment, which is not part of the invention, when the method adopts EI mode processing to achieve target image, the RF data transmitting and storage module 400 is used to get ultrasonic RF signals of the same scan sample in different scan time. The ultrasonic RF signals include a reference signal S_r and a delay signal S_d.

[0092] In the current embodiment, the ultrasonic RF signals are RF data.

[0093] The image processing module 500 is applied to select a section containing the current position of the reference signal S_r and the delay signal S_d via CrossCorrelation operation in order to get integer multiple initial delay of the current location sampling period.

[0094] It is understandable that, for easy calculation and low amount of calculation, the image processing module 500 usually selects a section containing the current position of the reference signal S_r and the delay signal S_d for CrossCorrelation operation. Besides, in a preferred embodiment of the present application, the selected section could be a signal having the current position as its center, which will not be described in detail herein.

[0095] In the present embodiment, after the image processing module 500 conducting the CrossCorrelation operation regarding the section containing the current position of the reference signal S_r and the delay signal S_d, the CrossCorrelation function will be expressed as follows:

$$R_{cc}(m,n,d)=\sum_{m'=-M}^{M}\sum_{n'=-N}^{N}S_r(m+m',n+n')S_d(m+m'+d,n+n')$$

[0096] Wherein, m represents signal axis location, n represents signal horizontal location. Value range of m' is between -M to M. Value range of n' is between -N to N. The range between -M and M represents 2M plus one points with the point (m, n) as a center, along the axis direction. The range between -N and N represents 2N plus one point with the point (m, n) as a center, along the horizontal direction. That is to say, the mutual window of the location (m, n) is [2M+1, 2N+1]. Wherein, d represents signal axial relative shift. $R_{cc}(m, n, d)$ represents a CrossCorrelation coefficient, when the signal is located at the location (m, n) and the axial relative shift is d. If the maximum search range d belongs to [-D, D], after calculating all the CrossCorrelation coefficients of the range, assuming the maximum location of the CrossCorrelation coefficient is d_0, the d_0T_s is exactly the integer multiple initial delay of the current location sampling period.

[0097] In a preferred embodiment, which is not part of the invention, the method for the image processing module 500 to obtain integer multiple initial delay of the current location sampling period can also be applied to obtain integer multiple initial delay of the current location sampling period of adjacent locations, which will not be depicted in detail herein.

[0098] Normally, the CrossCorrelation operation only provides integer multiple initial delay of the current location sampling period and does not accompany the entire process. In order to avoid strange value of the integer multiple initial delay of the current location sampling period, the image processing module 500 usually conducts CrossCorrelation operation applied to multiple adjacent locations in order to get integer multiple initial delay of the current location sampling period of the adjacent locations. Then, a filtering processing will be took regarding the obtained multiple initial delay in order to get a middle value as the initial time delay of the current location.

[0099] Further, in the present embodiment, the image processing module 500 conducts Hilbert transformation of the reference signal S_r and the delay signal S_d respectively in order to achieve multiple domain analytic signal.

[0100] In the present embodiment, using the CS_r and CS_d to represent the multiple domain analytic signals obtained by Hilbert transformation of the reference signal S_r and the delay signal S_d, respectively, the AutoCorrelation function will be expressed as follows:

$$R_{ac}(m,n,d)=\sum_{m'=-M}^{M}\sum_{n'=-N}^{N}CS_r(m+m',n+n')CS_d^{*}(m+m'+d,n+n')$$

[0101] Wherein, symbol * represents conjugate, m represents signal axis location, n represents signal horizontal location. Value range of m' is between -M to M. Value range of n' is between -N to N. The range between -M and M represents 2M plus one points with the point (m, n) as a center, along the axis direction. The range between -N and N represents 2N plus one point with the point (m, n) as a center, along the horizontal direction. That is to say, the mutual window of the location (m, n) is [2M+1, 2N+1]. Wherein, d represents signal axial relative shift. $R_{ac}(m, n, d)$ represents a AutoCorrelation coefficient, when the signal is located at the location (m, n) and the axial relative shift is d.

[0102] Since the center frequency of the ultrasonic signals is slowly changing with depth going deeply, phase of partial signal keeps linearity.

[0103] Further, in the present embodiment, the image processing module 500 conducts AutoCorrelation operation of the multiple domain analytic signal of the present location based on a relative shift between the initial time delay and a second initial time delay in order to achieve the AutoCorrelation coefficient of at least two adjacent points. The second initial time delay is a time delay which has an adjacent value of the initial time delay, and is achieved by retaking an integer multiple sampling cycle with respect to the initial time delay.

[0104] Considered the continuity in space of the ultrasound signal delay, each calculated output time delay of the current location can be used as an initial time delay of a next location (axial) or an adjacent location (horizontal). As a result, follow-up calculation process does not need relying on the mutual related exhaustive search. It is only needed to calculate the AutoCorrelation coefficients of at least two points with respect to the initial time delay, which greatly reduces calculation load.

[0105] In the above example, the initial time delay of the determined location (m, n) is d_0T_s. In the present embodiment, AutoCorrelation coefficients of the relative shift d_0 and at least two adjacent points will be calculated. Take three points for example, AutoCorrelation coefficients will be calculated in turn and obtained as [R(m,n,d_0-1), R(m,n,d_0), R(m,n,d_0+1)].

[0106] Further, in the present embodiment, the image processing module 500 is used to achieve a phase based on the AutoCorrelation coefficients of at least two adjacent points, and a fine time delay by using zero-phase linear fitting method.

[0107] In a specific embodiment, which is not part of the invention, referring to FIGS. 8A and 8B, the difference between the initial time delay and the actual time delay is less than one sampling period according to the zero-phase linear fitting shown in FIG. 8A. The difference between the initial time delay and the actual time delay is greater than one sampling period according to the zero-phase linear fitting shown in FIG. 8B.

[0108] Accordingly, the phase obtained by the image processing module 500 based on the AutoCorrelation coefficients of at least two adjacent points and the fine time delay obtained by using zero-phase linear fitting method specifically include calculating each phase according to the AutoCorrelation coefficients of at least two adjacent points; getting slope and intercept of the phases of the obtained at least two points by linear fitting operations; and taking the time delay corresponding to the fitted linear zero phase according to the calculated slope and the calculated intercept as the fine time delay.

[0109] Zero-phase linear fit ensures the accuracy of the sub sample delay so that the final time delay estimation precision is guaranteed. Specifically, based on phase linear characteristics of partial signal, the image processing module 500 conducts linear fit of the above AutoCorrelation coefficients in order to obtain line y=kx+b. Wherein k represents the slope, b represents the intercept, the symbol ∠ represents achieving phase angle which means ∠ (x+jy) =arctan (y/x). As a result, the intersection of the line and the X axis represents the zero phase location, and the time delay corresponds to the intersection is $-\frac{b}{k}T_s$. Further, the fine time delay is actually the time delay $-\frac{b}{k}T_s$.

[0110] Further, in the present embodiment, the image processing module 500 is also used for adding the obtained initial time delay and the obtained fine time delay in order to get a high precision output delay of the current location.

[0111] According to the above example, the high precision output delay of the current location is $-\frac{b}{k}T_s+d_0T_s$.

[0112] It is understandable that in the present application, it is possible to use a least square method as a linear fit method, which will not be detailed herein.

[0113] Further, under normal circumstances, it is necessary to calculate time delays of all locations of a frame signal in an ultrasound scanning process. The frame signal usually includes multiple signals each of which includes time delays corresponding to multiple locations at different depths.

[0114] Further, the image processing module 500 takes integer value of the sampling period as an initial time delay of the next location based on the high precision output delay of the current location, and then calculating the time delay of the high precision output delay of the next location using the above method. The next location is a location corresponding to a next depth of a signal which is in the same column of the current signal, or the same depth of a signal of an adjacent column of the current signal.

[0115] Referring to FIG. 9, in a preferred embodiment of the present application, the initial time delay of all locations of the column signal is obtained through CrossCorrelation operation. In order to remove strange values, further in adopting EI mode processing to obtain the target image, the image processing module 500 conducts a middle value filtering processing to treat the initial time delay of all locations of the column signal. Then, high precision output delay of all the locations of the column signal will be calculated and obtained. As shown by the arrows of FIG. 9, the high precision output delay of the current location will be took as an initial time delay of a corresponding location of an adjacent signal. Following this rule in turn, calculations will be completed until both the left and the right reach the boundary.

[0116] Further, the image processing module 500 is further used to integrate the high precision output delays of all the locations of the obtained frame signal in order to form an image or achieve a new image based on the image in subsequent processing.

[0117] In a word, when the image processing module 500 adopts the B mode proceeding, the CF mode proceeding, the PW proceeding and the EI mode processing to obtain the target image, in the process of directly calculating and searching the RF data, it directly conducts ultrasonic imaging based on the obtained RF data in order to obtain the target image. Comparing with existing technology, the present application obtains I/Q orthogonal signal based on the processing of the RF data, and gets the target image based on the I/Q orthogonal signal via ultrasound imaging processing. The sampling data obtained in such process is more accurate and the calculation result is more accurate as well. Besides, when using the EI mode processing to obtain target image, the EI mode has the advantages of low calculation load and excellent robustness capability, which has very high utility value.

[0118] Referring to FIG. 5, FIG. 5 shows a module schematic diagram of an ultrasonic imaging processing system based on RF data in accordance with a second embodiment of the present application. In order that the target image obtained based on the RF data becomes clearer, the ultrasound imaging processing system based on the RF data shown in FIG. 5 adds a pretreatment module 600 based on the first embodiment shown in FIG. 4. The pretreatment module 600 is applied to pretreat the obtained RF data and remove the system noise of the RF data in order to eventually get a clearer and smoother target image.

[0119] Accordingly, there are a lot of ways for the pretreatment module 600 to pretreat the acquired RF data and remove the system noise in the RF data. In a preferred embodiment of the present application, the following method is adopted by the pretreatment module 600 for removing the system noise in the RF data.

[0120] Accordingly, noise RF signal data I_0 is removed when the collection system is under a silent status. By assuming that the RF signal data of the ultrasonic echo in practical application is I, it is possible for the pretreatment module 600 to remove the background noise by using I minus I_0.

[0121] According to the above description, the ultrasonic imaging processing method and system based on RF data according to the present application are also called RF data platform technology. It is possible to directly conduct ultrasonic imaging treatment based on the obtained RF data of the echo signals in order to obtain the target image. The ultrasonic imaging processing system based on RF data according to the present application is simple and with no loss of data information. Besides, real-time performance and image quality of ultrasonic diagnose appliance by using such method and system are improved, which makes diagnostic information and axial resolution in more detail and clearer, and also lowers the cost of manufacture and usage at the same time.

[0122] In describing the above system, for convenient description, the system is divided into various modules with different functionality. Of course, in implementing the present application, it is feasible to realize the functions of all the modules within one or more software and/or hardware.

[0123] It is understandable according to the above description that those of ordinary skill in the art can clearly understand the present application can be realized by software and required universal hardware platform. Based on such understanding, the essential technical solution of the present application or the part makes contribution to the existing technology can be expressed through software products. The software products can be saved in media, such as ROM/RAM, disk, and CD etc. Besides, it also possible to use a computer equipment (such as a PC, or an information exchange server, or a network equipment) to executive the method of each embodiment or some parts of the embodiments of the present application.

[0124] The embodiments of the system described above are only schematic, in which the modules described separately may be or may not be physically separated. The parts for module display may be or may not be a physical module, which means they can be located in one place or distributed in multiple network modules. It is possible to select part or all modules to realize the purpose of the present application, which is feasible for those of ordinary skill in the art to understand and implement the present application without paying creative work.

Claims

1. An ultrasonic imaging processing method based on RF data comprising the following steps:

   S1, receiving echo signals which are obtained by sending ultrasound signals;
   S2, beamforming the echo signals;
   S3, obtaining the RF data of the echo signals; and
   S4, adopting B mode processing based on the obtained RF data in order to obtain a target image, **characterised in that** the B mode processing to obtain the target image concretely comprises:
   conducting gray scale map imaging of the obtained RF data, wherein the gray scale map imaging of the obtained RF data concretely comprises:
   when the RF signal data output by the beamforming is *I*, constructing *I'* using following formulas:

$$I = A \times Cos\omega t$$

$$I^{'} = A \times Cos(\omega t + \emptyset).$$

then achieving following formulas:

$$\begin{cases} I + I' = 2ACos\left(\omega t + \frac{\emptyset}{2}\right) Cos\left(\frac{\emptyset}{2}\right) \\ I - I' = 2ASin\left(\omega t + \frac{\emptyset}{2}\right) Sin\left(\frac{\emptyset}{2}\right) \end{cases}$$

then achieving following formula from the above formulas:

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{I - I'}{I + I'} ctg\left(\frac{\emptyset}{2}\right)$$

then, in combination with a formula:

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{tg(\omega t) + tg(\emptyset/2)}{1 - tg(\omega t) tg(\emptyset/2)}$$

achieving $tg(\omega t)$; wherein under this condition, a mode $|A|$ of the RF signal data is took for the gray scale map imaging using a following formula:

$$|A| = |I/\cos \omega t|.$$

2. The ultrasonic imaging processing method based on RF data as claimed in claim 1, wherein after the step S3, the method further comprises:
pretreating the acquired RF data and removing system noise of the RF data.

Patentansprüche

1. Auf RF-Daten basierendes Ultraschallbildgebungsverfahren mit folgenden Schritten:

S1, Empfangen von Echosignalen, die durch das Senden von Ultraschallsignalen erhalten werden;
S2, Beamforming der Echosignale;
S3, Erhalten der RF-Daten der Echosignale; und
S4, Anwenden der B-Modus-Verarbeitung basierend auf den erhaltenen RF-Daten, um ein Zielbild zu erhalten, **dadurch gekennzeichnet, dass** die B-Modus-Verarbeitung zum Erhalten des Zielbildes konkret umfasst: Durchführen einer Graustufenkartenbildgebung der erhaltenen RF-Daten, wobei die Graustufenkartenbildgebung der erhaltenen RF-Daten konkret umfasst:
Wenn die durch das Beamforming ausgegebenen RF-Signaldaten *I* sind, Konstruieren von *I'* mittels folgender Formeln:

$$I = A \times Cos\omega t$$

$$I' = A \times Cos(\omega t + \emptyset),$$

dann Erlangen der folgenden Formeln:

$$\begin{cases} I + I' = 2ACos\left(\omega t + \frac{\emptyset}{2}\right) Cos\left(\frac{\emptyset}{2}\right) \\ I - I' = 2ASin\left(\omega t + \frac{\emptyset}{2}\right) Sin\left(\frac{\emptyset}{2}\right) \end{cases},$$

dann Erlangen der folgenden Formel aus den obigen Formeln:

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{I - I'}{I + I'} ctg\left(\frac{\emptyset}{2}\right),$$

dann, in Kombination mit einer Formel

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{tg(\omega t) + tg(\emptyset/2)}{1 - tg(\omega t) tg(\emptyset/2)},$$

Erlangen von tg(ωt); wobei
unter dieser Bedingung ein Modus $|A|$ der RF-Signaldaten für die Graustufenkartenbildgebung unter Verwendung einer folgenden Formel gewählt wird:

$$|A| = |I/Cos\omega t|.$$

2. Auf RF-Daten basierendes Ultraschallbildgebungsverfahren nach Anspruch 1, wobei das Verfahren nach dem Schritt S3 ferner umfasst:
Vorbehandeln der ermittelten RF-Daten und Entfernen von Systemrauschen der RF-Daten.

Revendications

1. Procédé de traitement d'imagerie ultrasonore basé sur des données RF comprenant les étapes suivantes :

S1, la réception de signaux d'écho qui sont obtenus en envoyant des signaux d'ultrason ;
S2, la formation de faisceau des signaux d'écho ;
S3, l'obtention des données RF des signaux d'écho ; et
S4, l'adoption d'un traitement de mode B basé sur les données RF obtenues afin d'obtenir une image cible, **caractérisé en ce que** le traitement de mode B pour obtenir l'image cible comprend concrètement :
la réalisation d'une imagerie de carte d'échelle de gris des données RF obtenues, dans lequel l'imagerie de carte d'échelle de gris des données RF obtenues comprend concrètement :
lorsque les données de signal RF fournies en sortie par la formation de faisceau sont *I*, la construction de *I'* à l'aide des formules suivantes :

$$I = A \times Cos\omega t$$

$$I' = A \times Cos(\omega t + \emptyset)$$

puis le fait de parvenir aux formules suivantes :

$$\begin{cases} I + I' = 2ACos\left(\omega t + \frac{\emptyset}{2}\right) Cos\left(\frac{\emptyset}{2}\right) \\ I - I' = 2ASin\left(\omega t + \frac{\emptyset}{2}\right) Sin\left(\frac{\emptyset}{2}\right) \end{cases}$$

puis le fait de parvenir à la formule suivante à partir des formules ci-dessus :

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{I - I'}{I + I'} ctg\left(\frac{\emptyset}{2}\right)$$

puis, en combinaison avec une formule :

$$tg\left(\omega t + \frac{\emptyset}{2}\right) = \frac{tg(\omega t) + tg(\emptyset/2)}{1 - tg(\omega t) tg(\emptyset/2)}$$

le fait de parvenir à $tg(\omega t)$; dans lequel
dans cette condition, un mode $|A|$ des données de signal RF est pris pour l'imagerie de carte d'échelle de gris à l'aide d'une formule suivante :

$$|A| = |I/\cos \omega t|.$$

2. Procédé de traitement d'imagerie ultrasonore basé sur des données RF selon la revendication 1, dans lequel après l'étape S3, le procédé comprend en outre :
le prétraitement des données RF acquises et l'élimination d'un bruit système des données RF.

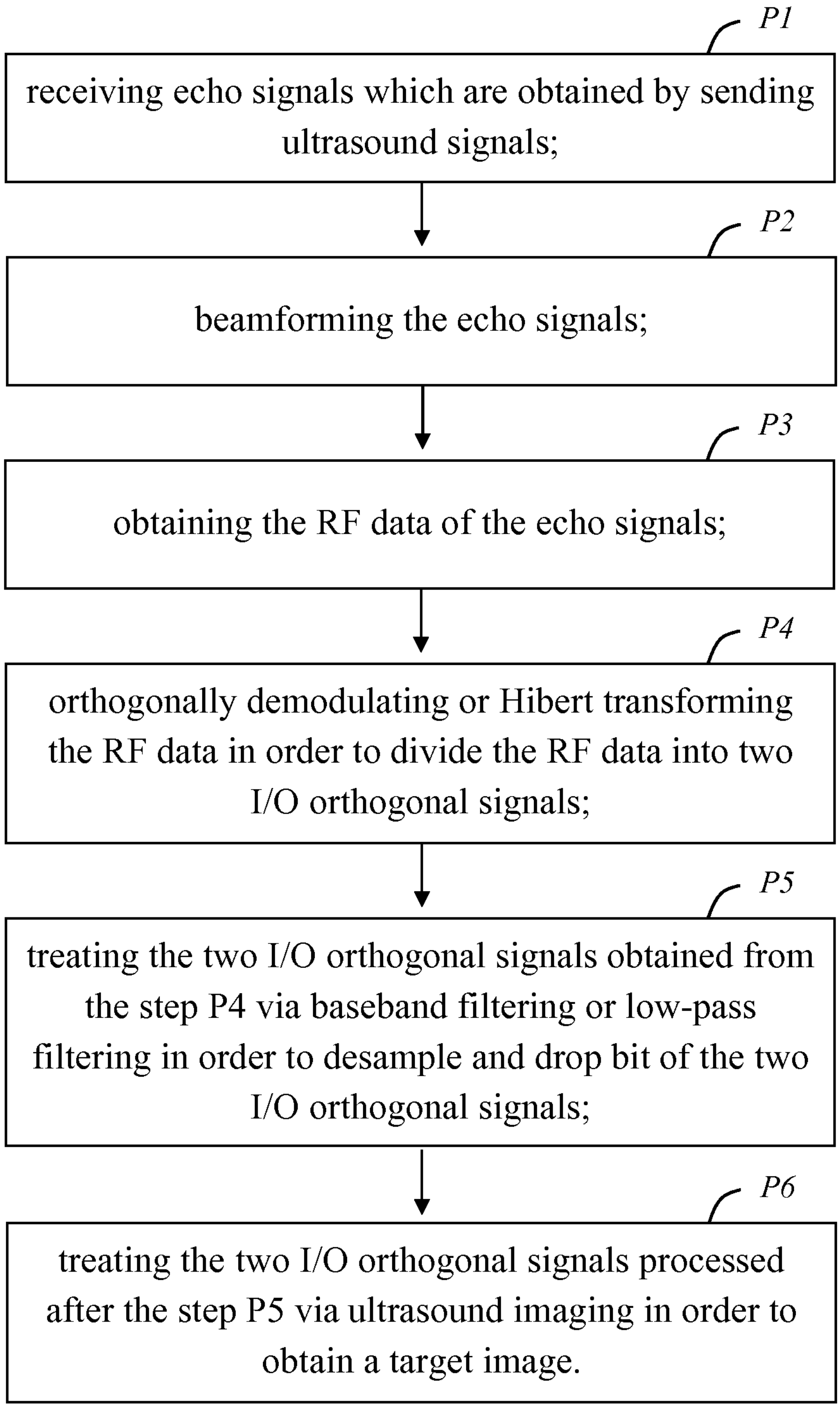


FIG. 1
<Prior Art>

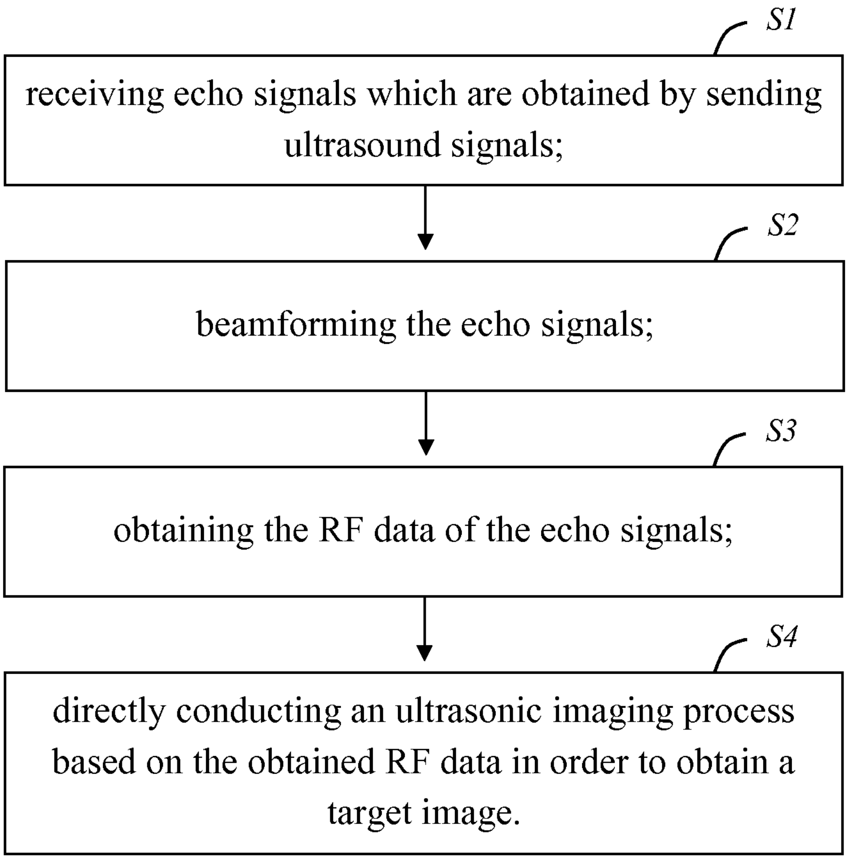

S1
receiving echo signals which are obtained by sending ultrasound signals;
S2
beamforming the echo signals;
S3
obtaining the RF data of the echo signals;
S4
directly conducting an ultrasonic imaging process based on the obtained RF data in order to obtain a target image.

FIG. 2

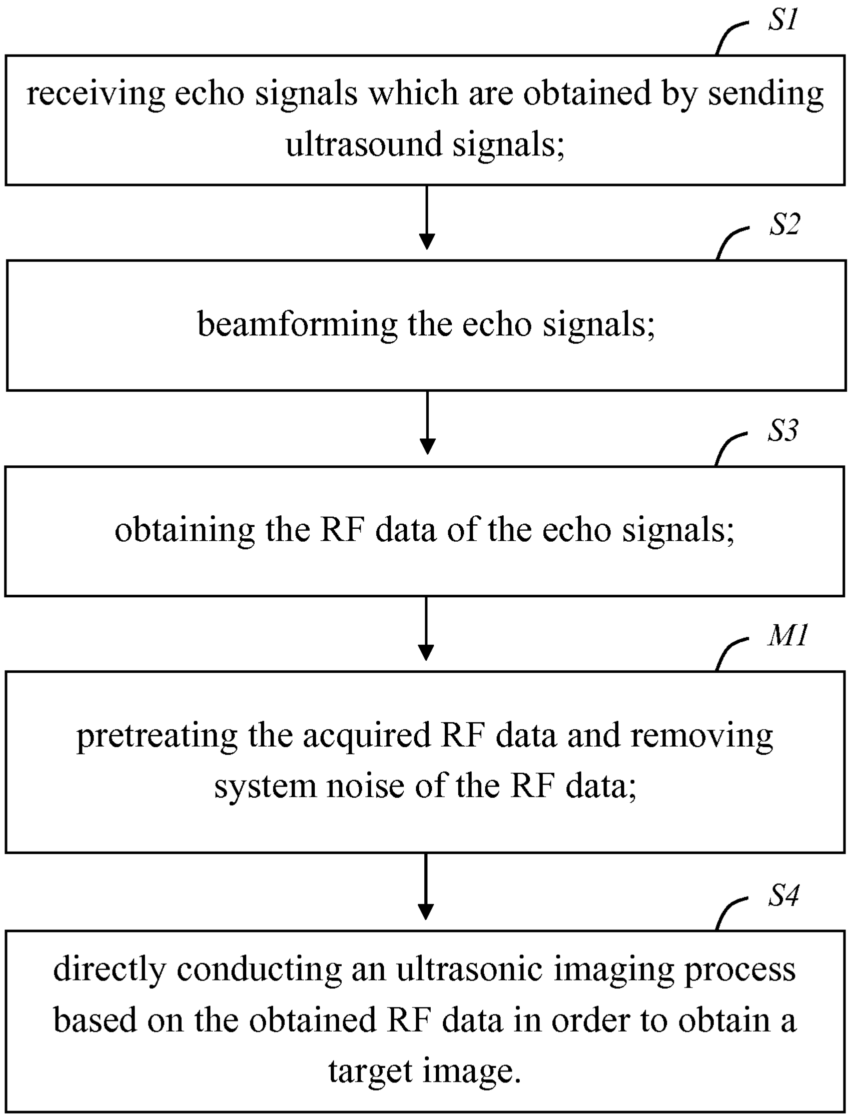

S1
receiving echo signals which are obtained by sending ultrasound signals;
S2
beamforming the echo signals;
S3
obtaining the RF data of the echo signals;
M1
pretreating the acquired RF data and removing system noise of the RF data;
S4
directly conducting an ultrasonic imaging process based on the obtained RF data in order to obtain a target image.

FIG. 3

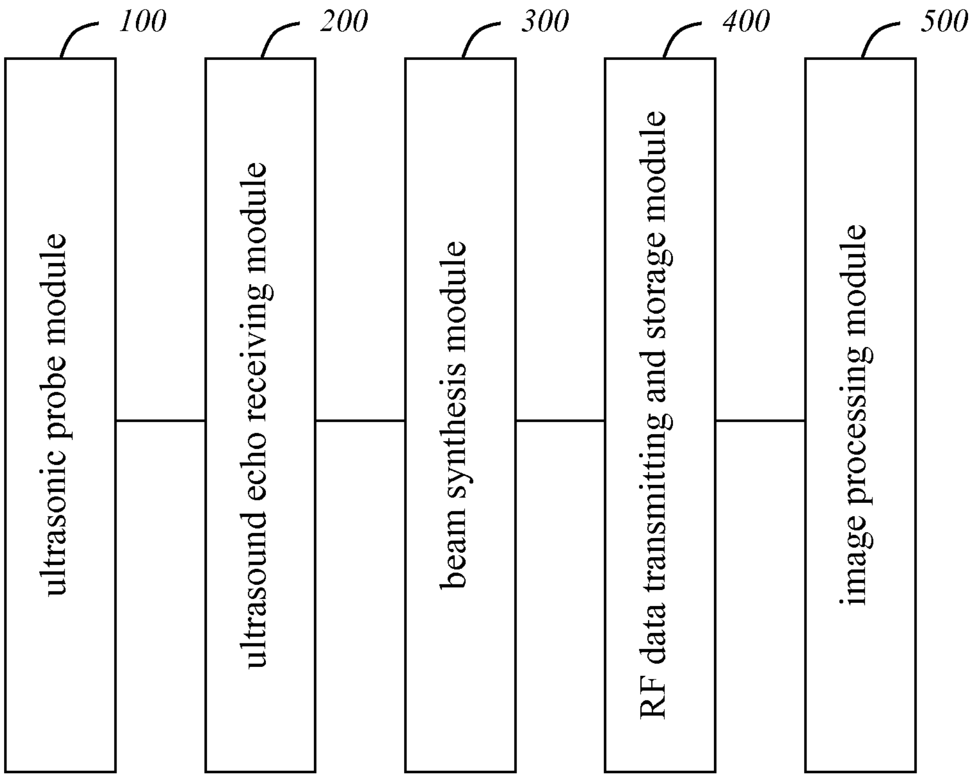

100
200
300
400
500
ultrasonic probe module
ultrasound echo receiving module
beam synthesis module
RF data transmitting and storage module
image processing module

FIG. 4

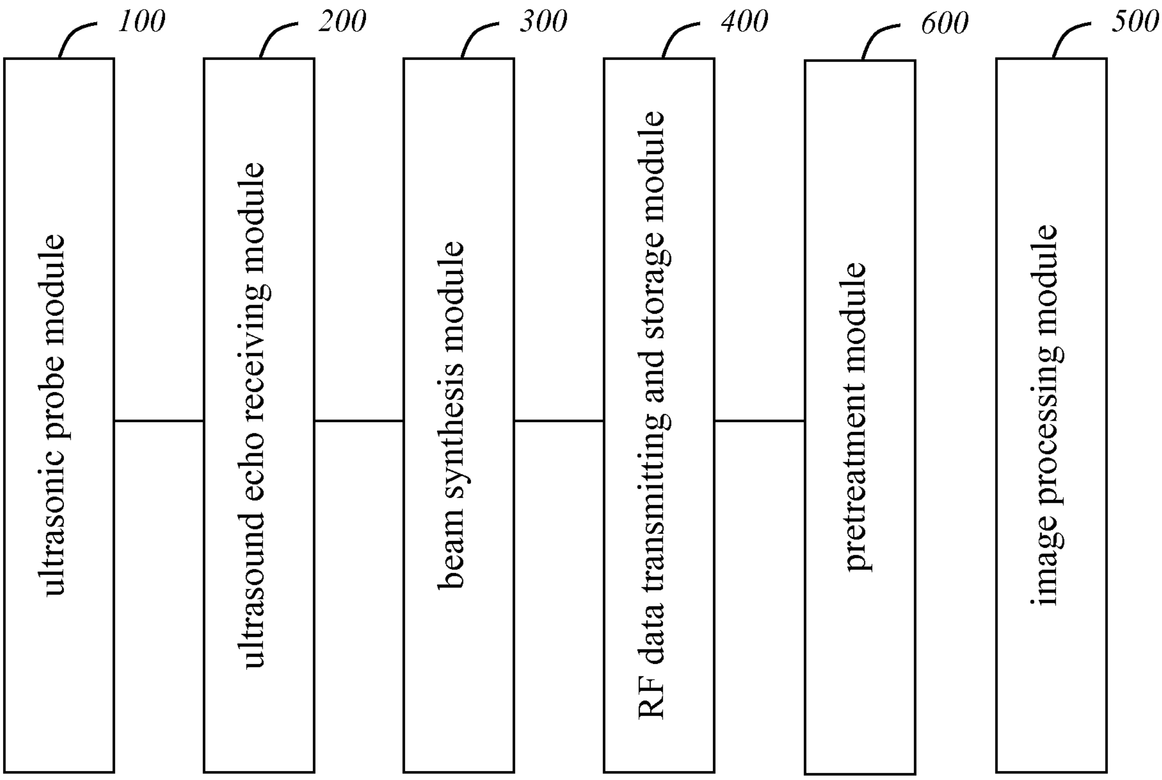

100
200
300
400
600
500
ultrasonic probe module
ultrasound echo receiving module
beam synthesis module
RF data transmitting and storage module
pretreatment module
image processing module

FIG. 5

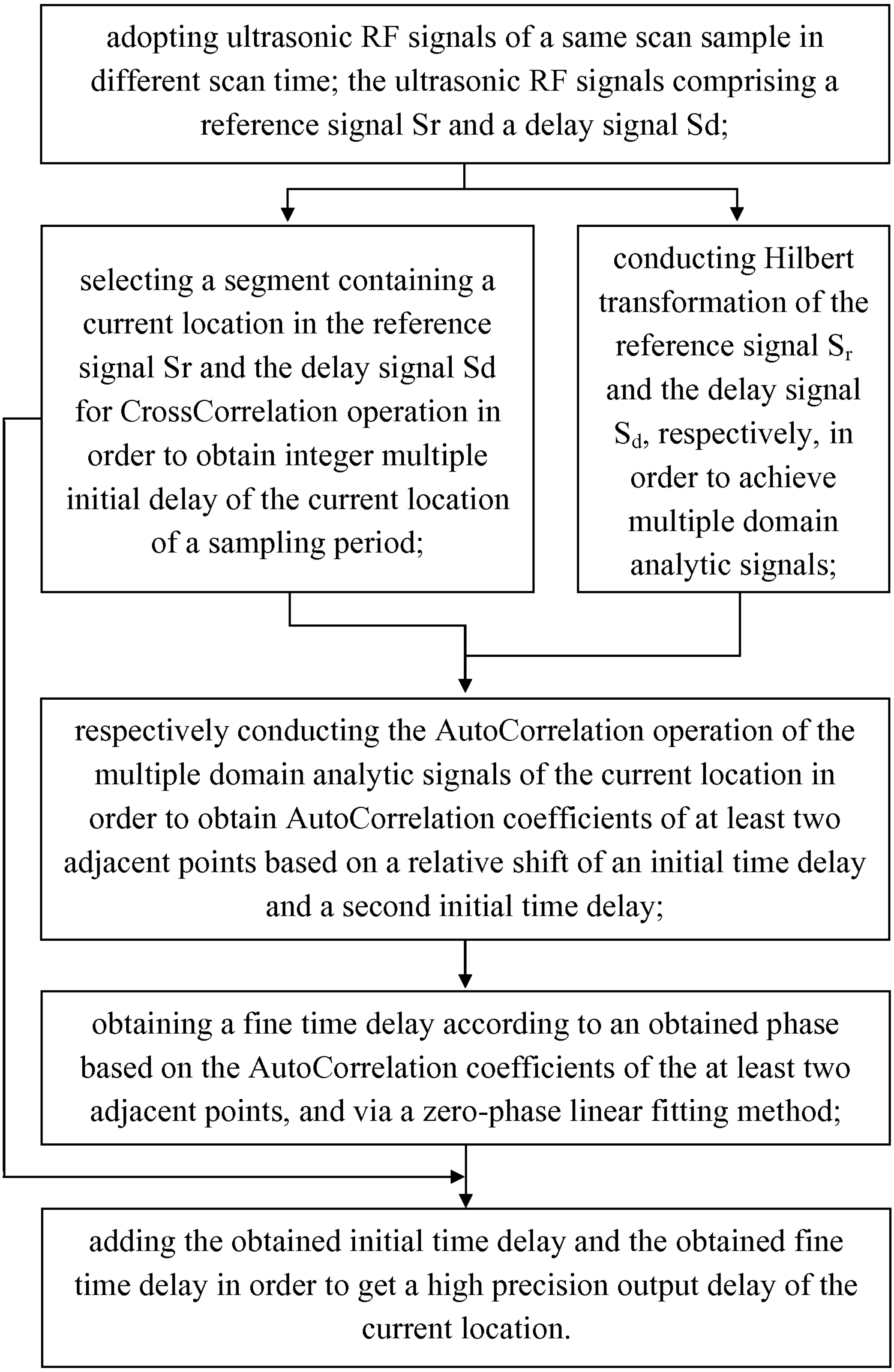
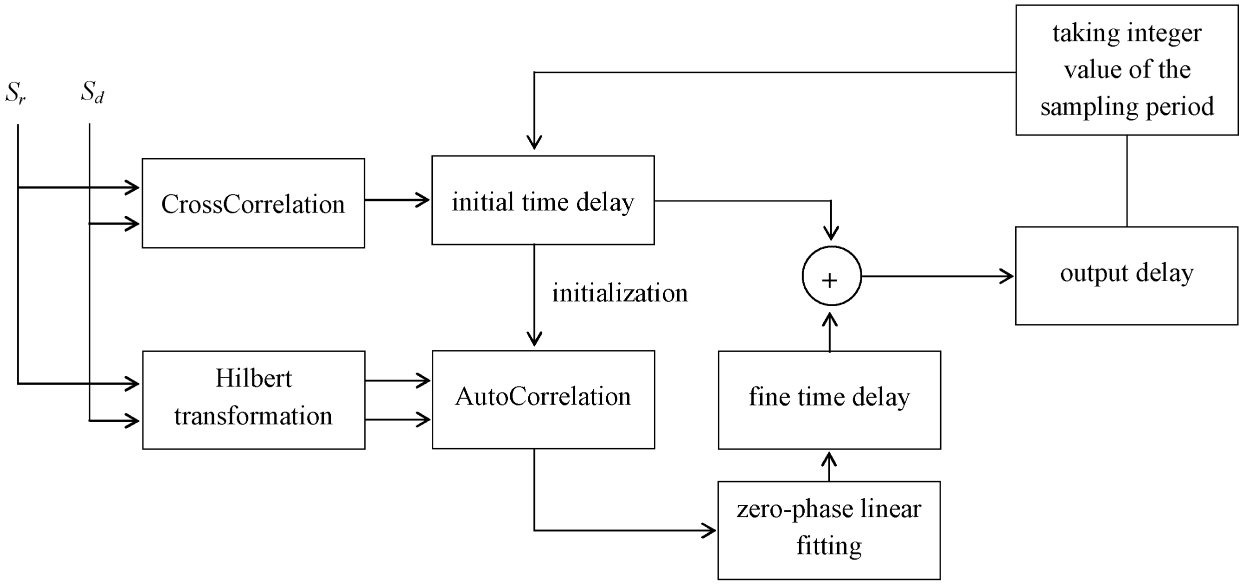

adopting ultrasonic RF signals of a same scan sample in different scan time; the ultrasonic RF signals comprising a reference signal Sr and a delay signal Sd;
selecting a segment containing a current location in the reference signal Sr and the delay signal Sd for CrossCorrelation operation in order to obtain integer multiple initial delay of the current location of a sampling period;
conducting Hilbert transformation of the reference signal S_r and the delay signal S_d, respectively, in order to achieve multiple domain analytic signals;
respectively conducting the AutoCorrelation operation of the multiple domain analytic signals of the current location in order to obtain AutoCorrelation coefficients of at least two adjacent points based on a relative shift of an initial time delay and a second initial time delay;
obtaining a fine time delay according to an obtained phase based on the AutoCorrelation coefficients of the at least two adjacent points, and via a zero-phase linear fitting method;
adding the obtained initial time delay and the obtained fine time delay in order to get a high precision output delay of the current location.

FIG. 6



S_r
S_d
taking integer value of the sampling period
CrossCorrelation
initial time delay
+
output delay
initialization
Hilbert transformation
AutoCorrelation
fine time delay
zero-phase linear fitting

FIG. 7

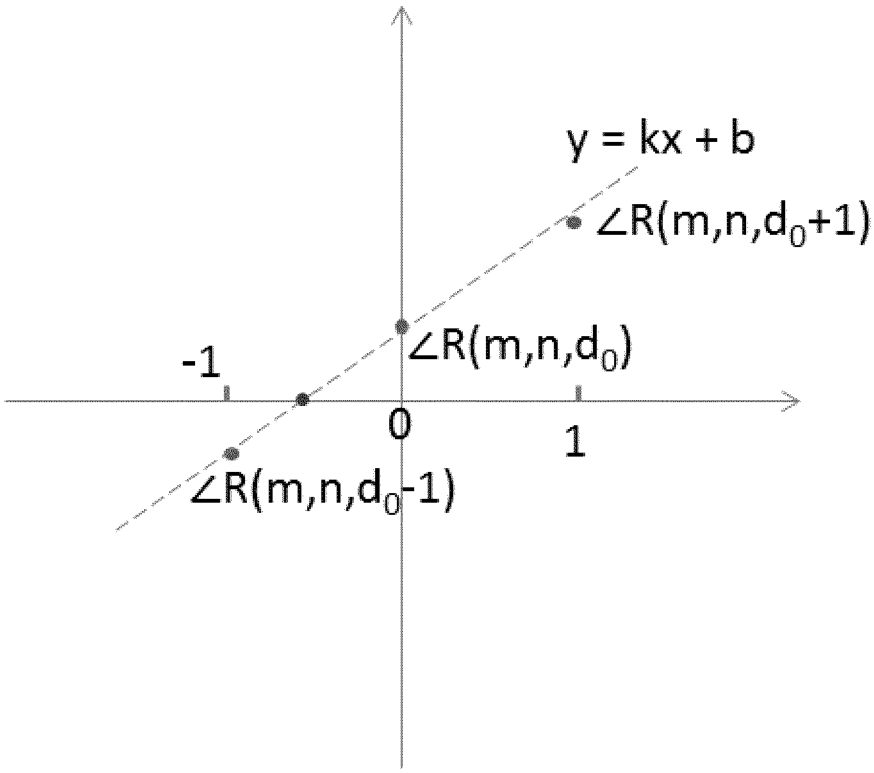


FIG. 8A

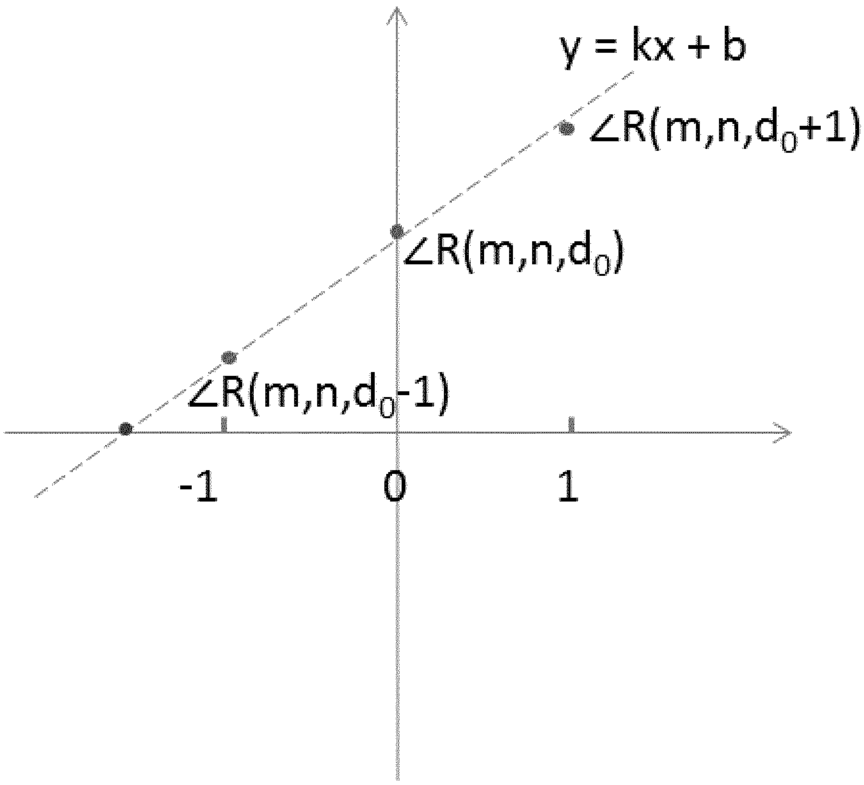


FIG. 8B

CrossCorrelation
initialization

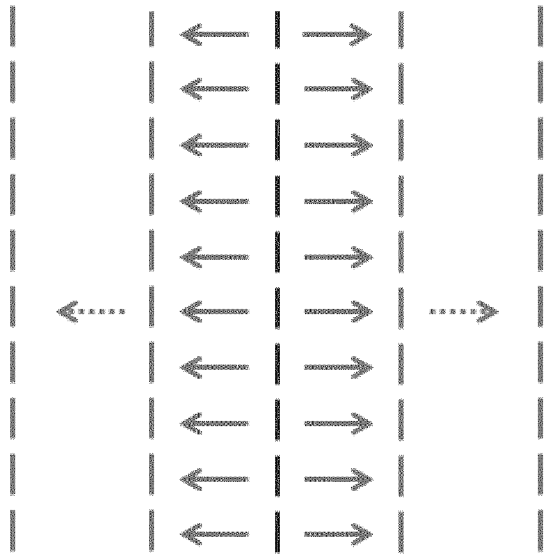


FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2013231563 A1 **[0003]**
- CN 103454640 A **[0003]**
- CN 191175 A **[0003]**

Non-patent literature cited in the description

- A Digital Envelope Detection Filter for Real-Time Operation. **CARLOS FRITSCH et al.** IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT. IEEE SERVICE CENTER, 01 December 1999, vol. 48 **[0003]**
- Real-Time Hand-Held Ultrasound Medical-Imaging Device Based on a New Digital Quadrature Demodulation Processor. **LEVESQUE P et al.** IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS AND FREQUENCY CONTROL. IEEE, 01 August 2009, vol. 56, 1654-1665 **[0003]**

patsnap

专利名称(译)	基于射频数据的超声成像方法		
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当前申请(专利权)人(译)	VINNO科技（苏州）有限公司.		
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外部链接	Espacenet		

摘要(译)

本申请公开了一种基于RF数据的超声成像处理方法，也称为RF数据平台技术。该方法包括以下步骤：S1，接收通过发送超声信号获得的回声信号; S2，波束形成回波信号; S3，获取回波信号的RF数据; S4，基于获得的RF数据直接进行超声成像处理，以获得目标图像。基于根据本申请的RF数据的超声成像处理方法和系统基于所获得的回波信号的RF数据直接进行超声成像处理，以获得目标图像。与现有技术相比，该系统简单且不丢失数据信息。此外，利用这种方法和系统改进了超声诊断设备的实时性能和图像质量，使诊断信息和轴向分辨率更加细致，清晰，同时降低了制造和使用成本。

$$I = A \times Cos(\omega t + \Phi),$$