



(11) **EP 3 158 938 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
26.04.2017 Bulletin 2017/17

(51) Int Cl.:
A61B 8/00 (2006.01)

(21) Application number: **15810379.6**

(86) International application number:
PCT/JP2015/062133

(22) Date of filing: **21.04.2015**

(87) International publication number:
WO 2015/194253 (23.12.2015 Gazette 2015/51)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

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(30) Priority: **17.06.2014 JP 2014124536**

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(54) **ULTRASONIC DIAGNOSTIC DEVICE**

(57) Provided is an ultrasonic diagnostic device in which a transmission unit (12) outputs a transmission signal to a probe (10) such that an ultrasonic wave is transmitted a plurality of times while the position of a sound source is changed. A reception unit (14) obtains the received ultrasonic wave signal from the probe (10) for each of the plurality of times that the transmission signal is transmitted. A synthesis processing unit (20) synthesizes the received ultrasonic wave signals that are

obtained over the plurality of times. A higher harmonic extraction unit (30) extracts a higher harmonic component from the synthesized received ultrasonic wave signal. An image forming unit (40) forms an ultrasonic wave image on the basis of the extracted higher harmonic component. A control unit (50) adjusts the time interval of the plurality of times that the ultrasonic wave is transmitted and controls the transmission voltage of the transmission signal.

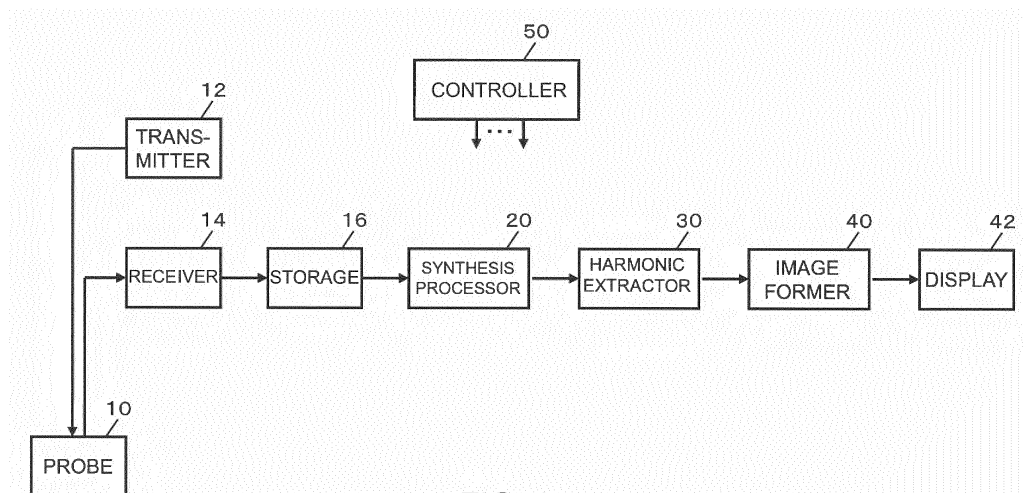


FIG. 1

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an ultrasound diagnostic apparatus, and in particular to an apparatus which uses harmonics of ultrasound.

BACKGROUND

[0002] There is known a harmonic imaging technique which uses harmonic components which are generated by a nonlinear effect of ultrasound which propagates within a living body. Ultrasound diagnostic apparatuses equipped with the function of the harmonic imaging are widely in use because the device is not easily affected by an artifact such as multiple echo because a propagation distance of the ultrasound is short and harmonic components are not generated in a large amount near a surface of the body, that contrast resolution can be improved because a side lobe is reduced because the harmonic component is generated proportional to a square of sound pressure, or the like.

[0003] In addition, as a technique related to transmission and reception of the ultrasound, synthetic transmit aperture is known (for example, refer to Patent Document 1). Synthetic transmit aperture has attracted much attention as an alternative technique of a method in which an ultrasound beam is formed and scanned by phasing addition process or the like.

CITATION LIST

PATENT LITERATURE

[0004] Patent Document 1: JP 2009-101165 A

SUMMARY

TECHNICAL PROBLEM

[0005] In view of the related art described above, the present inventors have repeated research and development for a technique related to harmonics of the ultrasound such as, for example, harmonic imaging, and in particular, has looked into combining a technique related to the harmonics of the ultrasound and a technique related to the synthetic transmit aperture.

[0006] The present disclosure has been made in the research and development, and an advantage thereof lies in provision of an improved technique combining a technique related to the harmonics of the ultrasound and a technique related to synthetic transmit aperture.

SOLUTION TO PROBLEM

[0007] According to one aspect of the present disclosure, there is provided an ultrasound diagnostic apparatus

tus comprising: a probe that transmits and receives ultrasound; a transmitter that outputs a transmission signal to the probe to transmit ultrasound a plurality of times while changing a position of a sound source; a receiver that obtains a reception signal of ultrasound from the probe for each time of the transmission over the plurality of times; a synthesis processor that synthesizes reception signals of ultrasound obtained over the plurality of times; a harmonic extractor that extracts a harmonic component from the synthesized reception signal of ultrasound; an image former that forms an ultrasound image based on the extracted harmonic component; and a controller that adjusts a time interval of the transmission over the plurality of times and controls a transmission voltage of the transmission signal.

[0008] In the above-described apparatus, the probe desirably includes a plurality of transducer elements each of which transmits and receives ultrasound. The position of the sound source may be, for example, on a transmission and reception surface of the probe (including a region nearby), or a position distanced away from the probe; for example, a transmission focus position, may be set as a virtual sound source. Moreover, the harmonic component may be extracted using a band-pass filter (high-pass filter) or by a known method such as pulse inversion or the like.

[0009] According to the above-described apparatus, when the transmission voltage is controlled, by adjusting the time interval of transmission, for example, an allowable range of the transmission voltage can be changed. With such a configuration, for example, it becomes possible to control the transmission voltage so that a desired transmission energy is not exceeded.

[0010] According to another aspect of the present disclosure, the controller controls the transmission voltage in such a manner that the transmission voltage is \sqrt{m} times a standard voltage which is set as a standard state, wherein m is a real number greater than 1. With such a configuration, for example, a signal value of a harmonic component can be set to be m times that of the standard state.

[0011] According to another aspect of the present disclosure, in controlling the transmission voltage to be \sqrt{m} times the standard voltage, the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state. With such a configuration, for example, the signal value of the harmonic component can be set to be m times that of the standard state while maintaining a transmission energy of the standard state.

[0012] According to another aspect of the present disclosure, in adjusting the time interval of transmission over the plurality of times and controlling the transmission voltage of the transmission signal, the controller sets a number of transmissions according to the adjusted time interval of transmission. By setting the number of transmissions according to the adjusted time interval of transmission, it becomes possible, for example, to suppress

a change in a frame rate due to the adjustment of the time interval of transmission.

[0013] According to another aspect of the present disclosure, the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state, wherein m is a real number greater than 1, and sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state. With such a configuration, for example, the frame rate of the standard state can be maintained.

[0014] According to another aspect of the present disclosure, the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state, sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state, and controls the transmission voltage in such a manner that the transmission voltage is \sqrt{m} times a standard voltage which is set as a standard state. With such a configuration, for example, a signal-to-noise ratio of the harmonic component can be set to be \sqrt{m} times that of the standard state while maintaining the transmission energy and the frame rate of the standard state.

ADVANTAGEOUS EFFECTS OF INVENTION

[0015] According to various aspects of the present disclosure, an improved technique is provided by combining the technique related to the harmonics of the ultrasound and the technique related to the synthetic transmit aperture.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

FIG. 1 is a diagram showing the overall structure of an ultrasound diagnostic apparatus according to an embodiment of the present disclosure.

FIG. 2 is a diagram for explaining a first specific configuration of synthetic transmit aperture.

FIG. 3 is a diagram for explaining a second specific example of synthetic transmit aperture.

FIG. 4 is a diagram showing a specific example control by a controller.

DESCRIPTION OF EMBODIMENTS

[0017] FIG. 1 is an overall structural diagram of an ultrasound diagnostic apparatus according to an embodiment of the present disclosure. A probe 10 is an ultrasound probe which transmits and receives ultrasound to and from a region including a diagnosis target. The probe 10 comprises a plurality of transducer elements which transmit and receive ultrasound, and is desirably, for ex-

ample, a linear-type or sector-type ultrasound probe, but may alternatively be an ultrasound probe of another type.

[0018] A transmitter 12 outputs a transmission signal to the probe 10, to transmit ultrasound over a plurality of times while changing a position of a sound source. A receiver 14 obtains a reception signal of ultrasound from the probe 10 for each time of the transmission over the plurality of times. The reception signals of ultrasound obtained over the plurality of times are stored in a storage 16.

[0019] A synthesis processor 20 applies a synthesis process of the reception signals (reception signal data) stored in the storage 16; that is, the ultrasound reception signals obtained over the plurality of times. The transmitter 12, the receiver 14, and the synthesis processor 20 execute a transmission and reception process called synthetic transmit aperture, to obtain a synthesized ultrasound reception signal.

[0020] FIG. 2 is a diagram for explaining a first specific configuration of the synthetic transmit aperture. FIG. 2 shows a specific example configuration in which transmissions of N times from transmission 1 to transmission N (wherein N is a natural number) are executed while changing the position of the sound source, reception signals of N times from reception 1 to reception N are obtained, and a synthesis process of the N reception signals is executed to obtain frame data after the synthesis process. In FIG. 2, the probe 10 comprises N transducer elements, which are each shown with a rectangle and with an element number ($1 \sim N$) shown within the rectangle.

[0021] In the first specific configuration shown in FIG. 2, in the transmission of each time, ultrasound is transmitted from one transducer element, and in the reception of each time, ultrasound is received by N transducer elements. For example, in the transmission of a first time, ultrasound is transmitted only from the transducer 1, and a reflection involved with the transmitted ultrasound is received by each of the transducer elements $1 \sim N$. In other words, the ultrasound reception signal is obtained at each of the transducer elements $1 \sim N$. In the transmission of a second time, the ultrasound is transmitted only from the transducer 2, and a reflection involved with the transmitted ultrasound is received by each of the transducer elements $1 \sim N$. Similarly, transmissions and receptions of third and later times are repeated. In the transmission of an N th time, the ultrasound is transmitted only from the transducer element N , and the ultrasound reception signal is obtained by each of the transducer elements $1 \sim N$.

[0022] In addition, in the first specific configuration of FIG. 2, in the reception of each time, N reception beams corresponding to N beam lines shown by broken lines are formed. Specifically, based on the reception signals received by the transducer elements $1 \sim N$, each reception beam is formed with each of a plurality of sample points on each beam line as a reception focus, and a reception signal corresponding to each beam line (reception beam signal) is obtained. FIG. 2 shows a sample

point P as a representative of the plurality of sample points on each beam line.

[0023] The synthesis processor 20 applies a synthesis process on the reception signals over the plurality of times from the reception 1 to reception N, to obtain frame data formed from the synthesized reception signals. In the first specific configuration of FIG. 2, the synthesis processor 20 applies an addition process on the reception signals of each of the sample points included in the reception signals (reception beam signals) from the reception 1 to the reception N, to obtain a reception signal after the synthesis process related to the sample point. For example, N reception signals at a sample point P included in the reception signals from the reception 1 to the reception N are added, to obtain the reception signal after the synthesis process at the sample point P.

[0024] With the first specific configuration of FIG. 2, it is possible to obtain the synthesis-processed frame data formed from reception signals at a plurality of sample points while realizing both transmission focus and reception focus at each sample point.

[0025] Alternatively, in place of forming the reception beam at the reception of each time, for example, it is also possible to obtain a reception signal from each of the transducer elements 1 ~ N at the reception of each time, and the synthesis process may be applied to the reception signals over N times from reception 1 to reception N, to obtain the synthesis-processed frame data.

[0026] Alternatively, transmissions of M times (wherein M is a natural number smaller than N) may be executed dispersively by M transducer elements with several transducer elements therebetween, ultrasound may be received by N transducer elements at the reception of each time, and the reception signals obtained over M times may be synthesized to obtain the synthesis-processed frame data. In executing the transmission of M times, for example, the positions of the sound sources (transducer elements transmitting the ultrasound) are desirably at a constant interval, but the interval of the sound sources is not limited to a constant interval.

[0027] FIG. 3 is a diagram for explaining a second specific configuration of the synthetic transmit aperture. In the second specific configuration of FIG. 3, a virtual sound source is realized by transmission focus, transmissions of N times from transmission 1 to transmission N (wherein N is a natural number) are executed while changing the position of the virtual sound source, reception signals of N times from reception 1 to reception N are obtained, and the reception signals of N times are synthesized to obtain frame data after the synthesis process. The probe 10 shown in FIG. 3 also includes N transducer elements, each of which is shown with a rectangle and with an element number (1 ~ N) shown within the rectangle.

[0028] In the second specific configuration of FIG. 3, ultrasound is transmitted from several transducer elements in order to realize the transmission focus at the transmission of each time, and the ultrasound is received

by N transducer elements at the reception of each time. For example, in the transmission of a first time, ultrasound is transmitted from transducer elements 1 ~ 5 with a transmission focus F1 as the focal point, and a reflection involved with the transmitted ultrasound is received by each of the transducer elements 1 ~ N. In other words, a reception signal of the ultrasound is obtained at each of the transducer elements 1 ~ N. In the transmission of a second time, ultrasound is transmitted from the transducer elements 2 ~ 6 with a transmission focus F2 as the focal point, and a reflection involved with the transmitted ultrasound is received at each of the transducer elements 1 ~ N. Similarly, the transmission and reception of third and later times are repeated, and, at the transmission of an Nth time, ultrasound is transmitted from the transducer element N and nearby transducer elements with a transmission focus FN as the focal point, and a reception signal of the ultrasound is obtained at each of the transducer elements 1 ~ N.

[0029] In addition, in the second specific configuration of FIG. 3, in the reception of each time, N reception beams corresponding to N beam lines shown with broken lines are formed. Specifically, based on the reception signals received by the transducer elements 1 ~ N, each reception beam is formed with each of a plurality of sample points on each beam line as a reception focus, and a reception signal (reception beam signal) corresponding to each beam line is obtained. FIG. 3 shows a sample point P as a representative of the plurality of sample points on each beam line.

[0030] The synthesis processor 20 applies the synthesis process on the reception signals over the plurality of times from the reception 1 to the reception N, to obtain frame data formed from the synthesized reception signal. Similar to the first specific configuration of FIG. 2, in the second specific configuration of FIG. 3 also, the synthesis processor 20 applies an addition process on the reception signals of each sample point included in the reception signals (reception beam signals) from the reception 1 to the reception N, to obtain the synthesized reception signal related to the sample point. For example, N reception signals at the sample point P included in the reception signals from the reception 1 to the reception N are added, to obtain the synthesis-processed reception signal at the sample point P.

[0031] Alternatively, in place of forming the reception beam at the reception of each time, for example, a reception signal may be obtained from each of the transducer elements 1 ~ N at the reception of each time, and the reception signals over N times from the reception 1 to the reception N may be synthesized to obtain the synthesis-processed frame data.

[0032] Alternatively, the interval of the virtual sound source (transmission foci F1, F2, ...) may be widened, and, for example, transmission of M times (wherein M is a natural number smaller than N) may be executed with each of M transmission foci F1 ~ FM as the focal point, ultrasound may be received by N transducer elements

at the reception of each time, and the reception signals obtained over M times may be synthesized, to obtain the synthesis-processed frame data. In executing the transmission of M times, for example, the positions of the virtual sound sources (transmission foci F1 ~ FM) are desirably at a constant interval, but the interval of the sound sources is not limited to the constant interval.

[0033] Referring back to FIG. 1, a harmonic extractor 30 extracts a harmonic component included in the synthesized reception signal obtained from the synthesis processor 20. The harmonic extractor 30 obtains synthesized frame data (refer to FIGs. 2 and 3) from the synthesis processor 20, and extracts a harmonic component (for example, a second-order harmonic component) from the synthesized reception signal included in the frame data, for example, the synthesized reception signal corresponding to each beam line. The harmonic component may be extracted, for example, using a band-pass filter (high-pass filter) or by a known method such as pulse inversion or the like.

[0034] An image former 40 forms an ultrasound image (image data) based on the harmonic component extracted by the harmonic extractor 30. The image former 40 forms the ultrasound image of, for example, the harmonic imaging. The ultrasound image formed by the image former 40 is displayed on a display 42.

[0035] A controller 50 controls the overall ultrasound diagnostic apparatus shown in FIG. 1. The ultrasound diagnostic apparatus of FIG. 1 desirably includes an operation device such as, for example, a mouse, a keyboard, a trackball, a touch panel, a joystick, or the like. In the overall control by the controller, commands received from the user through the operation device or the like are also reflected.

[0036] Of the structures shown in FIG. 1 (units with reference numerals attached), each of the transmitter 12, the receiver 14, the synthesis processor 20, the harmonic extractor 30, and the image former 40 may be realized using hardware such as, for example, an electronic or electric circuit, a processor, or the like, and a device such as a memory may be used as necessary in realizing these units. Alternatively, the functions corresponding to these units may be realized by a cooperation of hardware such as a CPU, a processor, and a memory, and software (program) defining operations of the CPU and the processor.

[0037] Desirable specific examples of the storage 16 include a semiconductor memory, a hard disk drive, or the like, and desirable specific examples of the display 42 include a liquid crystal display or the like. The controller 50 can be realized, for example, by a cooperation of hardware such as a CPU, a processor, and a memory, and software (program) defining operations of the CPU and the processor.

[0038] In the ultrasound diagnostic apparatus of FIG. 1, when the controller 50 uses the synthetic transmit aperture in the harmonic imaging, the controller 50 adjusts a time interval of transmission over a plurality of times,

to control a transmission voltage of the transmission signal. Further, in adjusting the time interval of the transmission over the plurality of times and controlling the transmission voltage of the transmission signal, the controller 50 adjusts the number of transmissions according to the adjusted time interval of transmission.

[0039] The transmission voltage is a maximum voltage of the transmission signal which is output from the transmitter 12 to each transducer of the probe 10 (for example, a maximum voltage within a transmission pulse waveform), the time interval of transmission is a time between transmissions in the transmission over a plurality of times in the synthetic transmit aperture (that is, a pulse repetition period: PRT), and the number of transmissions is the number of transmissions in the synthetic transmit aperture.

[0040] In the ultrasound diagnostic apparatus, from the viewpoint of safety with respect to the subject, various restrictions (for example, Ispta, MI, TI, probe surface temperature increase, or the like) are applied on design. Of various restrictions, in particular, the probe surface temperature increase is in many cases the strictest condition. The probe surface temperature increase is proportional to an electric power energy introduced to the probe 10. Specifically, the probe surface temperature increase is proportional to a product of introduced electric power and 1/PRT, and thus, is proportional to a product of a square of the transmission voltage and 1/PRT.

[0041] In general, PRT is determined according to a roundtrip time of the ultrasound to and from a depth to be diagnosed. Thus, a PRT which is set as a standard in the apparatus with the depth to be diagnosed as a reference; that is, a PRT (time interval of transmission) which is set as a standard state, is referred to as a standard PRT. In addition, a maximum transmission voltage according to the restriction of the probe surface temperature increase (a value which does not exceed the limit) at the standard PRT is referred to as a standard transmission voltage V.

[0042] In the ultrasound diagnostic apparatus of FIG. 1, when the controller 50 uses the synthetic transmit aperture in the harmonic imaging, the controller 50 sets a longer PRT (larger PRT) than the standard PRT. For example, the PRT (time interval of transmission) in the synthetic transmit aperture is set to be m times (wherein m is a real number greater than 1) the standard PRT.

[0043] By setting the PRT to be m times the standard PRT, the maximum transmission voltage according to the restriction of the probe surface temperature increase can be increased to \sqrt{m} times the standard transmission voltage V. This is because the probe surface temperature increase is proportional to the electric power energy introduced to the probe 10, and thus is proportional to a product of a square of the transmission voltage and 1/PRT.

[0044] Further, the controller 50 adjusts the number of transmissions according to the adjusted PRT (time interval of transmission). That is, the standard number of

transmissions which is set as the standard state is adjusted. The controller 50 sets, for example, the number of transmissions to $1/m$ times the standard number of transmissions when the controller 50 sets the PRT to be m times the standard PRT. With this process, the frame rate at the standard state can be maintained.

[0045] When the transmission voltage is set at \sqrt{m} times the standard transmission voltage V , the harmonic signal (harmonic component extracted from the reception signal) becomes m times that in the standard transmission voltage V . This is because the harmonic signal (for example, the second-order harmonic component) is proportional to the square of the transmission voltage. Therefore, when the transmission voltage becomes \sqrt{m} times the standard transmission voltage V , because the electrical noise is unchanged, an SNR (signal-to-noise ratio) of the harmonic signal becomes m times that in the case of the standard transmission voltage V .

[0046] On the other hand, in the synthetic transmit aperture, when the number of transmission is set $1/m$ times the standard number of transmissions, the SNR becomes $1/\sqrt{m}$ times that in the case of the standard number of transmissions.

[0047] With the combined improvement (m times) of the SNR due to the adjustment of the transmission voltage and the change ($1/\sqrt{m}$ times) of the SNR due to the adjustment of the number of transmissions, the SNR becomes \sqrt{m} times that of the standard state. In other words, in the harmonic imaging by synthetic transmit aperture, the SNR can be improved while complying with the restrictions on the probe surface temperature increase. Further, as already described, the frame rate at the standard state can also be maintained.

[0048] In general, as the number of transmissions is reduced in the synthetic transmit aperture, the transmission and reception characteristics of the ultrasound are degraded, and artifacts such as a side lobe and a grating lobe tend to appear more often. In the harmonic imaging, because the number of these artifacts is originally small, the reduction in the number of transmissions in the synthetic transmit aperture can be permitted to a certain degree. However, when the number m is set too large; that is, when the number of transmissions is reduced excessively, the influence of the artifacts or the like would be increased to a degree that the artifacts cannot be ignored. Thus, it is desirable to suitably set the number m according to a balance between the improvement of the SNR of the image and the artifacts or the like appearing in the image.

[0049] FIG. 4 is a diagram showing a specific example control by the controller 50. FIG. 4 shows a specific example control related to the transmission time interval (PRT) or the like when the synthetic transmit aperture is used in the harmonic imaging.

[0050] As already described, the controller 50 sets the transmission time interval (PRT) to be m times the standard PRT, the maximum transmission voltage to be \sqrt{m} times the standard transmission voltage, and the number

of transmissions to be $1/m$ times the standard number of transmissions. With such a configuration, the harmonic signal becomes m times that in the case of the standard transmission voltage V , and the SNR becomes \sqrt{m} times that in the case of the standard state.

[0051] FIG. 4 also shows a comparative example of a case where the synthetic transmit aperture is used in the fundamental wave mode, for comparison with the harmonic imaging. In the fundamental wave mode, the fundamental wave component (fundamental wave signal) included in the reception signal is used. When the transmission voltage is set to \sqrt{m} times the standard transmission voltage V , the fundamental wave component becomes \sqrt{m} times that in the case of the standard transmission voltage V . Therefore, in the fundamental wave mode, when the transmission voltage is set to be \sqrt{m} times the standard transmission voltage V , the SNR (signal-to-noise ratio) becomes \sqrt{m} times that in the case of the standard transmission voltage V . On the other hand, when the number of transmissions is set to be $1/m$ times the standard number of transmissions in the synthetic transmit aperture, the SNR becomes $1/\sqrt{m}$ times that in the case of the standard number of transmissions. In the fundamental wave mode, because of the improvement (\sqrt{m} times) of the SNR due to the adjustment of the transmission voltage and the change ($1/\sqrt{m}$ times) of the SNR due to the adjustment of the number of transmissions, the total SNR becomes 1 times, and the SNR is not improved.

[0052] An embodiment of the present disclosure has been described. The above-described embodiment is merely exemplary from all aspects, and does not limit the scope of the present disclosure. The present disclosure includes various modifications within the scope and spirit thereof.

REFERENCE SIGNS LIST

[0053] 10 PROBE; 12 TRANSMITTER; 14 RECEIVER; 16 STORAGE; 20 SYNTHESIS PROCESSOR; 30 HARMONIC EXTRACTOR; 40 IMAGE FORMER; 42 DISPLAY; 50 CONTROLLER.

Claims

1. An ultrasound diagnostic apparatus comprising:

- a probe that transmits and receives ultrasound;
- a transmitter that outputs a transmission signal to the probe to transmit ultrasound over a plurality of times while changing a position of a sound source;
- a receiver that obtains a reception signal of ultrasound from the probe for each time of the transmission over the plurality of times;
- a synthesis processor that synthesizes reception signals of ultrasound obtained over the plu-

rality of times;
 a harmonic extractor that extracts a harmonic component from the synthesized reception signal of ultrasound;
 an image former that forms an ultrasound image based on the extracted harmonic component;
 and
 a controller that adjusts a time interval of the transmission over the plurality of times and controls a transmission voltage of the transmission signal.

2. The ultrasound diagnostic apparatus according to Claim 1, wherein

the controller controls the transmission voltage in such a manner that the transmission voltage is \sqrt{m} times a standard voltage which is set as a standard state, wherein m is a real number greater than 1.

3. The ultrasound diagnostic apparatus according to Claim 2, wherein

in controlling the transmission voltage to be \sqrt{m} times the standard voltage, the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state.

4. The ultrasound diagnostic apparatus according to Claim 1, wherein

in adjusting the time interval of transmission over the plurality of times and controlling the transmission voltage of the transmission signal, the controller sets a number of transmissions according to the adjusted time interval of transmission.

5. The ultrasound diagnostic apparatus according to Claim 4, wherein

the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state, wherein m is a real number greater than 1, and sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state.

6. The ultrasound diagnostic apparatus according to Claim 5, wherein

the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a

standard state, sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state, and controls the transmission voltage in such a manner that the transmission voltage is \sqrt{m} times a standard voltage which is set as a standard state.

7. The ultrasound diagnostic apparatus according to Claim 3, wherein

in adjusting the time interval of transmission over the plurality of times and controlling the transmission voltage of the transmission signal, the controller sets a number of transmissions according to the adjusted time interval of transmission.

8. The ultrasound diagnostic apparatus according to Claim 7, wherein

the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state, wherein m is a real number greater than 1, and sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state.

9. The ultrasound diagnostic apparatus according to Claim 8, wherein

the controller adjusts the time interval of transmission in such a manner that the time interval is m times a standard time which is set as a standard state, sets the number of transmissions in such a manner that the number of transmissions is $1/m$ times a standard number which is set as a standard state, and controls the transmission voltage in such a manner that the transmission voltage is \sqrt{m} times a standard voltage which is set as a standard state.

10. The ultrasound diagnostic apparatus according to Claim 1, wherein

the probe comprises a plurality of transducer elements, ultrasound is transmitted from one transducer element at transmission of each time, and the transmitter changes the position of the sound source by changing a transducer element to transmit the ultrasound in the transmission over the plurality of times.

11. The ultrasound diagnostic apparatus according to Claim 1, wherein

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the probe comprises a plurality of transducer elements,
ultrasound is transmitted from several transducer elements to realize transmission focus at transmission of each time, and
the transmitter changes the position of the sound source by changing a position of the transmission focus in the transmission over the plurality of times.

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12. The ultrasound diagnostic apparatus according to Claim 1, wherein

the probe comprises a plurality of transducer elements, and
the receiver forms reception beams corresponding to a plurality of beam lines based on receptions received by the plurality of transducer elements of the probe, and obtains a reception signal corresponding to each beam line, for each time of the transmission over the plurality of times.

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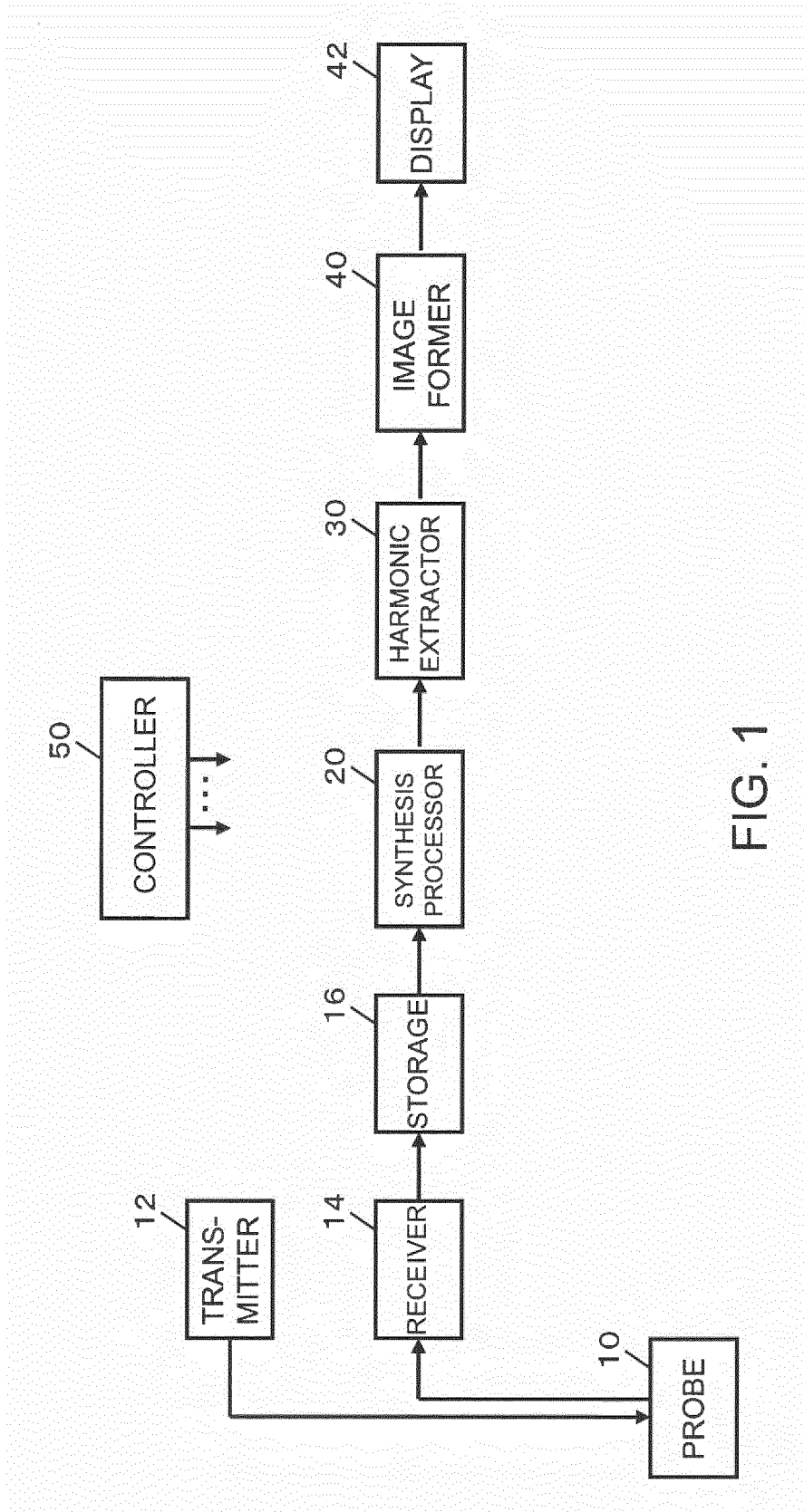


FIG. 1

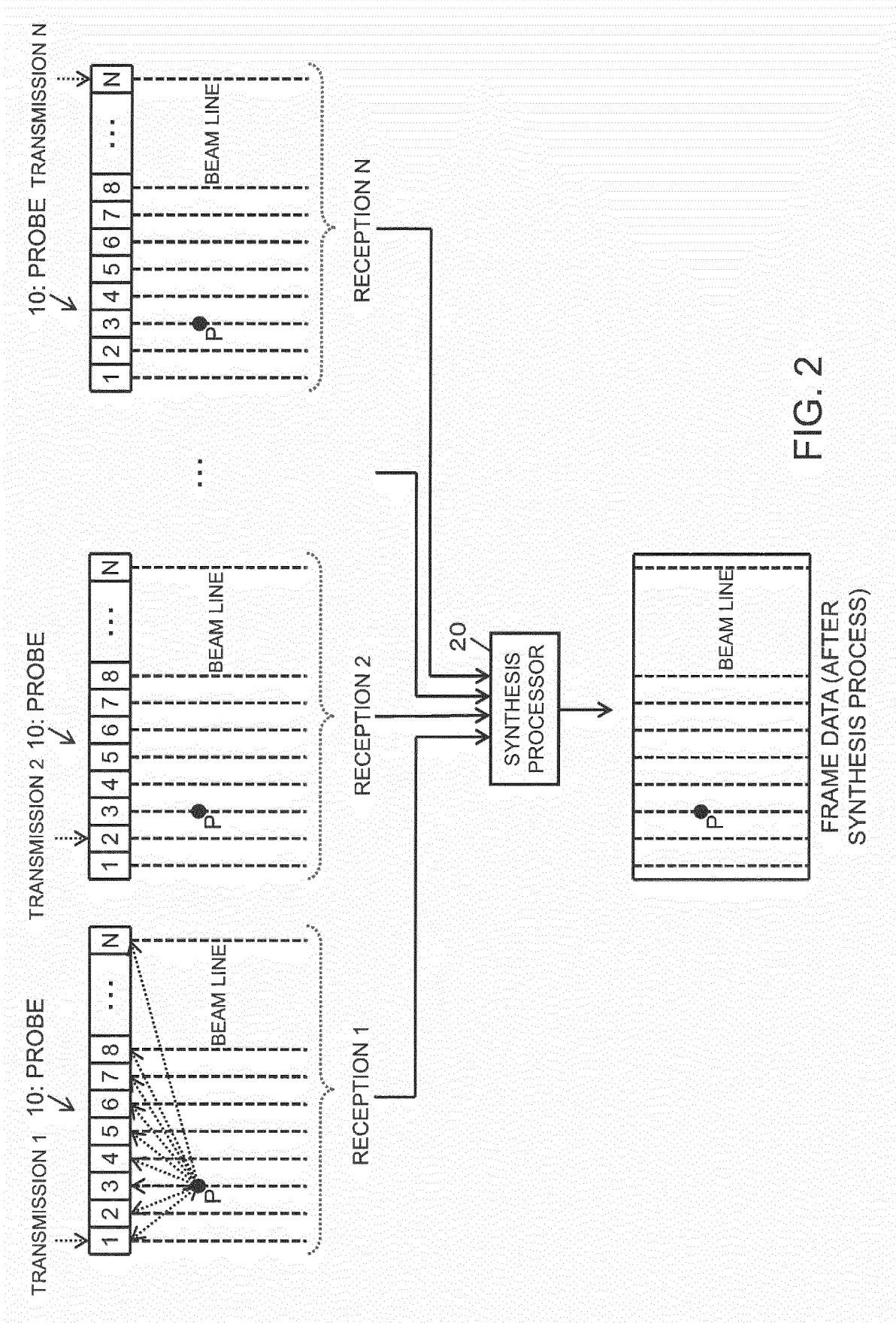


FIG. 2

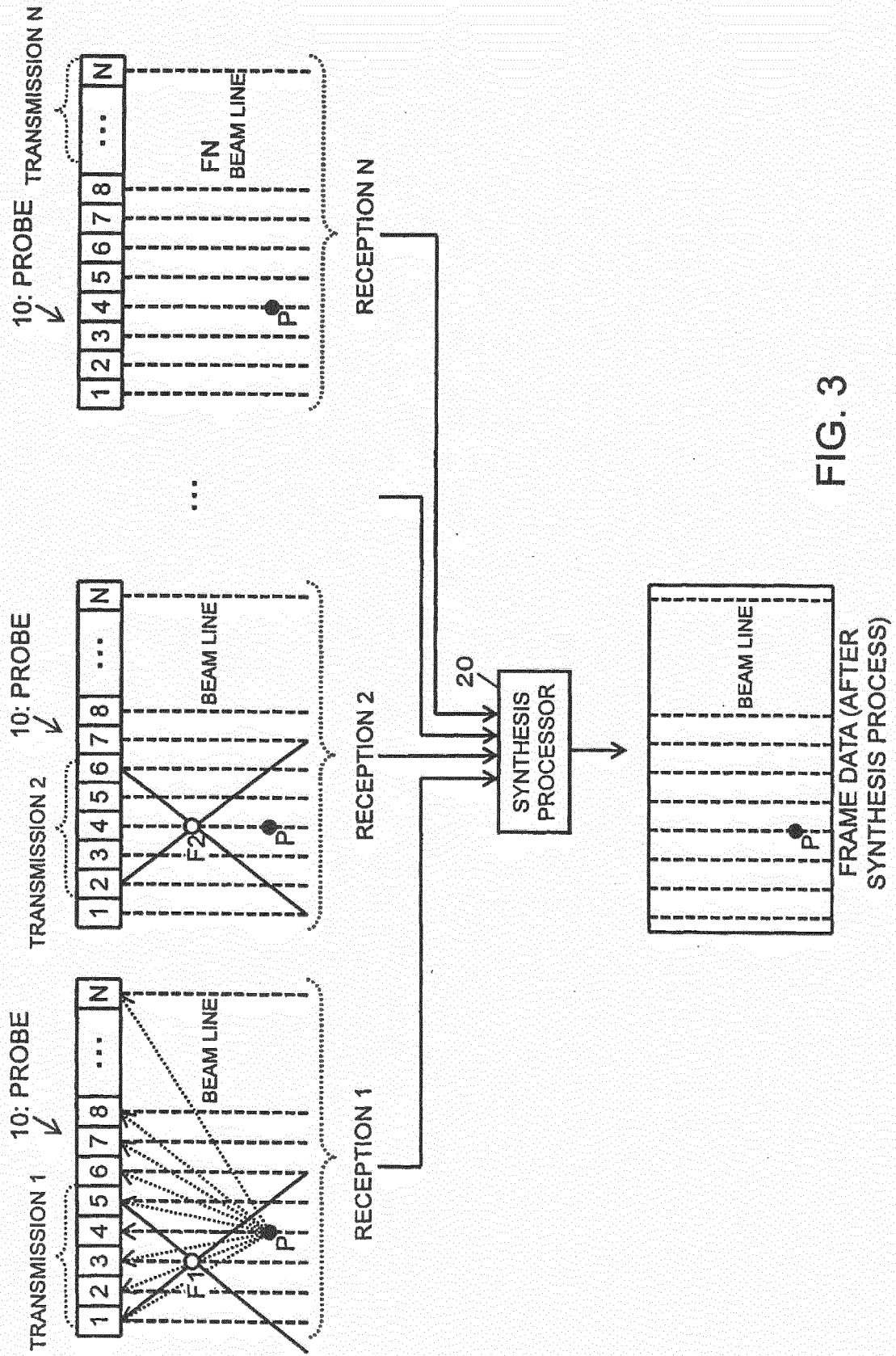


FIG. 3

<SPECIFIC EXAMPLE> HARMONIC IMAGE + SYNTHETIC TRANSMIT APERTURE

TRANSMISSION TIME INTERVAL (PRT)	TRANSMISSION VOLTAGE (MAXIMUM VOLTAGE)	MAXIMUM SIGNAL VALUE (HARMONIC SIGNAL)	NUMBER OF TRANSMISSIONS (NUMBER OF OVERLAPS)	MAXIMUM SNR
m TIMES	\sqrt{m} TIMES	m TIMES	1/m TIMES	\sqrt{m} TIMES

<COMPARATIVE EXAMPLE> FUNDAMENTAL WAVE MODE + SYNTHETIC TRANSMIT APERTURE

TRANSMISSION TIME INTERVAL (PRT)	TRANSMISSION VOLTAGE (MAXIMUM VOLTAGE)	MAXIMUM SIGNAL VALUE (FUNDAMENTAL WAVE SIGNAL)	NUMBER OF TRANSMISSIONS (NUMBER OF OVERLAPS)	MAXIMUM SNR
m TIMES	\sqrt{m} TIMES	\sqrt{m} TIMES	1/m TIMES	1 TIMES

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/062133

5	A. CLASSIFICATION OF SUBJECT MATTER A61B8/00(2006.01) i	
	According to International Patent Classification (IPC) or to both national classification and IPC	
10	B. FIELDS SEARCHED	
	Minimum documentation searched (classification system followed by classification symbols) A61B8/00-8/15	
15	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015 Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015	
	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)	
20	C. DOCUMENTS CONSIDERED TO BE RELEVANT	
	Category*	Citation of document, with indication, where appropriate, of the relevant passages
25	Y A	JP 2001-245884 A (GE Yokogawa Medical Systems, Ltd.), 11 September 2001 (11.09.2001), paragraphs [0015] to [0016] (Family: none)
30	Y A	JP 2001-61841 A (Toshiba Corp.), 13 March 2001 (13.03.2001), paragraphs [0053] to [0055] (Family: none)
35	A	JP 2014-512243 A (B-K Medical ApS), 22 May 2014 (22.05.2014), paragraphs [0027] to [0028], [0036] to [0041]; fig. 2, 4 & US 2014/0050048 A1 & WO 2012/146946 A1 & EP 2702426 A1
40	<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.	
45	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
50	Date of the actual completion of the international search 15 July 2015 (15.07.15)	Date of mailing of the international search report 28 July 2015 (28.07.15)
55	Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009101165 A [0004]

专利名称(译)	超声诊断设备		
公开(公告)号	EP3158938A1	公开(公告)日	2017-04-26
申请号	EP2015810379	申请日	2015-04-21
[标]申请(专利权)人(译)	株式会社日立制作所		
申请(专利权)人(译)	HITACHI, LTD.		
当前申请(专利权)人(译)	HITACHI, LTD.		
[标]发明人	YOSHIZAWA SHINGO HISATSU MASANORI		
发明人	YOSHIZAWA, SHINGO HISATSU, MASANORI		
IPC分类号	A61B8/00		
CPC分类号	A61B8/48 A61B8/00 G01S7/5202 G01S7/52038 G01S7/52085 G01S15/8927 G01S15/8997		
优先权	2014124536 2014-06-17 JP		
其他公开文献	EP3158938A4		
外部链接	Espacenet		

摘要(译)

本发明提供一种超声波诊断装置，其中，发送单元（12）向探头（10）输出发送信号，使得在声源的位置改变的同时多次发送超声波。接收单元（14）针对发送传输信号的多次中的每一次获得从探测器（10）接收的超声波信号。合成处理单元（20）合成在多次获得的接收的超声波信号。高次谐波提取单元（30）从合成的接收超声波信号中提取高次谐波分量。图像形成单元（40）基于提取的高次谐波分量形成超声波图像。控制单元（50）调节发送超声波的多次的时间间隔，并控制发送信号的发送电压。

