US 20170105705A1

(19) **United States**

(12) **Patent Application Publication**

YOON et al.

(10) **Pub. No.: US 2017/0105705 A1**

(43) **Pub. Date: Apr. 20, 2017**

(54) **ADAPTIVE DEMODULATION METHOD AND APPARATUS FOR ULTRASOUND IMAGE**

(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(72) Inventors: **Hee-chul YOON**, Seoul (KR); **Kang-won JEON**, Yongin-si (KR); **Yong-sup PARK**, Seoul (KR); **Hyun-taek LEE**, Seoul (KR)

(73) Assignee: **SAMSUNG ELECTRONICS CO., LTD.**, Suwon-si (KR)

(21) Appl. No.: **15/129,156**

(22) PCT Filed: **Mar. 17, 2015**

(86) PCT No.: **PCT/KR2015/002549**

§ 371 (c)(1),
(2) Date: **Sep. 26, 2016**

(30) **Foreign Application Priority Data**

Mar. 26, 2014 (KR) 10-2014-0035380

Publication Classification

(51) **Int. Cl.**

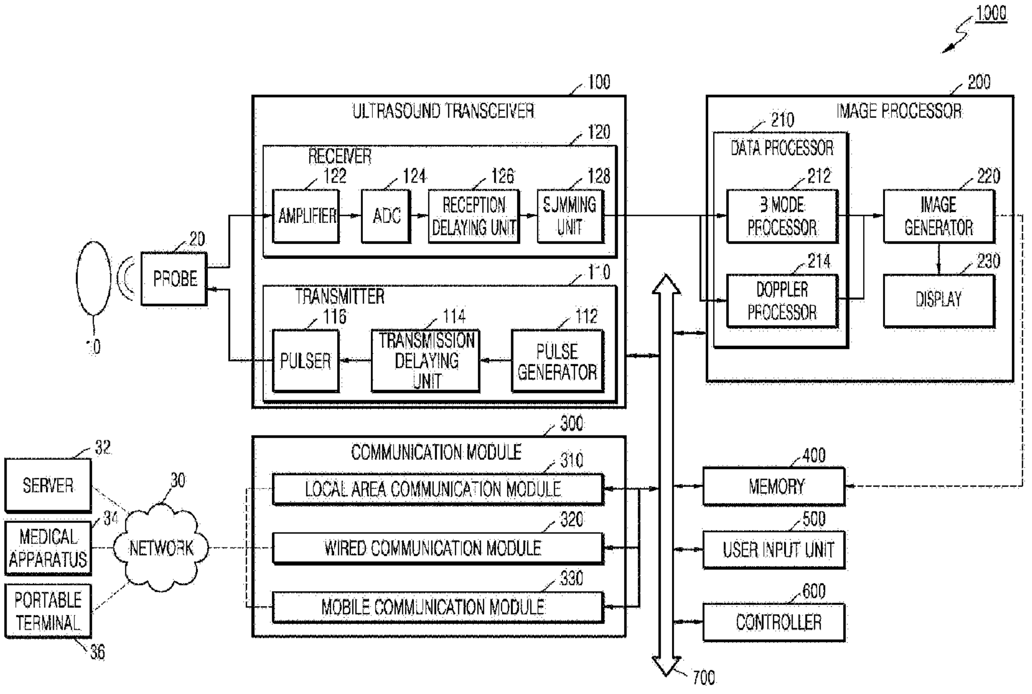
A61B 8/08 (2006.01)
A61B 5/00 (2006.01)
A61B 8/14 (2006.01)
G01S 7/52 (2006.01)

(52) **U.S. Cl.**

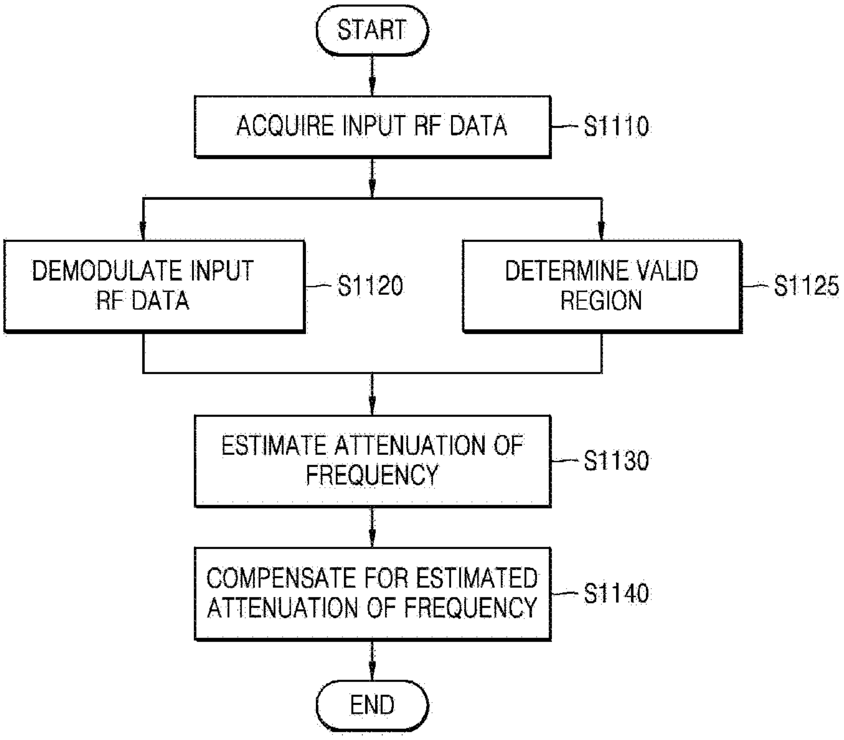
CPC ***A61B 8/5269*** (2013.01); ***G01S 7/52085*** (2013.01); ***A61B 5/7228*** (2013.01); ***A61B 5/7246*** (2013.01); ***A61B 5/7221*** (2013.01); ***A61B 8/5207*** (2013.01); ***A61B 8/14*** (2013.01)

(57) **ABSTRACT**

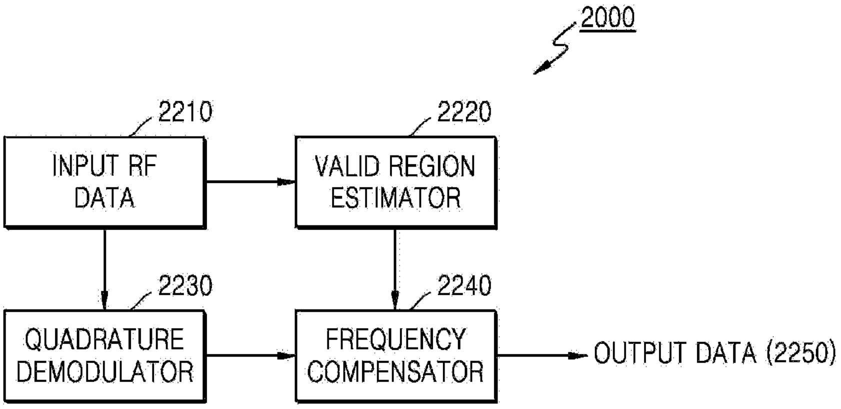
Disclosed are a method and an apparatus, which enhance a quality of an ultrasound image to provide an improved image. An adaptive demodulation method includes acquiring input radio frequency (RF) data, quadrature-demodulating the input RF data to output an inphase-quadrature (IQ) signal, determining a valid region for the input RF data, and estimating attenuation of a frequency of the IQ signal, based on data included in the valid region among the input RF data and performing frequency compensation corresponding to the estimated attenuation of the frequency.



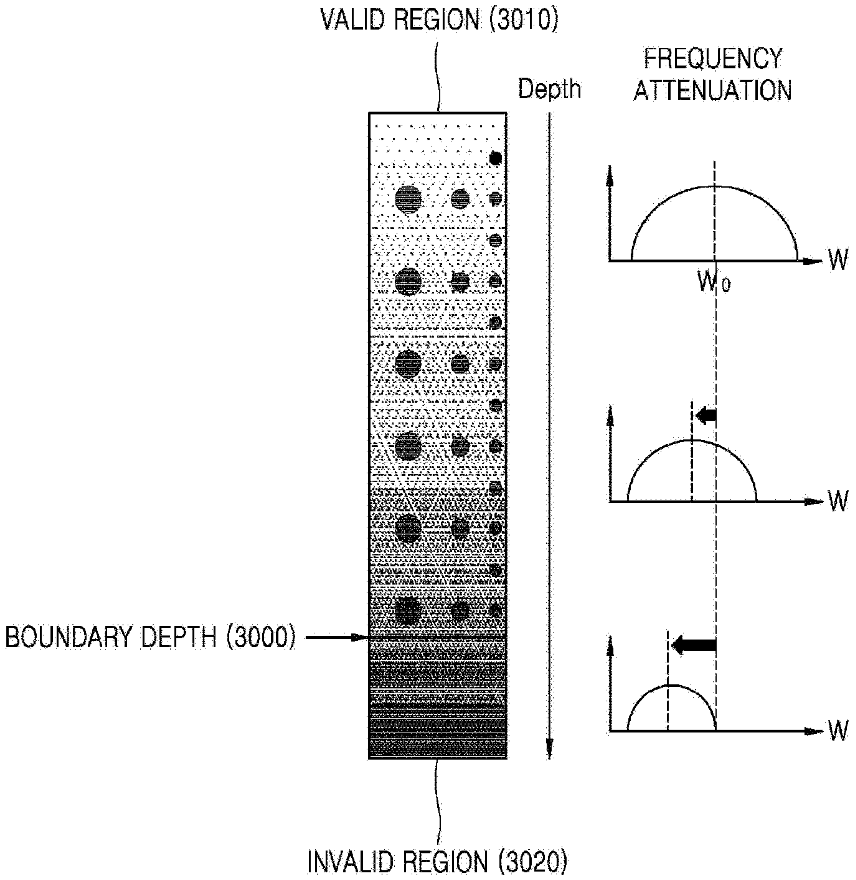
【Figure 1】



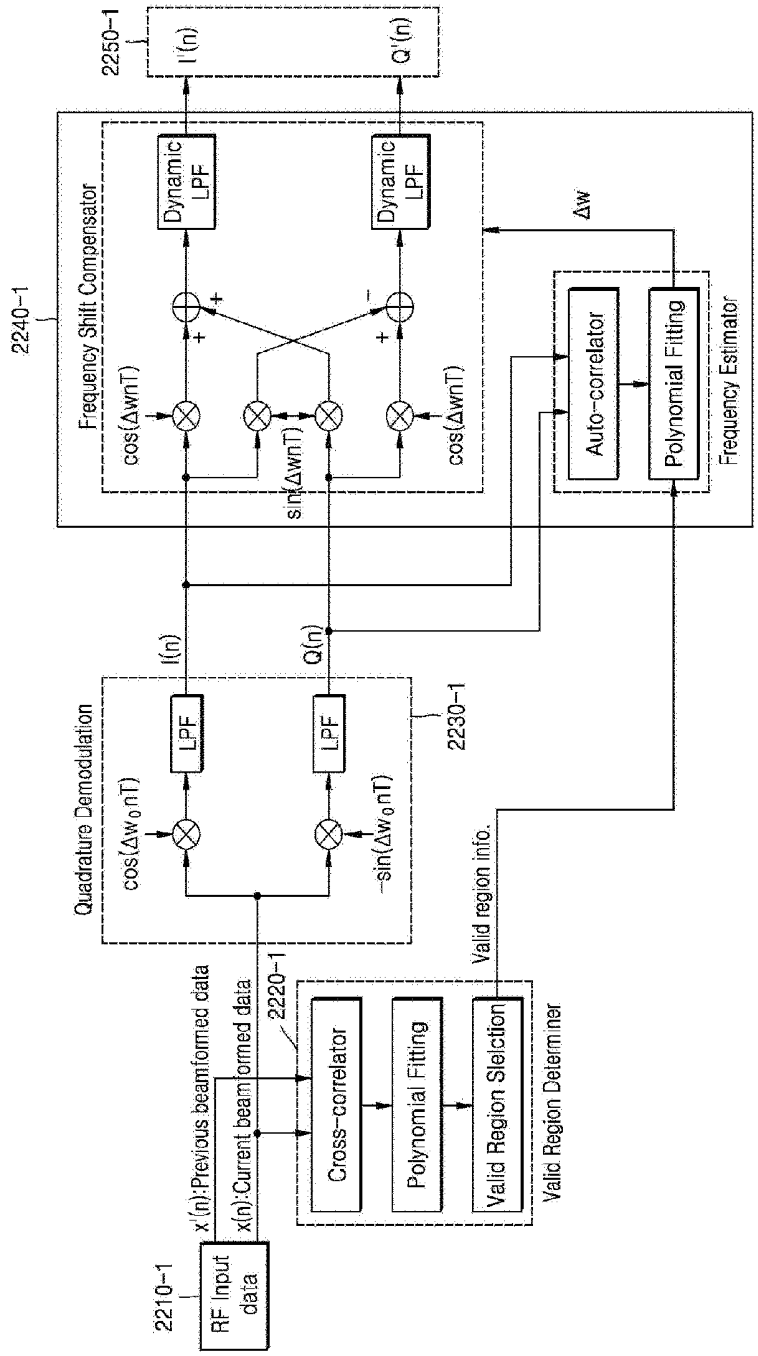
【Figure 2】



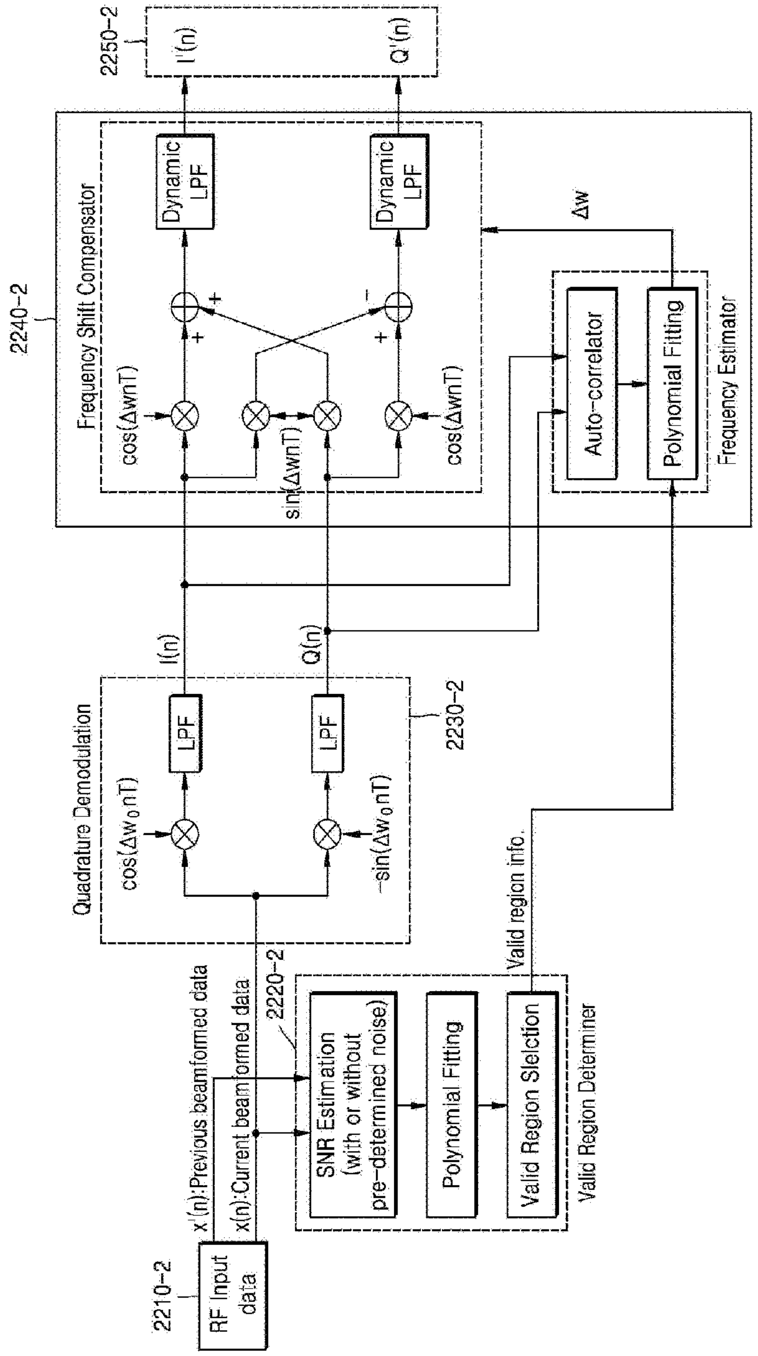
【Figure 3】


VALID REGION (3010)
Depth
FREQUENCY ATTENUATION
W
W_0
W
W
BOUNDARY DEPTH (3000)
INVALID REGION (3020)

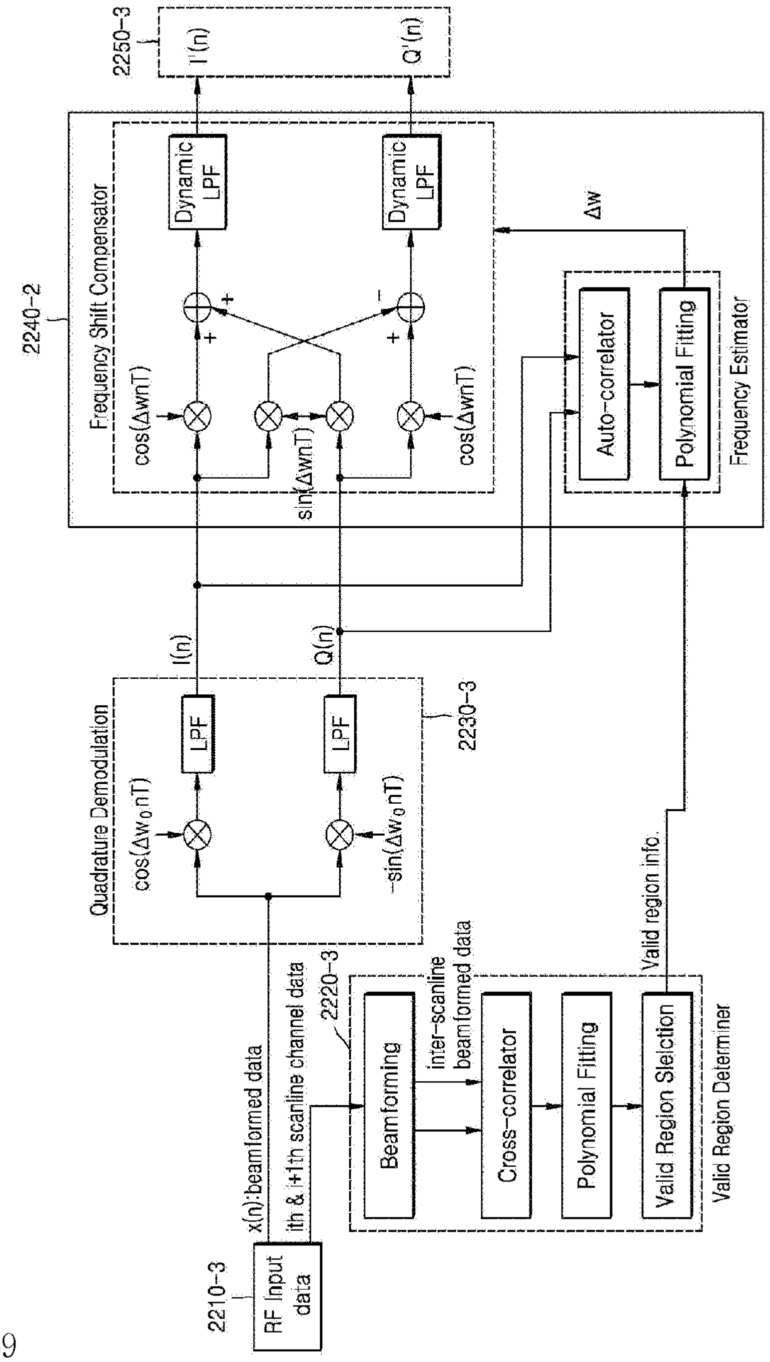
【Figure 4】


2210-1
RF Input data
x'(n):Previous beamformed data
x(n):Current beamformed data
2220-1
Cross-correlator
Polynomial Fitting
Valid Region Slelction
Valid Region Determiner
Valid region info.
Quadrature Demodulation
cos(Δw0nT)
-sin(Δw0nT)
LPF
LPF
2230-1
I(n)
Q(n)
2240-1
Frequency Shift Compensator
cos(ΔwnT)
sin(ΔwnT)
cos(ΔwnT)
+
+
-
+
Dynamic LPF
Dynamic LPF
Δw
Auto-correlator
Polynomial Fitting
Frequency Estimator
2250-1
I'(n)
Q'(n)

【Figure 5】

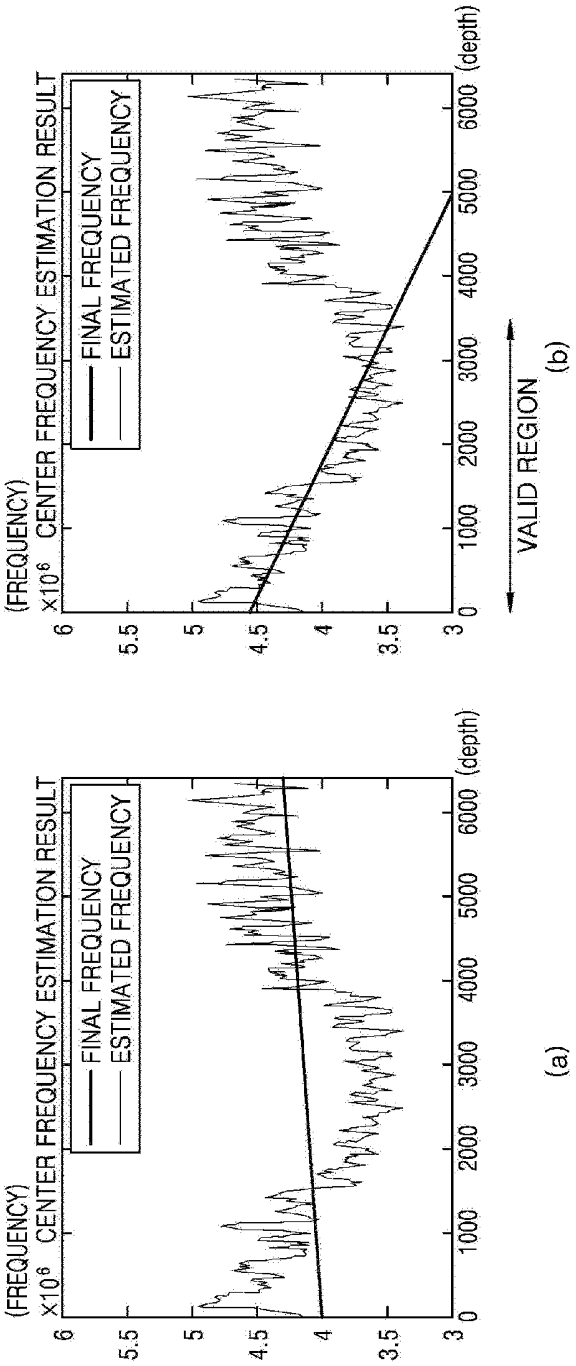

2210-2
RF Input data
x'(n):Previous beamformed data
x(n):Current beamformed data
2220-2
SNR Estimation (with or without pre-determined noise)
Polynomial Fitting
Valid Region Slelction
Valid Region Determiner
Valid region info.
Quadrature Demodulation
cos(Δw₀nT)
-sin(Δw₀nT)
LPF
LPF
2230-2
I(n)
Q(n)
2240-2
Frequency Shift Compensator
cos(ΔwnT)
sin(ΔwnT)
cos(ΔwnT)
+
+
+
-
Dynamic LPF
Dynamic LPF
Auto-correlator
Polynomial Fitting
Frequency Estimator
Δw
2250-2
I'(n)
Q'(n)

【Figure 6】


2210-3
RF Input data
x(n):beamformed data
ith & i+1th scanline channel data
2220-3
Beamforming
inter-scanline beamformed data
Cross-correlator
Polynomial Fitting
Valid Region Slelction
Valid Region Determiner
Valid region info.
Quadrature Demodulation
$\cos(\Delta w_0 nT)$
$-\sin(\Delta w_0 nT)$
LPF
LPF
2230-3
I(n)
Q(n)
2240-2
Frequency Shift Compensator
$\cos(\Delta wnT)$
$\sin(\Delta wnT)$
$\cos(\Delta wnT)$
+
+
+
−
Dynamic LPF
Dynamic LPF
Δw
Auto-correlator
Polynomial Fitting
Frequency Estimator
2250-3
I'(n)
Q'(n)

*169

【Figure 7】

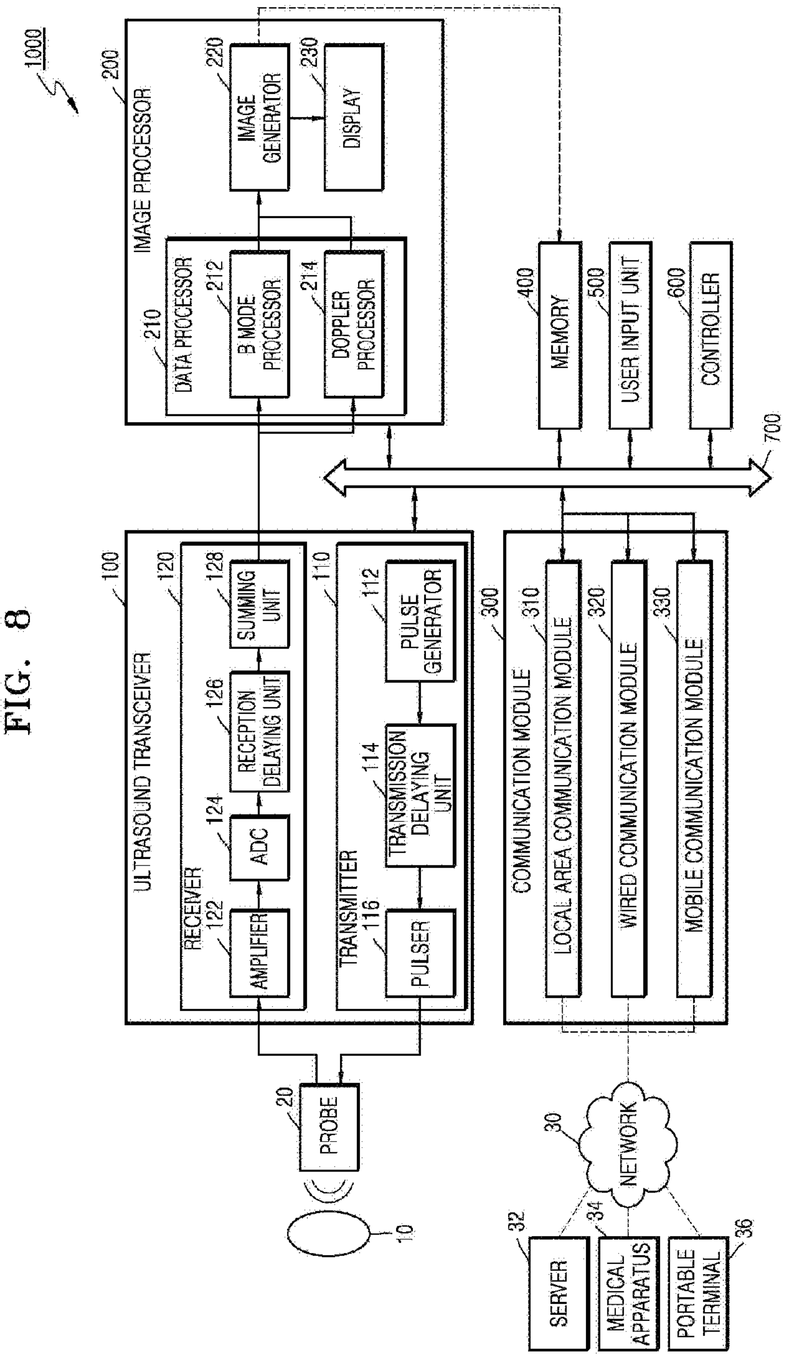

(FREQUENCY)
×10^6
CENTER FREQUENCY ESTIMATION RESULT
FINAL FREQUENCY
ESTIMATED FREQUENCY
6
5.5
5
4.5
4
3.5
3
0
1000
2000
3000
4000
5000
6000
(depth)
VALID REGION

(a)

(b)

【Figure 8】

FIG. 8



ADAPTIVE DEMODULATION METHOD AND APPARATUS FOR ULTRASOUND IMAGE

TECHNICAL FIELD

[0001] One or more exemplary embodiments relate to an adaptive demodulation method and apparatus, and more particularly, to an adaptive demodulation method and apparatus in which performance is enhanced by accurately estimating a frequency.

BACKGROUND ART

[0002] Various imaging apparatuses are used for noninvasively observing the inside of a human body. In particular, ultrasound images have more stability than other images using X-rays, and since a human body is not exposed to radiation, the ultrasound images are stable. Therefore, ultrasound images are widely used. Ultrasound diagnosis apparatuses transmit ultrasound signals generated by transducers of a probe to an object and receive echo signals reflected from the object, thereby obtaining at least one image of an internal part of the object. In particular, ultrasound diagnosis apparatuses are used for medical purposes including observation of the interior of an object, detection of foreign substances, and diagnosis of damage to the object.

[0003] A physical characteristic (for example, attenuation) of an ultrasound wave is greatly changed depending on objects (for example, human bodies of patients). For this reason, a quality of an ultrasound image is degraded depending on a feature of an object. Therefore, a method of providing a high-quality image irrespective of a feature of an object is needed.

DISCLOSURE

Technical Problem

[0004] One or more exemplary embodiments include a method and an apparatus, which enhance a quality of an ultrasound image to provide an improved image.

Technical Solution

[0005] According to one or more exemplary embodiments, an adaptive demodulation method includes: a) acquiring input radio frequency (RF) data; b) quadrature-demodulating the input RF data to output an inphase-quadrature (IQ) signal; c) determining a valid region for the input RF data; and d) estimating attenuation of a frequency of the IQ signal, based on data included in the valid region from among the input RF data and performing frequency compensation corresponding to the estimated attenuation of the frequency.

Advantageous Effects

[0006] One or more exemplary embodiments include an image demodulation method and apparatus in which a performance of restoring an image is enhanced by detecting a region where attenuation of a frequency is validly estimated.

DESCRIPTION OF DRAWINGS

[0007] These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with the accompanying drawings in which:

[0008] FIG. **1** is a flowchart illustrating a process of demodulating an image, according to an exemplary embodiment;

[0009] FIG. **2** is a block diagram illustrating an image demodulation apparatus according to an exemplary embodiment;

[0010] FIG. **3** is a conceptual diagram illustrating a valid region according to an exemplary embodiment;

[0011] FIG. **4** is a structure diagram illustrating an image demodulation apparatus according to an exemplary embodiment;

[0012] FIG. **5** is a structure diagram illustrating an image demodulation apparatus according to another exemplary embodiment;

[0013] FIG. **6** is a structure diagram illustrating an image demodulation apparatus according to another exemplary embodiment;

[0014] FIG. **7** is a graph showing a result obtained by estimating a center frequency; and

[0015] FIG. **8** is a block diagram illustrating an ultrasound diagnosis according to an exemplary embodiment.

BEST MODE

[0016] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented exemplary embodiments.

[0017] According to one or more exemplary embodiments, an adaptive demodulation method includes: a) acquiring input radio frequency (RF) data; b) quadrature-demodulating the input RF data to output an inphase-quadrature (IQ) signal; c) determining a valid region for the input RF data; and d) estimating attenuation of a frequency of the IQ signal, based on data included in the valid region from among the input RF data and performing frequency compensation corresponding to the estimated attenuation of the frequency.

[0018] Step c) may include: acquiring a cross-correlation of the input RF data; and determining the valid region, based on the cross-correlation.

[0019] The acquiring of the cross-correlation may include acquiring a cross-correlation between previous beamformed data and current beamformed data.

[0020] Step c) may further include performing beamforming of a virtual scan line by using ith scan line channel data and i+1st scan line channel data, and the acquiring of the cross-correlation may include acquiring a cross-correlation of beamformed data.

[0021] The determining of the valid region may include: acquiring a signal-to-noise (SNR) value from previous beamformed data and current beamformed data; and determining the valid region, based on the SNR value.

[0022] Step d) may include: acquiring an auto-correlation of the IQ signal; performing polynomial fitting, based on the auto-correlation and the valid region; and performing frequency shift compensation, based on a result of the polynomial fitting.

[0023] According to one or more exemplary embodiments, an adaptive demodulation apparatus includes: an input data acquirer that acquires input radio frequency (RF) data; a quadrature demodulator that quadrature-demodulates the input RF data to output an inphase-quadrature (IQ) signal; a valid region determiner that determines a valid region for the input RF data; and a frequency compensator that estimates attenuation of a frequency of the IQ signal, based on data included in the valid region from among the input RF data and performs frequency compensation corresponding to the estimated attenuation of the frequency.

[0024] The valid region determiner may include: a cross-correlator that acquires a cross-correlation of the input RF data; a polynomial function fitting unit that performs polynomial fitting on the input RF data, based on the cross-correlation; and a valid region selector that determines the valid region, based on a result of the polynomial fitting.

[0025] The cross-correlator may acquire a cross-correlation between previous beamformed data and current beamformed data.

[0026] The valid region determiner may include: a beamformer that performs beamforming of a virtual scan line by using ith scan line channel data and i+1st scan line channel data; a cross-correlator that acquires a cross-correlation, based on the virtual scan line; a polynomial function fitting unit that performs polynomial fitting, based on the cross-correlation; and a valid region selector that determines the valid region, based on a result of the polynomial fitting by the polynomial function fitting unit.

[0027] The valid region determiner may include: a signal-to-noise (SNR) estimator that estimates an SNR value from previous beamformed data and current beamformed data; a polynomial function fitting unit that performs polynomial fitting, based on the estimated SNR value; and a valid region selector that determines the valid region, based on a result of the polynomial fitting by the polynomial function fitting unit.

[0028] The frequency compensator may include: an auto-correlator that acquires an auto-correlation of the IQ signal; a polynomial function fitting unit that performs polynomial fitting, based on the auto-correlation and the valid region; and a frequency shift compensator that performs frequency shift compensation, based on a result of the polynomial fitting.

[0029] A non-transitory computer-readable storage medium according to exemplary embodiments may store a program for executing the adaptive demodulation method.

MODE FOR INVENTION

[0030] Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present exemplary embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the exemplary embodiments are merely described below, by referring to the figures, to explain aspects of the present description.

[0031] Exemplary embodiments of the inventive concept capable of being easily embodied by one of ordinary skill in the art will now be described in detail with reference to the accompanying drawings. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. In the accompanying drawings, a portion irrelevant to a description of the inventive concept will be omitted for clarity. Moreover, like reference numerals refer to like elements throughout.

[0032] Terms used in the inventive concept have been selected as general terms which are widely used at present, in consideration of the functions of the inventive concept, but may be altered according to the intent of an operator of ordinary skill in the art, conventional practice, or introduction of new technology. Also, if there is a term which is arbitrarily selected by the applicant in a specific case, in which case a meaning of the term will be described in detail in a corresponding description portion of the inventive concept. Therefore, the terms should be defined on the basis of the entire content of this specification instead of a simple name of each of the terms.

[0033] In this disclosure below, when one part (or element, device, etc.) is referred to as being 'connected' to another part (or element, device, etc.), it should be understood that the former may be 'directly connected' to the latter, or 'electrically connected' to the latter via an intervening part (or element, device, etc.). When a part "includes" or "comprises" an element, unless there is a particular description contrary thereto, the part can further include other elements, not excluding the other elements.

[0034] Throughout the specification, it will also be understood that when a component "includes" an element, unless there is another opposite description thereto, it should be understood that the component does not exclude another element and may further include another element. In addition, terms such as ". . . unit", ". . . module", or the like refer to units that perform at least one function or operation, and the units may be implemented as hardware or software or as a combination of hardware and software.

[0035] Throughout the specification, an "ultrasound image" refers to an image of an object, which is obtained using ultrasound waves. Furthermore, an "object" may be a human, an animal, or a part of a human or animal. For example, the object may be an organ (e.g., the liver, the heart, the womb, the brain, a breast, or the abdomen), a blood vessel, or a combination thereof. Also, the object may be a phantom. The phantom means a material having a density, an effective atomic number, and a volume that are approximately the same as those of an organism.

[0036] Throughout the specification, a "user" may be, but is not limited to, a medical expert, for example, a medical doctor, a nurse, a medical laboratory technologist, or a medical imaging expert, or a technician who repairs medical apparatuses.

[0037] In this disclosure below, a valid region denotes a region in which frequency estimation by an image demodulation apparatus is valid. Also, in an ultrasound wave, as a depth of an object becomes deeper, a frequency is attenuated. Frequency estimation denotes estimating an attenuation of a frequency for compensating for an attenuated frequency.

[0038] Hereinafter, exemplary embodiments will be described in detail with reference to the accompanying drawings.

[0039] FIG. **1** is a flowchart illustrating a process of demodulating an image, according to an exemplary embodiment.

[0040] In operation **S1110**, an image demodulation apparatus may acquire input radio frequency (RF) data. Here, the input RF data may be data which is acquired based on an echo signal of an ultrasound signal transmitted from an ultrasound diagnostic apparatus.

[0041] Subsequently, in operation **S1120**, the image demodulation apparatus may demodulate the input RF data. Here, the image demodulation apparatus may quadrature-demodulate the input RF data. The image demodulation apparatus may output an inphase-quadrature (IQ) signal as a result obtained by demodulating the input RF data.

[0042] As illustrated in FIG. **3**, in the acquired input RF data, as a depth becomes deeper, a frequency is attenuated. A depth denotes a distance from a surface of an object to the inside. In operation **S1130**, the image demodulation apparatus may estimate a center frequency for compensating for attenuation caused by a depth. However, when a depth is equal to or greater than a boundary depth (**3000**), the center frequency estimated by the image demodulation apparatus becomes higher as the depth increases. That is, when a depth of an image is outside a valid region (**3010**) and is equal to or greater than the boundary depth (**3000**), an efficiency of frequency estimation is reduced by data included in an invalid region (**3020**).

[0043] Therefore, in operation **S1125**, the image demodulation apparatus may determine a valid region for the input RF data. A method of determining the valid region may be variously implemented.

[0044] According to an exemplary embodiment, in operation **S1125**, the image demodulation apparatus may acquire a cross-correlation of the input RF data. Here, a cross-correlation value may be a cross-correlation value between previous beamformed data and current beamformed data. The image demodulation apparatus may determine a valid region, based on the cross-correlation. That is, the image demodulation apparatus may determine, as the valid region, a region in which the cross-correlation value is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0045] Moreover, according to another exemplary embodiment, in operation **S1125**, the image demodulation apparatus may perform beamforming of a virtual scan line by using ith scan line channel data and i+1st scan line channel data. The image demodulation apparatus may acquire a cross-correlation of the beamformed virtual scan line. The image demodulation apparatus may determine a valid region, based on the cross-correlation. That is, the image demodulation apparatus may determine, as the valid region, a region in which a value of the cross-correlation is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0046] Moreover, according to another exemplary embodiment, in operation **S1125**, the image demodulation apparatus may acquire a signal-to-noise ratio (SNR) value from previous beamformed data and current beamformed data. The image demodulation apparatus may determine, as a valid region, a region in which an SRN is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0047] A detailed exemplary embodiment of determining a valid region will be described in detail with reference to FIGS. **4** to **6**.

[0048] The image demodulation apparatus may perform frequency estimation for the valid region which is determined in operation **S1130**. That is, the image demodulation apparatus may perform an auto-correlation from the IQ signal and perform polynomial fitting, based on the determined valid region and a result obtained by performing the auto-correlation.

[0049] Subsequently, in operation **S1135**, the image demodulation apparatus may compensate for attenuation of a frequency which is estimated in operation **S1130**. That is, the image demodulation apparatus may perform frequency shift compensation on the IQ signal, based on the frequency which is estimated in operation **S1130**.

[0050] FIG. **2** is a block diagram illustrating an image demodulation apparatus **2000** according to an exemplary embodiment.

[0051] The image demodulation apparatus **2000** according to an exemplary embodiment may include a valid region estimator **2220** that estimates a valid region, a quadrature demodulator **2230** that demodulates input RF data **2210**, and a frequency compensator **2240** that estimates attenuation of a frequency of an IQ signal and performs frequency compensation corresponding to the estimated attenuation of the frequency.

[0052] The quadrature demodulator **2230** may demodulate the input RF data **2210**. Here, the quadrature demodulator **2230** may quadrature-demodulate the input RF data **2210**. The quadrature demodulator **2230** may output the IQ signal as a result obtained by demodulating the input RF data **2210**.

[0053] As illustrated in FIG. **3**, in the acquired input RF data, as a depth becomes deeper, a frequency is attenuated. A depth denotes a distance from a surface of an object to the inside. The frequency compensator **2240** may estimate a center frequency for compensating for attenuation caused by a depth. When a depth is equal to or greater than the boundary depth (**3000**), the center frequency estimated by the image demodulation apparatus becomes higher as the depth increases. That is, when a depth of an image is out of the valid region (**3010**) and is equal to or greater than the boundary depth (**3000**), an efficiency of frequency estimation is reduced by data included in the invalid region (**3020**).

[0054] Therefore, the valid region estimator **2220** may determine a valid region for the input RF data **2210**. A method of determining the valid region may be variously implemented.

[0055] According to an exemplary embodiment, the valid region estimator **2220** may acquire a cross-correlation of the input RF data. Here, the cross-correlation may be a cross-correlation between previous beamformed data and current beamformed data. The image demodulation apparatus may determine a valid region, based on the cross-correlation. That is, the valid region estimator **2220** may determine, as the valid region, a region in which the cross-correlation value is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0056] Moreover, according to another exemplary embodiment, the valid region estimator **2220** may perform beamforming of the virtual scan line by using the ith scan line channel data and the i+1st scan line channel data. The valid region estimator **2220** may acquire a cross-correlation of the beamformed virtual scan line. The valid region estimator **2220** may determine a valid region, based on the cross-correlation. That is, the valid region estimator **2220** may determine, as the valid region, a region in which a value of the cross-correlation is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0057] Moreover, according to another exemplary embodiment, the valid region estimator **2220** may acquire an SNR value from previous beamformed data and current beamformed data. The valid region estimator **2220** may determine, as a valid region, a region in which an SRN is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value.

[0058] A detailed exemplary embodiment of determining a valid region will be described in detail with reference to FIGS. **4** to **6**.

[0059] The frequency compensator **2240** may include a frequency estimator (not shown) and a frequency shift compensator (not shown). The frequency estimator (not shown) may perform frequency estimation for the valid region determined by the valid region estimator **2220**. The frequency estimator (not shown) may include an auto-correlator (not shown) and a polynomial function fitting unit (not shown). The auto-correlator (not shown) may acquire an auto-correlation, based on the IQ signal output from the quadrature demodulator **2230**. The polynomial function fitting unit (not shown) may perform polynomial fitting, based on the auto-correlation and the valid region. The frequency shift compensator (not shown) may perform frequency shift compensation, based on a result of the polynomial fitting. The frequency compensator may perform frequency compensation on the IQ signal to output data **2250**.

[0060] FIG. **3** is a conceptual diagram illustrating a valid region according to an exemplary embodiment.

[0061] As illustrated in FIG. **3**, an original signal may have a frequency w0. However, as a depth increases, a frequency may be more lowered than w0. The image demodulation apparatus may validly estimate a frequency which is attenuated in the valid region (**3010**) having a depth equal to or less than the boundary depth **3000**. However, it is difficult for the image demodulation apparatus to perform accurate frequency estimation for the invalid region **3020** having a depth greater than the boundary depth **3000**.

[0062] FIG. **4** is a structure diagram illustrating an image demodulation apparatus according to an exemplary embodiment.

[0063] The image demodulation apparatus according to an exemplary embodiment may include a valid region determiner **2220-1**, a quadrature demodulator **2230-1**, and a frequency compensator **2240-1**.

[0064] The image demodulation apparatus may acquire input RF data **2210-1**. The quadrature demodulator **2230-1** may quadrature-demodulate current beamformed data x(n) to output an IQ signal.

[0065] Moreover, the valid region determiner **2220-1** may include a cross-correlator, a polynomial function fitting unit, and a valid region selector. The cross-correlator may acquire a cross-correlation between previous beamformed data and current beamformed data. The polynomial function fitting unit may perform polynomial fitting on the input RF data **2210-1**, based on the cross-correlation. Subsequently, the valid region selector may determine a valid region, based on the cross-correlation. For example, the valid region selector may select, as the valid region, a region in which a value of the cross-correlation is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value. The valid region determiner **2220-1** may supply information about the determined valid region to the frequency compensator **2240-1**.

[0066] The frequency compensator **2240-1** may include a frequency estimator and a frequency shift compensator. The frequency estimator may include an auto-correlator, which acquires an auto-correlation, and a polynomial function fitting unit that performs polynomial fitting. The polynomial function fitting unit may estimate a frequency, based on the auto-correlation and valid region information. The frequency estimator may supply Δw to the frequency shift compensator, based on the estimated frequency.

[0067] The frequency shift compensator may correct a frequency of an IQ signal, based on Δw and pass the corrected frequency through a low-pass filter (LPF), thereby outputting output data **2250-1** of which a frequency is compensated for based on the valid region.

[0068] FIG. **5** is a structure diagram illustrating an image demodulation apparatus according to another exemplary embodiment.

[0069] The image demodulation apparatus according to another exemplary embodiment may include a valid region determiner **2220-2**, a quadrature demodulator **2230-2**, and a frequency compensator **2240-2**.

[0070] The image demodulation apparatus may acquire input RF data **2210-2**. The quadrature demodulator **2230-2** may quadrature-demodulate current beamformed data x(n) to output an IQ signal.

[0071] Moreover, the valid region determiner **2220-2** may include an SNR estimator that estimates an SNR, a polynomial function fitting unit, and a valid region selector. The SNR estimator may estimate an SNR by using a previously estimated noise value or a noise value estimated from a current image. For example, the SNR estimator may acquire an SNR value from previous beamformed data and current beamformed data.

[0072] The polynomial function fitting unit may perform polynomial fitting, based on the SNR value. Subsequently, the valid region selector may determine a valid region, based on the SNR value. For example, the valid region selector may select, as the valid region, a region in which an SNR is equal to or greater than a threshold value. The threshold value may be set by using an experimental statistic value. The valid region determiner **2220-2** may supply information about the determined valid region to the frequency compensator **2240-2**.

[0073] The frequency compensator **2240-2** may include a frequency estimator and a frequency shift compensator. The frequency estimator may include an auto-correlator, which acquires an auto-correlation, and a polynomial function fitting unit that performs polynomial fitting. The polynomial function fitting unit may estimate a frequency, based on the auto-correlation and valid region information. The frequency estimator may supply Δw to the frequency shift compensator, based on the estimated frequency.

[0074] The frequency shift compensator may correct a frequency of an IQ signal, based on Δw and pass the corrected frequency through a low-pass filter (LPF), thereby outputting output data **2250-2** of which a frequency is compensated for based on the valid region.

[0075] FIG. **6** is a structure diagram illustrating an image demodulation apparatus according to another exemplary embodiment.

[0076] The image demodulation apparatus according to another exemplary embodiment may include a valid region determiner **2220-3**, a quadrature demodulator **2230-3**, and a frequency compensator **2240-3**.

[0077] The image demodulation apparatus may acquire input RF data **2210-3**. The quadrature demodulator **2230-3** may quadrature-demodulate current beamformed data x(n) to output an IQ signal.

[0078] Moreover, the valid region determiner **2220-3** may include a beamformer, a cross-correlator, a polynomial function fitting unit, and a valid region selector. The beamformer may perform beamforming of two virtual scan lines by using ith scan line channel data and i+1st scan line channel data. The cross-correlator may acquire a cross-correlation, based on beamformed data.

[0079] FIG. **7** is a graph showing a result obtained by estimating a center frequency.

[0080] Referring to FIG. **7**, as a depth decreases, an estimated frequency is reduced. However, when a depth is greater than about 3,500, it is estimated that a frequency increases. Therefore, by using a result obtained by estimating a frequency for each depth, as shown in FIG. **7** (*a*), a finally acquired frequency does not match attenuation of an actual frequency.

[0081] However, according to an exemplary embodiment, a region in which a depth is about 0 to about 3,500 may be determined as a valid region. By using only a result of frequency estimation for the valid region, a finally acquired frequency is more similar to attenuation of an actual frequency.

[0082] FIG. **8** is a block diagram showing an ultrasound diagnosis apparatus **1000** according to an embodiment. Referring to FIG. **1**, the ultrasound diagnosis apparatus **1000** may include a probe **20**, an ultrasound transceiver **100**, an image processor **200**, a communication module **300**, a display **300**, a memory **400**, an input device **500**, and a controller **600**, which may be connected to one another via buses **700**.

[0083] The ultrasound diagnosis apparatus **1000** may be a cart type apparatus or a portable type apparatus. Examples of portable ultrasound diagnosis apparatuses may include, but are not limited to, a picture archiving and communication system (PACS) viewer, a smartphone, a laptop computer, a personal digital assistant (PDA), and a tablet PC.

[0084] The probe **20** transmits ultrasound waves to an object **10** in response to a driving signal applied by the ultrasound transceiver **100** and receives echo signals reflected by the object **10**. The probe **20** includes a plurality of transducers, and the plurality of transducers oscillate in response to electric signals and generate acoustic energy, that is, ultrasound waves. Furthermore, the probe **20** may be connected to the main body of the ultrasound diagnosis apparatus **1000** by wire or wirelessly, and according to embodiments, the ultrasound diagnosis apparatus **1000** may include a plurality of probes **20**.

[0085] A transmitter **110** supplies a driving signal to the probe **20**. The transmitter **110** includes a pulse generator **112**, a transmission delaying unit **114**, and a pulser **116**. The pulse generator **112** generates pulses for forming transmission ultrasound waves based on a predetermined pulse repetition frequency (PRF), and the transmission delaying unit **114** delays the pulses by delay times necessary for determining transmission directionality. The pulses which have been delayed correspond to a plurality of piezoelectric vibrators included in the probe **20**, respectively. The pulser **116** applies a driving signal (or a driving pulse) to the probe **20** based on timing corresponding to each of the pulses which have been delayed.

[0086] A receiver **120** generates ultrasound data by processing echo signals received from the probe **20**. The receiver **120** may include an amplifier **122**, an analog-to-digital converter (ADC) **124**, a reception delaying unit **126**, and a summing unit **128**. The amplifier **122** amplifies echo signals in each channel, and the ADC **124** performs analog-to-digital conversion with respect to the amplified echo signals. The reception delaying unit **126** delays digital echo signals output by the ADC **124** by delay times necessary for determining reception directionality, and the summing unit **128** generates ultrasound data by summing the echo signals processed by the reception delaying unit **166**. In some embodiments, the receiver **120** may not include the amplifier **122**. In other words, if the sensitivity of the probe **20** or the capability of the ADC **124** to process bits is enhanced, the amplifier **122** may be omitted.

[0087] The image processor **200** generates an ultrasound image by scan-converting ultrasound data generated by the ultrasound transceiver **100** and displays the ultrasound image. The ultrasound image may be not only a grayscale ultrasound image obtained by scanning an object in an amplitude (A) mode, a brightness (B) mode, and a motion (M) mode, but also a Doppler image showing a movement of an object via a Doppler effect. The Doppler image may be a blood flow Doppler image showing flow of blood (also referred to as a color Doppler image), a tissue Doppler image showing a movement of tissue, or a spectral Doppler image showing a moving speed of an object as a waveform. According to exemplary embodiments, the image processor **200** may include an image demodulation apparatus.

[0088] A B mode processor **212** extracts B mode components from ultrasound data and processes the B mode components. An image generator **220** may generate an ultrasound image indicating signal intensities as brightness based on the extracted B mode components **212**.

[0089] Similarly, a Doppler processor **214** may extract Doppler components from ultrasound data, and the image generator **220** may generate a Doppler image indicating a movement of an object as colors or waveforms based on the extracted Doppler components.

[0090] According to an embodiment, the image generator **220** may generate a three-dimensional (3D) ultrasound image via volume-rendering with respect to volume data and may also generate an elasticity image by imaging deformation of the object **10** due to pressure. Furthermore, the image generator **220** may display various pieces of additional information in an ultrasound image by using text and graphics. In addition, the generated ultrasound image may be stored in the memory **400**.

[0091] A display **230** displays the generated ultrasound image. The display **230** may display not only an ultrasound image, but also various pieces of information processed by the ultrasound diagnosis apparatus **1000** on a screen image via a graphical user interface (GUI). In addition, the ultrasound diagnosis apparatus **1000** may include two or more displays **230** according to embodiments.

[0092] The communication module **300** is connected to a network **30** by wire or wirelessly to communicate with an external device or a server. The communication module **300** may exchange data with a hospital server or another medical apparatus in a hospital, which is connected thereto via a PACS. Furthermore, the communication module **300** may perform data communication according to the digital imaging and communications in medicine (DICOM) standard.

[0093] The communication module **300** may transmit or receive data related to diagnosis of an object, e.g., an ultrasound image, ultrasound data, and Doppler data of the object, via the network **30** and may also transmit or receive medical images captured by another medical apparatus, e.g., a computed tomography (CT) apparatus, a magnetic resonance imaging (MRI) apparatus, or an X-ray apparatus. Furthermore, the communication module **300** may receive information about a diagnosis history or medical treatment schedule of a patient from a server and utilizes the received information to diagnose the patient. Furthermore, the communication module **300** may perform data communication not only with a server or a medical apparatus in a hospital, but also with a portable terminal of a medical doctor or patient.

[0094] The communication module **300** is connected to the network **30** by wire or wirelessly to exchange data with a server **32**, a medical apparatus **34**, or a portable terminal **36**. The communication module **300** may include one or more components for communication with external devices. For example, the communication module **1300** may include a local area communication module **310**, a wired communication module **320**, and a mobile communication module **330**.

[0095] The local area communication module **310** refers to a module for local area communication within a predetermined distance. Examples of local area communication techniques according to an embodiment may include, but are not limited to, wireless LAN, Wi-Fi, Bluetooth, ZigBee, Wi-Fi Direct (WFD), ultra wideband (UWB), infrared data association (IrDA), Bluetooth low energy (BLE), and near field communication (NFC).

[0096] The wired communication module **320** refers to a module for communication using electric signals or optical signals. Examples of wired communication techniques according to an embodiment may include communication via a twisted pair cable, a coaxial cable, an optical fiber cable, and an Ethernet cable.

[0097] The mobile communication module **330** transmits or receives wireless signals to or from at least one selected from a base station, an external terminal, and a server on a mobile communication network. The wireless signals may be voice call signals, video call signals, or various types of data for transmission and reception of text/multimedia messages.

[0098] The memory **400** stores various data processed by the ultrasound diagnosis apparatus **1000**. For example, the memory **400** may store medical data related to diagnosis of an object, such as ultrasound data and an ultrasound image that are input or output, and may also store algorithms or programs which are to be executed in the ultrasound diagnosis apparatus **1000**.

[0099] The memory **400** may be any of various storage media, e.g., a flash memory, a hard disk drive, EEPROM, etc. Furthermore, the ultrasound diagnosis apparatus **1000** may utilize web storage or a cloud server that performs the storage function of the memory **400** online.

[0100] The input device **500** refers to a means via which a user inputs data for controlling the ultrasound diagnosis apparatus **1000**. The input device **500** may include hardware components, such as a keypad, a mouse, a touch panel, a touch screen, and a jog switch. However, embodiments are not limited thereto, and the input device **1600** may further include any of various other input units including an electrocardiogram (ECG) measuring module, a respiration measuring module, a voice recognition sensor, a gesture recognition sensor, a fingerprint recognition sensor, an iris recognition sensor, a depth sensor, a distance sensor, etc.

[0101] The controller **600** may control all operations of the ultrasound diagnosis apparatus **1000**. In other words, the controller **600** may control operations among the probe **20**, the ultrasound transceiver **100**, the image processor **200**, the communication module **300**, the memory **400**, and the input device **500** shown in FIG. **1**.

[0102] All or some of the probe **20**, the ultrasound transceiver **100**, the image processor **200**, the communication module **300**, the memory **400**, the input device **500**, and the controller **600** may be implemented as software modules. However, embodiments are not limited thereto, and some of the components stated above may be implemented as hardware modules. Furthermore, at least one selected from the ultrasound transceiver **100**, the image processor **200**, and the communication module **300** may be included in the controller **600**. However, embodiments of the present invention are not limited thereto.

[0103] As described above, according to the one or more of the above exemplary embodiments, a section in which frequency estimation is valid is detected, and then, attenuation of a frequency is estimated based on the valid section, thereby providing an improved image.

[0104] The exemplary embodiment of the inventive concept may be implemented in the form of a storage medium that includes computer executable instructions, such as program modules, being executed by a computer. Non-transitory computer-readable media may be any available media that may be accessed by the computer and includes volatile media such as RAM, nonvolatile media such as ROM, and removable and non-removable media. In addition, the non-transitory computer-readable media may include computer storage media and communication media. Computer storage media includes the volatile media, non-volatile media, and removable and non-removable media implemented as any method or technology for storage of information such as computer readable instructions, data structures, program modules, or other data. The medium of communication is typically computer-readable instructions, and other data in a modulated data signal such as data structures, or program modules, or other transport mechanism and includes any information delivery media. Examples of the computer storage media include ROM, RAM, flash memory, CD, DVD, magnetic discs, or magnetic tapes.

[0105] It should be understood that the exemplary embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each exemplary embodiment should typically be considered as available for other similar features or aspects in other exemplary embodiments.

[0106] While one or more exemplary embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

1. An adaptive demodulation method comprising:

acquiring input radio frequency (RF) data;

quadrature-demodulating the input RF data to output an inphase-quadrature (IQ) signal;

determining a valid region for the input RF data; and

estimating attenuation of a frequency of the IQ signal, based on data included in the valid region from among the input RF data and performing frequency compensation corresponding to the estimated attenuation of the frequency.

2. The adaptive demodulation method of claim **1**, wherein step c) comprises:

acquiring a cross-correlation of the input RF data; and

determining the valid region, based on the cross-correlation.

3. The adaptive demodulation method of claim **2**, wherein the acquiring of the cross-correlation comprises acquiring a cross-correlation between previous beamformed data and current beamformed data.

4. The adaptive demodulation method of claim **2**, wherein, step c) further comprises performing beamforming of a virtual scan line by using ith scan line channel data and i+1st scan line channel data, and

the acquiring of the cross-correlation comprises acquiring a cross-correlation of beamformed data.

5. The adaptive demodulation method of claim **1**, wherein the determining of the valid region comprises:

acquiring a signal-to-noise (SNR) value from previous beamformed data and current beamformed data; and

determining the valid region, based on the SNR value.

6. The adaptive demodulation method of claim **1**, wherein step d) comprises:

acquiring an auto-correlation of the IQ signal;

performing polynomial fitting, based on the auto-correlation and the valid region; and

performing frequency shift compensation, based on a result of the polynomial fitting.

7. An adaptive demodulation apparatus comprising:

an input data acquirer that acquires input radio frequency (RF) data;

a quadrature demodulator that quadrature-demodulates the input RF data to output an inphase-quadrature (IQ) signal;

a valid region determiner that determines a valid region for the input RF data; and

a frequency compensator that estimates attenuation of a frequency of the IQ signal, based on data included in the valid region from among the input RF data and performs frequency compensation corresponding to the estimated attenuation of the frequency.

8. The adaptive demodulation apparatus of claim **7**, wherein the valid region determiner comprises:

a cross-correlator that acquires a cross-correlation of the input RF data;

a polynomial function fitting unit that performs polynomial fitting on the input RF data, based on the cross-correlation; and

a valid region selector that determines the valid region, based on a result of the polynomial fitting.

9. The adaptive demodulation apparatus of claim **8**, wherein the cross-correlator acquires a cross-correlation between previous beamformed data and current beamformed data.

10. The adaptive demodulation apparatus of claim **7**, wherein the valid region determiner comprises:

a beamformer that performs beamforming of a virtual scan line by using ith scan line channel data and i+1st scan line channel data;

a cross-correlator that acquires a cross-correlation, based on the virtual scan line;

a polynomial function fitting unit that performs polynomial fitting, based on the cross-correlation; and

a valid region selector that determines the valid region, based on a result of the polynomial fitting by the polynomial function fitting unit.

11. The adaptive demodulation apparatus of claim **7**, wherein the valid region determiner comprises:

a signal-to-noise (SNR) estimator that estimates an SNR value from previous beamformed data and current beamformed data;

a polynomial function fitting unit that performs polynomial fitting, based on the estimated SNR value; and

a valid region selector that determines the valid region, based on a result of the polynomial fitting by the polynomial function fitting unit.

12. The adaptive demodulation apparatus of claim **7**, wherein the frequency compensator comprises:

an auto-correlator that acquires an auto-correlation of the IQ signal;

a polynomial function fitting unit that performs polynomial fitting, based on the auto-correlation and the valid region; and

a frequency shift compensator that performs frequency shift compensation, based on a result of the polynomial fitting.

13. A non-transitory computer-readable storage medium storing a program for executing the adaptive demodulation method of claim **1**.

* * * * *

专利名称(译)	用于超声图像的自适应解调方法和装置		
公开(公告)号	US20170105705A1	公开(公告)日	2017-04-20
申请号	US15/129156	申请日	2015-03-17
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD.		
[标]发明人	YOON HEE CHUL JEON KANG WON PARK YONG SUP LEE HYUN TAEK		
发明人	YOON, HEE-CHUL JEON, KANG-WON PARK, YONG-SUP LEE, HYUN-TAEK		
IPC分类号	A61B8/08 A61B5/00 A61B8/14 G01S7/52		
CPC分类号	A61B8/5269 G01S7/52085 A61B5/7228 A61B8/14 A61B5/7221 A61B8/5207 A61B5/7246 A61B8/469 A61B8/485 A61B8/488 G01S7/52047		
优先权	1020140035380 2014-03-26 KR		
外部链接	Espacenet USPTO		

摘要(译)

公开了一种方法和装置，其增强超声图像的质量以提供改进的图像。自适应解调方法包括获取输入射频（RF）数据，对输入RF数据进行正交解调以输出同相 - 正交（IQ）信号，确定输入RF数据的有效区域，以及估计频率的衰减。 IQ信号基于输入RF数据中的有效区域中包括的数据并且执行与估计的频率衰减相对应的频率补偿。