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# (54) ULTRASOUND DIAGNOSTIC DEVICE AND ULTRASOUND SIGNAL PROCESSING METHOD

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**Publication Classification**

(51) **Int. Cl.**

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| ***G01S 7/52*** | (2006.01) |

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

CPC .......... ***A61B 8/0841*** (2013.01); ***G01S 7/5209*** (2013.01); ***A61B 8/4483*** (2013.01); ***A61B 8/461*** (2013.01); ***A61B 8/5207*** (2013.01); ***A61B 8/4444*** (2013.01); ***A61B 8/5215*** (2013.01)

## (57) ABSTRACT

Ultrasound diagnostic device including: a transmitter that performs events by transmitting ultrasound focusing inside a subject by using a first transducer group that gradually shifts in an array direction between events; and a receiver that, for each event, generates receive signal sequences for transducers based on ultrasound reflection that the transducers receive in response to the event, that selects a second transducer group whose receive signals based on ultrasound reflection from a puncture needle have high intensity, that, for each event, sets a target area for generating a sub-frame data item inside a virtual area of the subject that receives ultrasound transmitted in the event, and generates the sub-frame data item by performing, for each measurement point in the target area, delay-and-sum processing on receive signal sequences for the second transducer group, and that generates a frame data item by combining sub-frame data items for events.

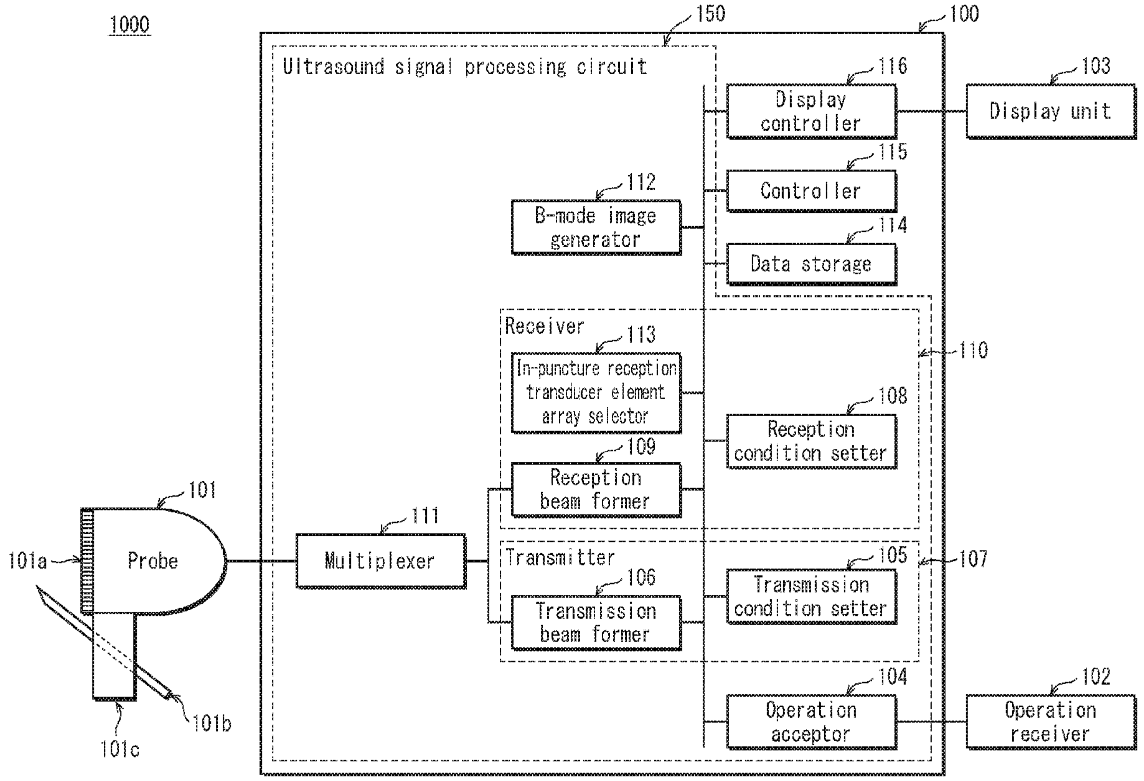


FIG. 1

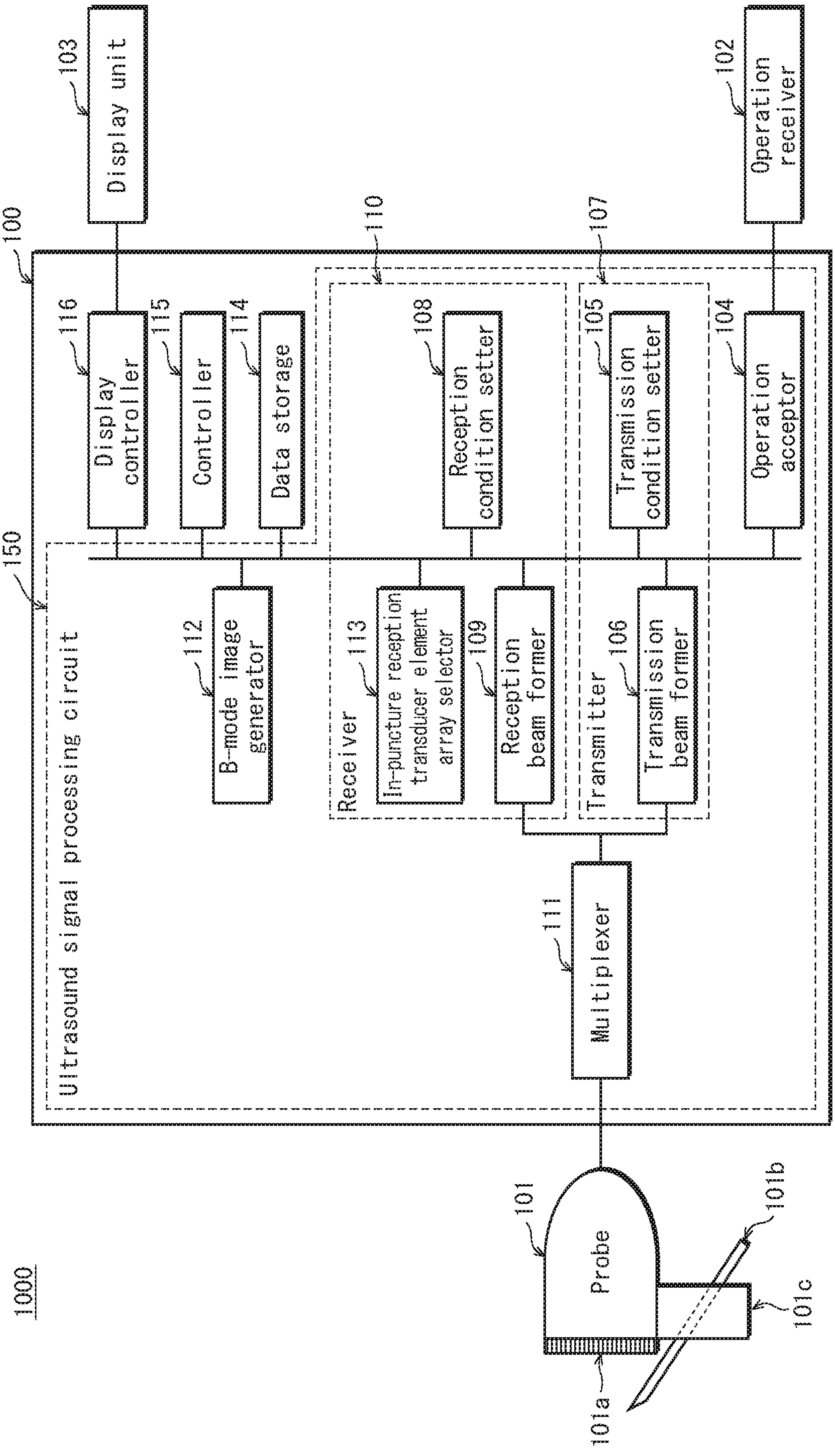

1000
100
150
Ultrasound signal processing circuit
103
Display unit
102
Operation receiver
116
Display controller
115
Controller
114
Data storage
110
108
Reception condition setter
107
105
Transmission condition setter
104
Operation acceptor
112
B-mode image generator
Receiver
113
In-puncture reception transducer element array selector
109
Reception beam former
Transmitter
106
Transmission beam former
111
Multiplexer
101
Probe
101a
101b
101c

FIG. 2

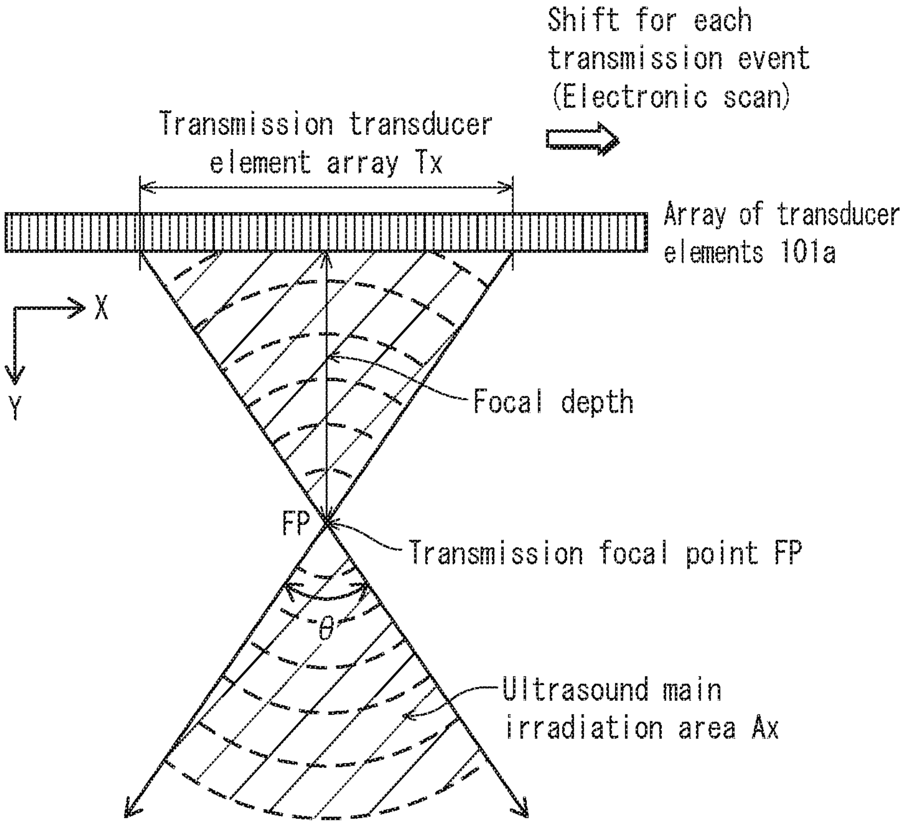

Shift for each
transmission event
(Electronic scan)
Transmission transducer
element array Tx
Array of transducer
elements 101a
X
Y
Focal depth
FP
Transmission focal point FP
θ
Ultrasound main
irradiation area Ax

FIG. 3

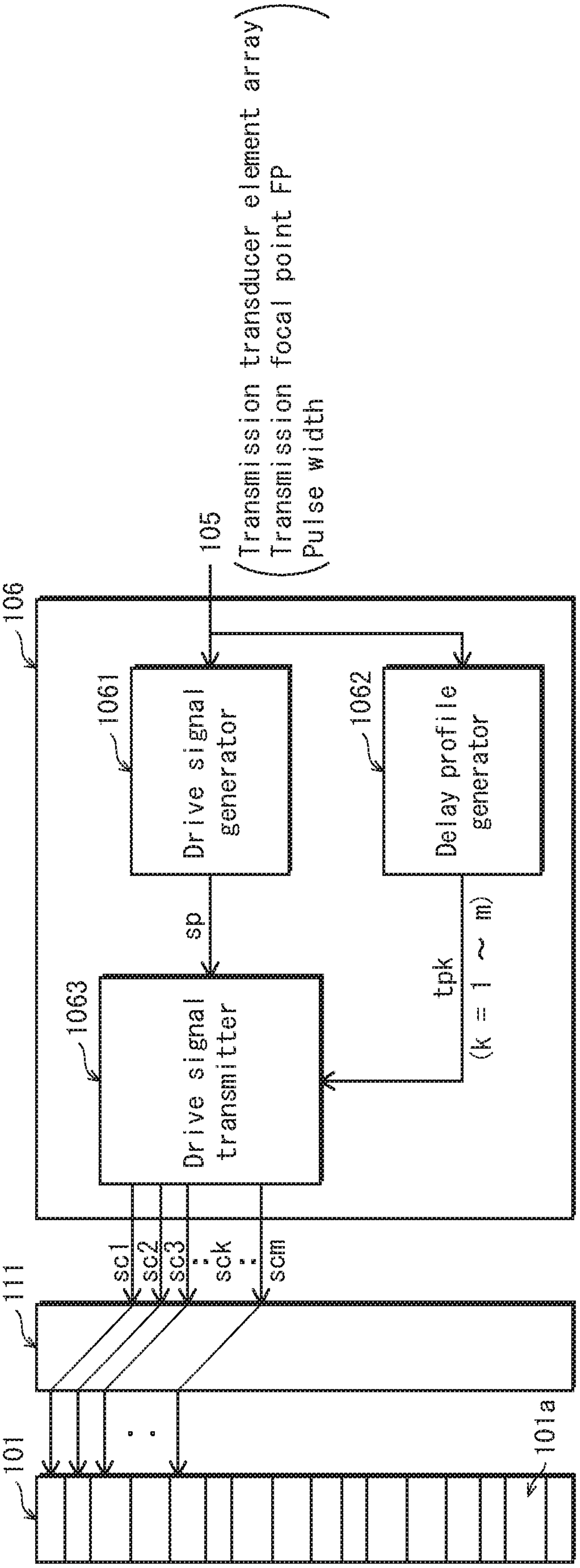

105
Transmission transducer element array
Transmission focal point FP
Pulse width
106
1061
Drive signal generator
1062
Delay profile generator
sp
tpk
(k = 1 ~ m)
1063
Drive signal transmitter
sc1
sc2
sc3
sck
scm
111
101
101a

FIG. 4

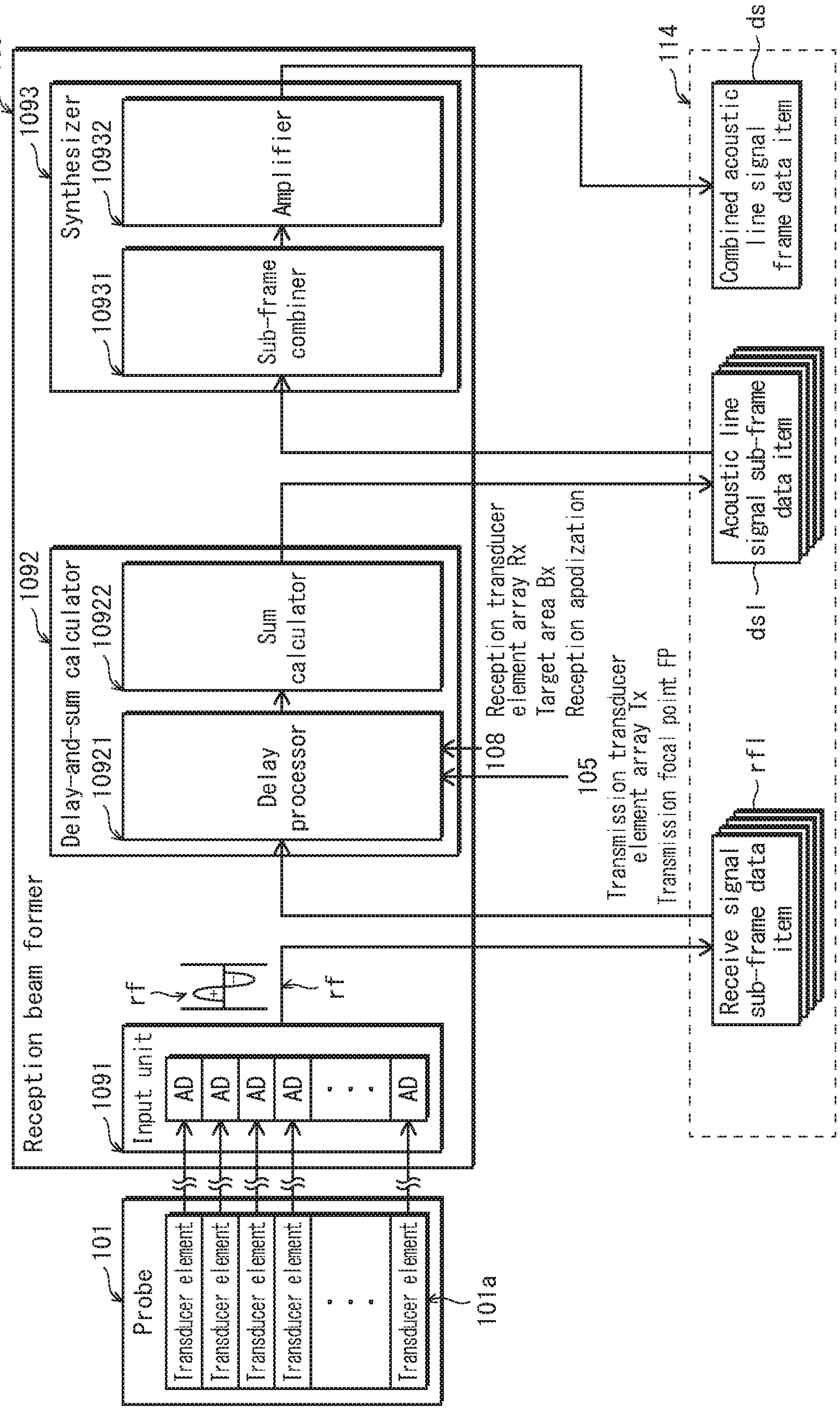

101
Probe
Transducer element
Transducer element
Transducer element
Transducer element
Transducer element
101a
109
Reception beam former
1091
Input unit
AD
AD
AD
AD
AD
rf
rf
1092
Delay-and-sum calculator
10921
Delay processor
10922
Sum calculator
108
Reception transducer element array Rx
Target area Bx
Reception apodization
105
Transmission transducer element array Tx
Transmission focal point FP
1093
Synthesizer
10931
Sub-frame combiner
10932
Amplifier
114
Receive signal sub-frame data item
rfl
Acoustic line signal sub-frame data item
dsl
Combined acoustic line signal frame data item
ds

FIG. 5

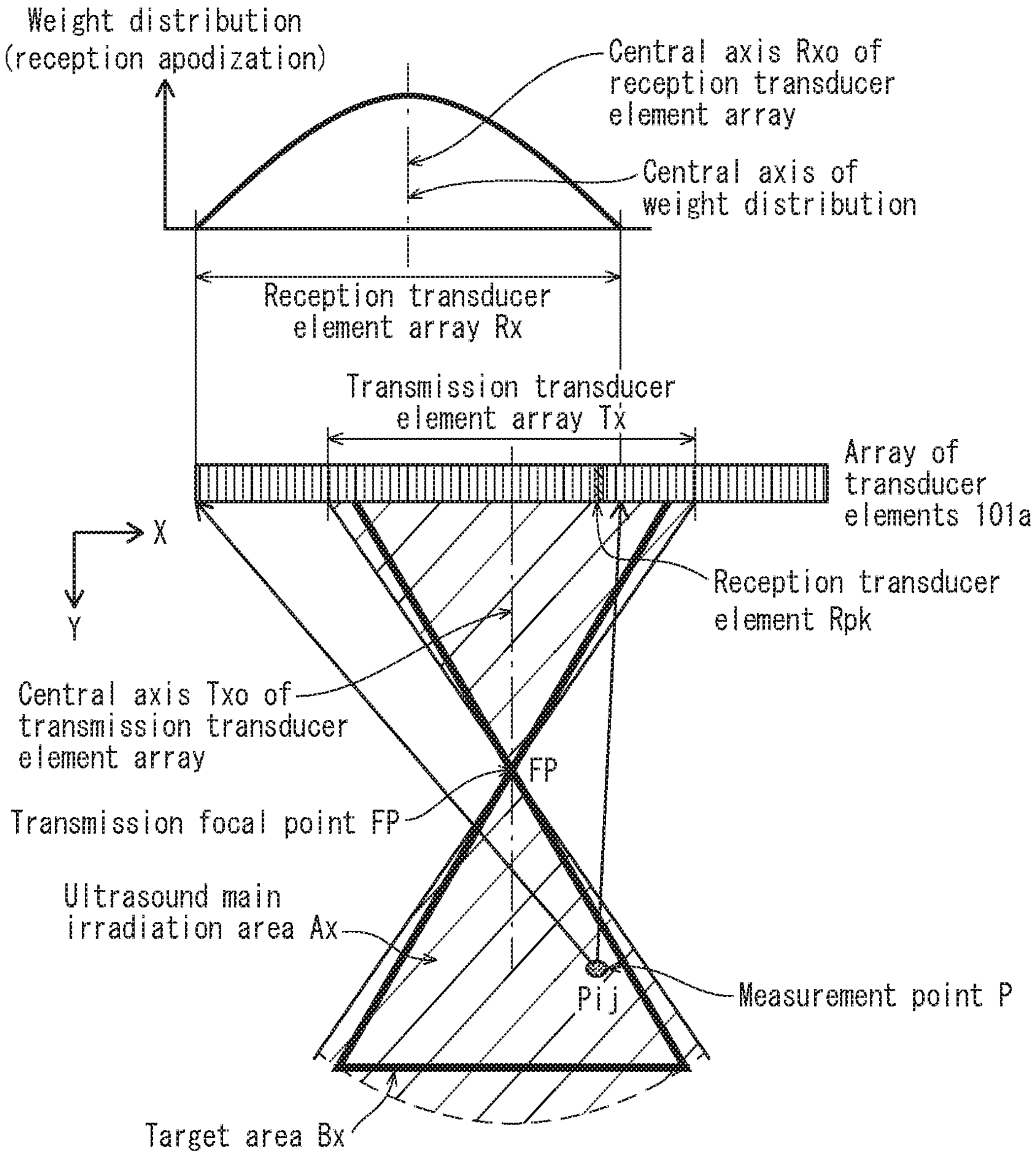

Weight distribution
(reception apodization)
Central axis Rxo of reception transducer element array
Central axis of weight distribution
Reception transducer element array Rx
Transmission transducer element array Tx
Array of transducer elements 101a
X
Y
Reception transducer element Rpk
Central axis Txo of transmission transducer element array
FP
Transmission focal point FP
Ultrasound main irradiation area Ax
Measurement point P
Pij
Target area Bx

FIG. 6A

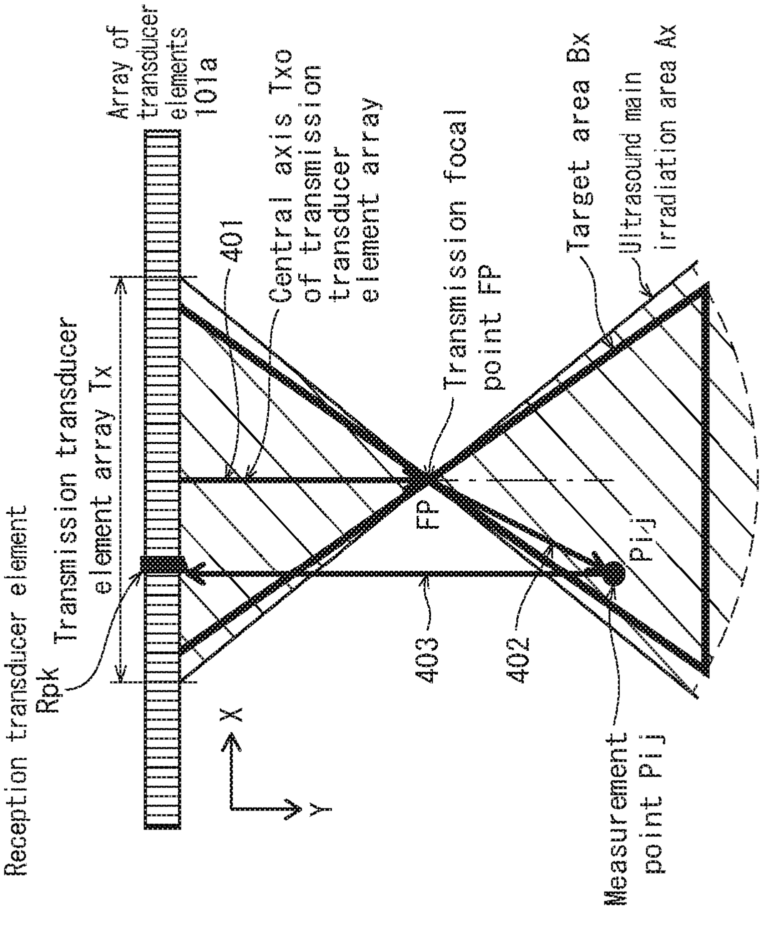

Reception transducer element Rpk
Transmission transducer element array Tx
Array of transducer elements 101a
401
Central axis Txo of transmission transducer element array
Transmission focal point FP
FP
Target area Bx
Ultrasound main irradiation area Ax
Pij
403
402
Measurement point Pij
X
Y

FIG. 6B

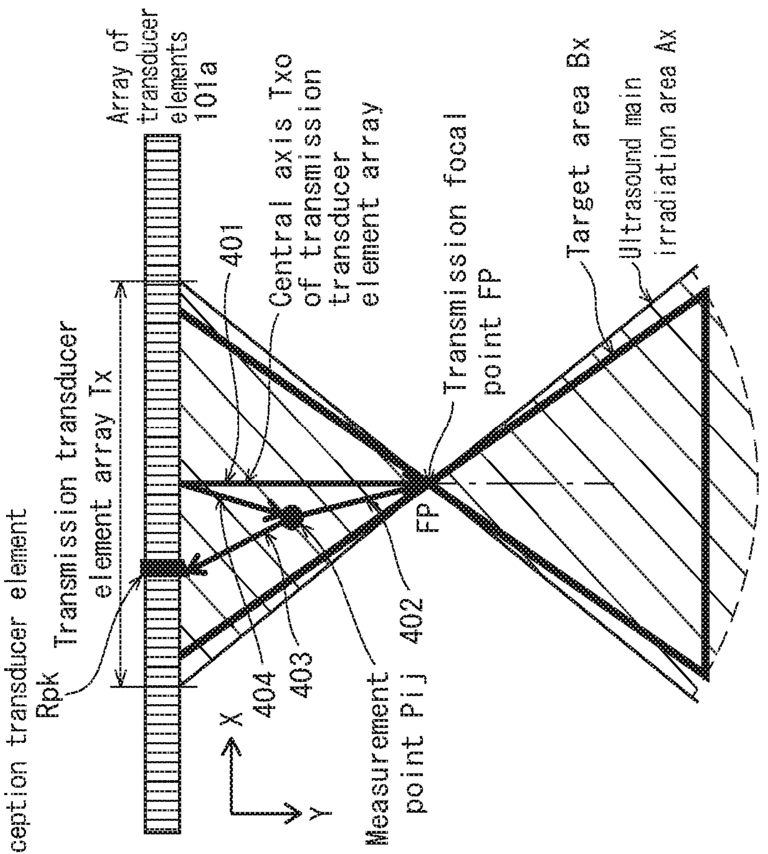

Reception transducer element Rpk
Transmission transducer element array Tx
Array of transducer elements 101a
401
Central axis Txo of transmission transducer element array
Transmission focal point FP
FP
Target area Bx
Ultrasound main irradiation area Ax
402
403
404
Measurement point Pij
X
Y

FIG. 7A

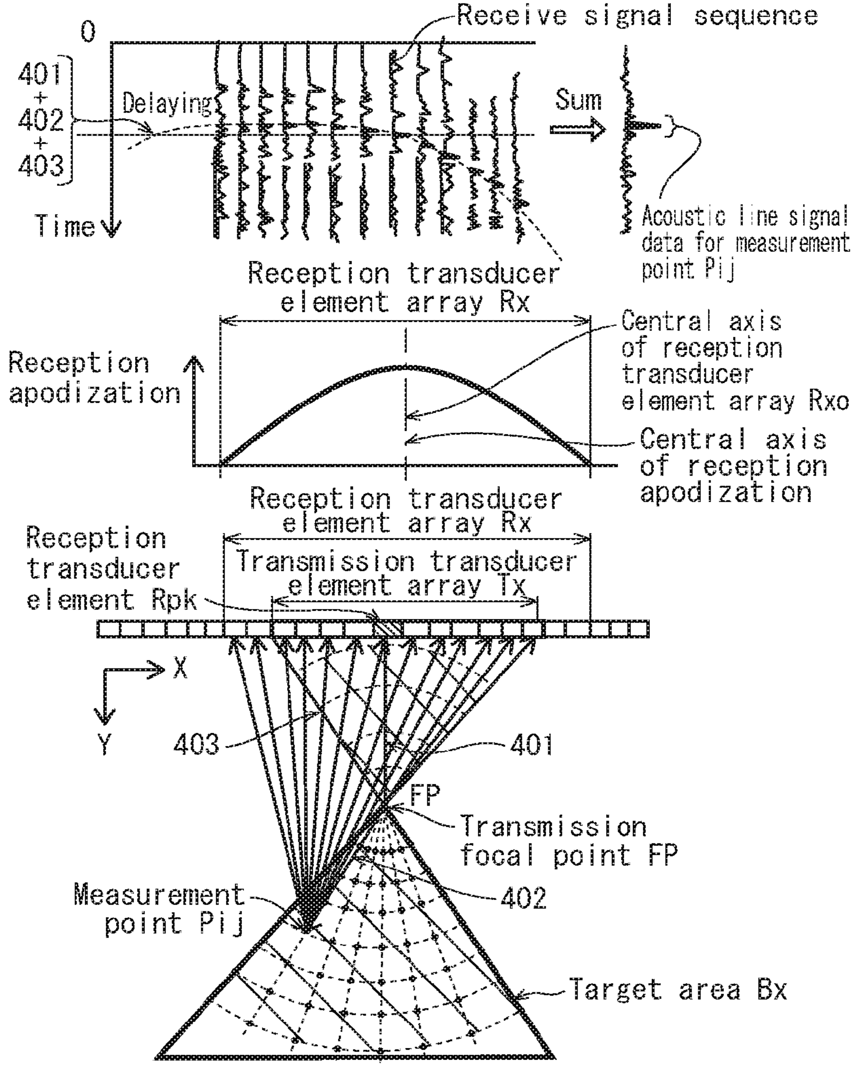

Receive signal sequence
0
401
+
402
+
403
Time
Delaying
Sum
Acoustic line signal data for measurement point Pij
Reception transducer element array Rx
Reception apodization
Central axis of reception transducer element array Rxo
Central axis of reception apodization
Reception transducer element array Rx
Reception transducer element Rpk
Transmission transducer element array Tx
X
Y
403
401
FP
Transmission focal point FP
Measurement point Pij
402
Target area Bx

FIG. 7B

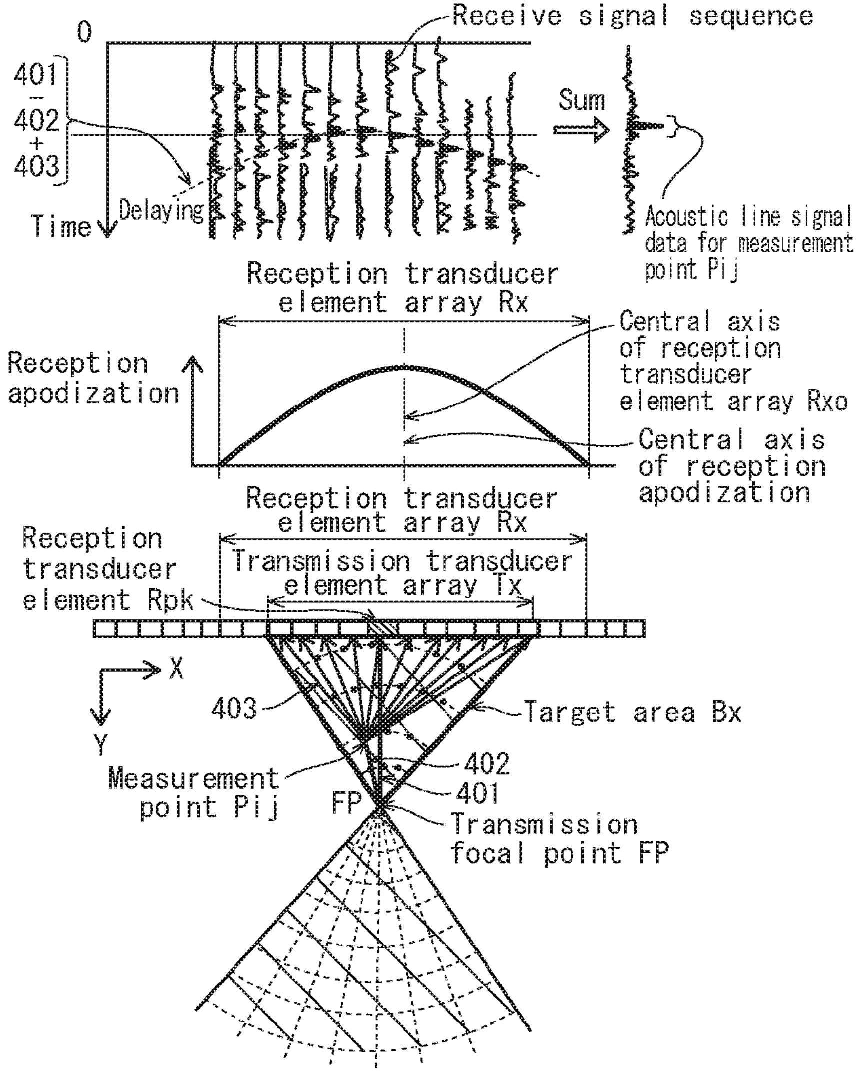

Receive signal sequence
0
401
−
402
+
403
Time
Delaying
Sum
Acoustic line signal data for measurement point Pij
Reception transducer element array Rx
Reception apodization
Central axis of reception transducer element array Rxo
Central axis of reception apodization
Reception transducer element array Rx
Reception transducer element Rpk
Transmission transducer element array Tx
X
Y
403
Target area Bx
Measurement point Pij
402
401
FP
Transmission focal point FP

FIG. 8

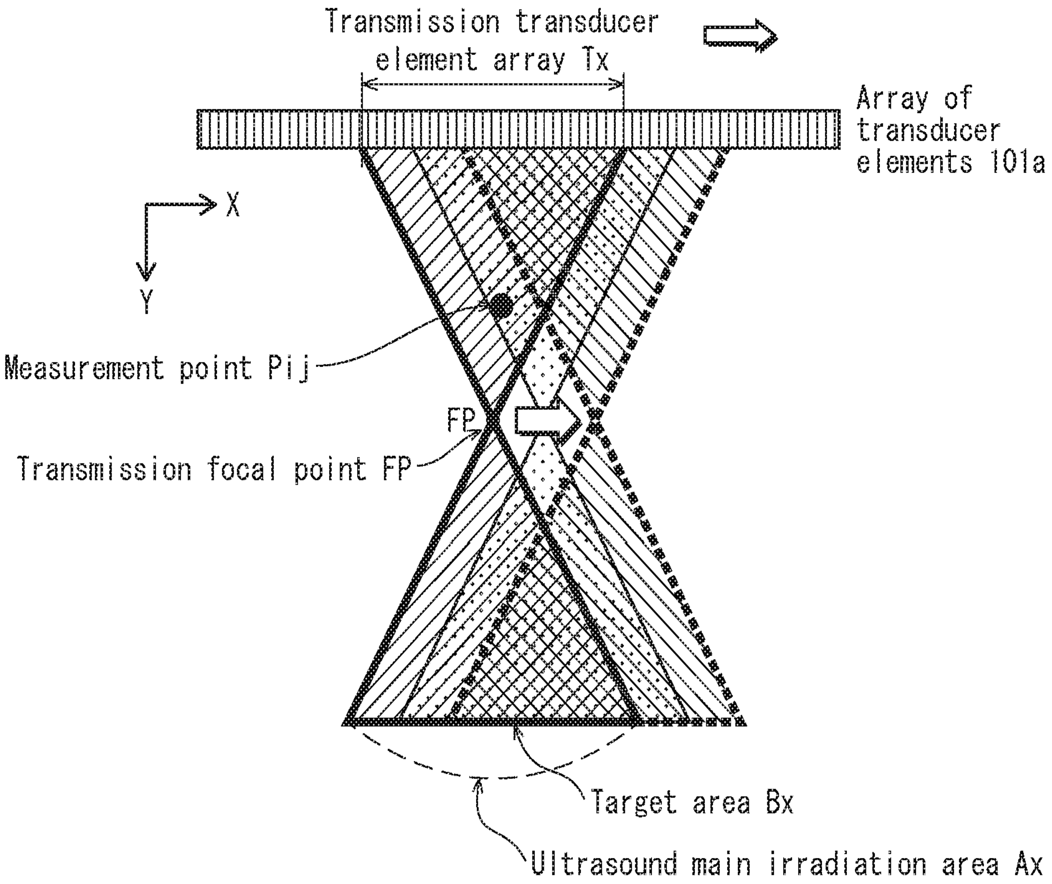

Transmission transducer element array Tx
Array of transducer elements 101a
X
Y
Measurement point Pij
FP
Transmission focal point FP
Target area Bx
Ultrasound main irradiation area Ax

FIG. 9A

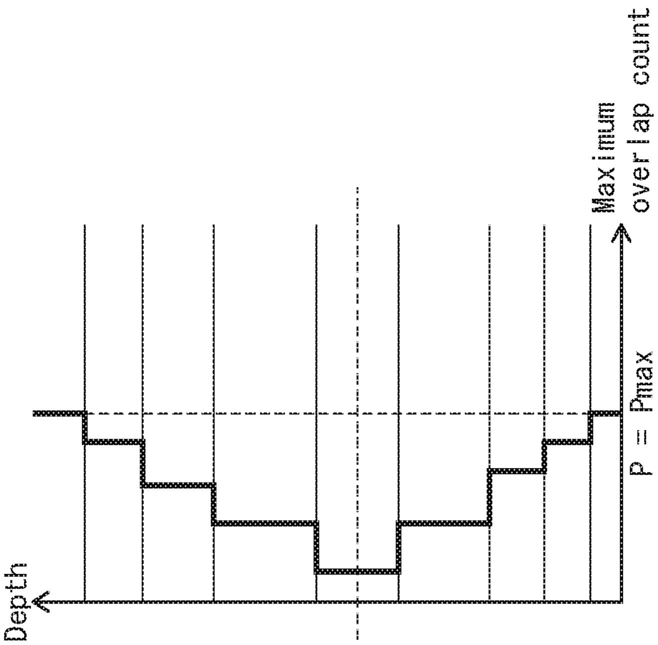

Depth
P = Pmax
Maximum overlap count

FIG. 9B

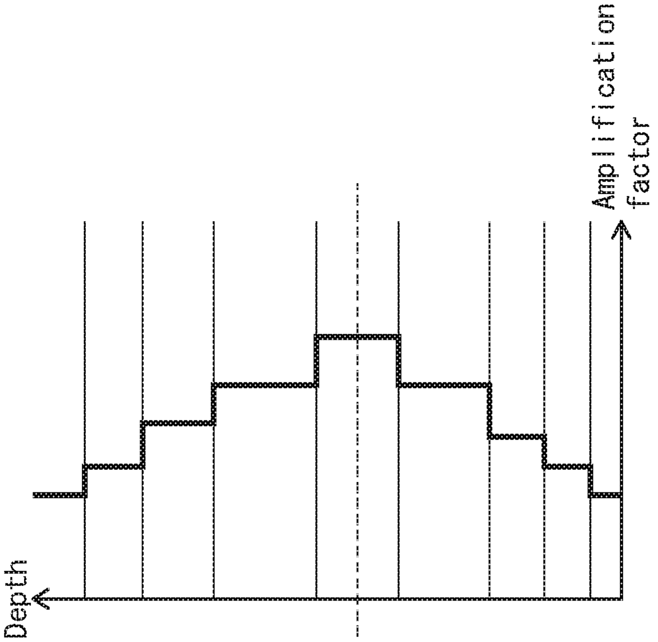

Depth
Amplification factor

FIG. 10

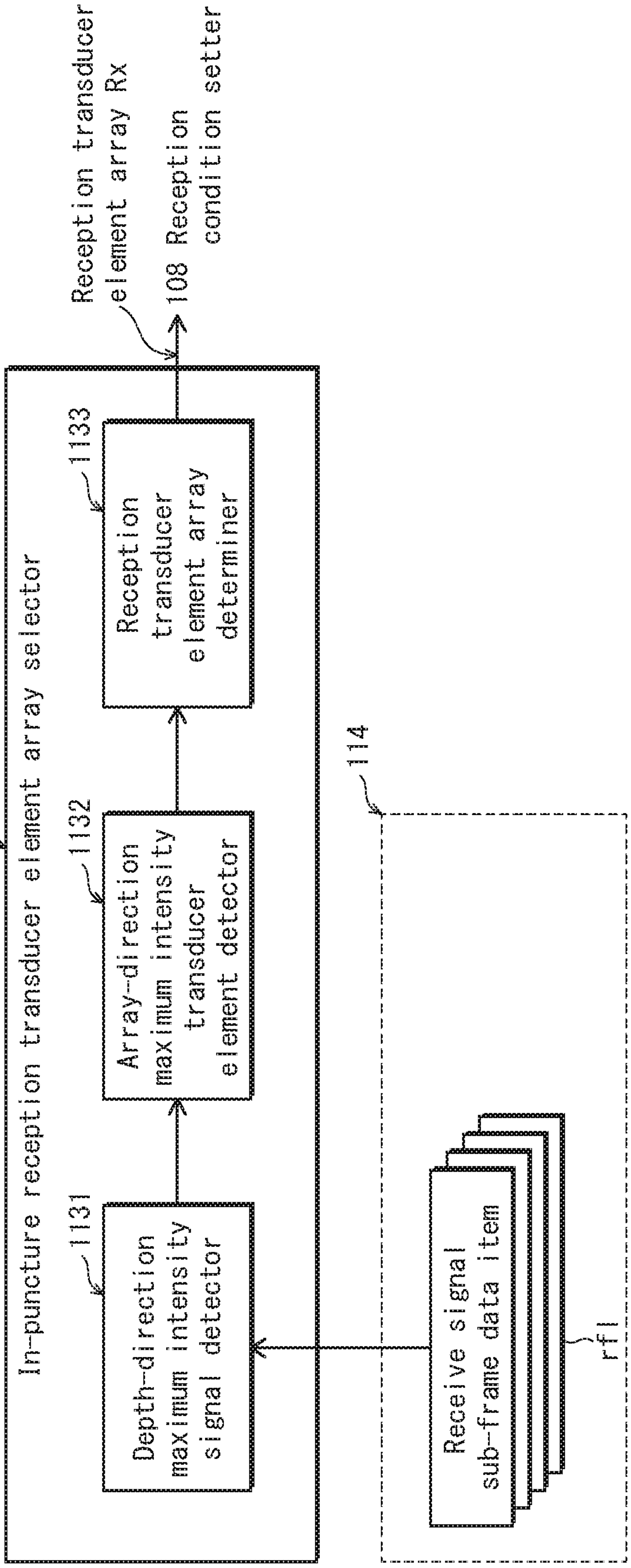

113
In-puncture reception transducer element array selector
1131
Depth-direction maximum intensity signal detector
1132
Array-direction maximum intensity transducer element detector
1133
Reception transducer element array determiner
Reception transducer element array Rx
108 Reception condition setter
114
Receive signal sub-frame data item
rfl

FIG. 11

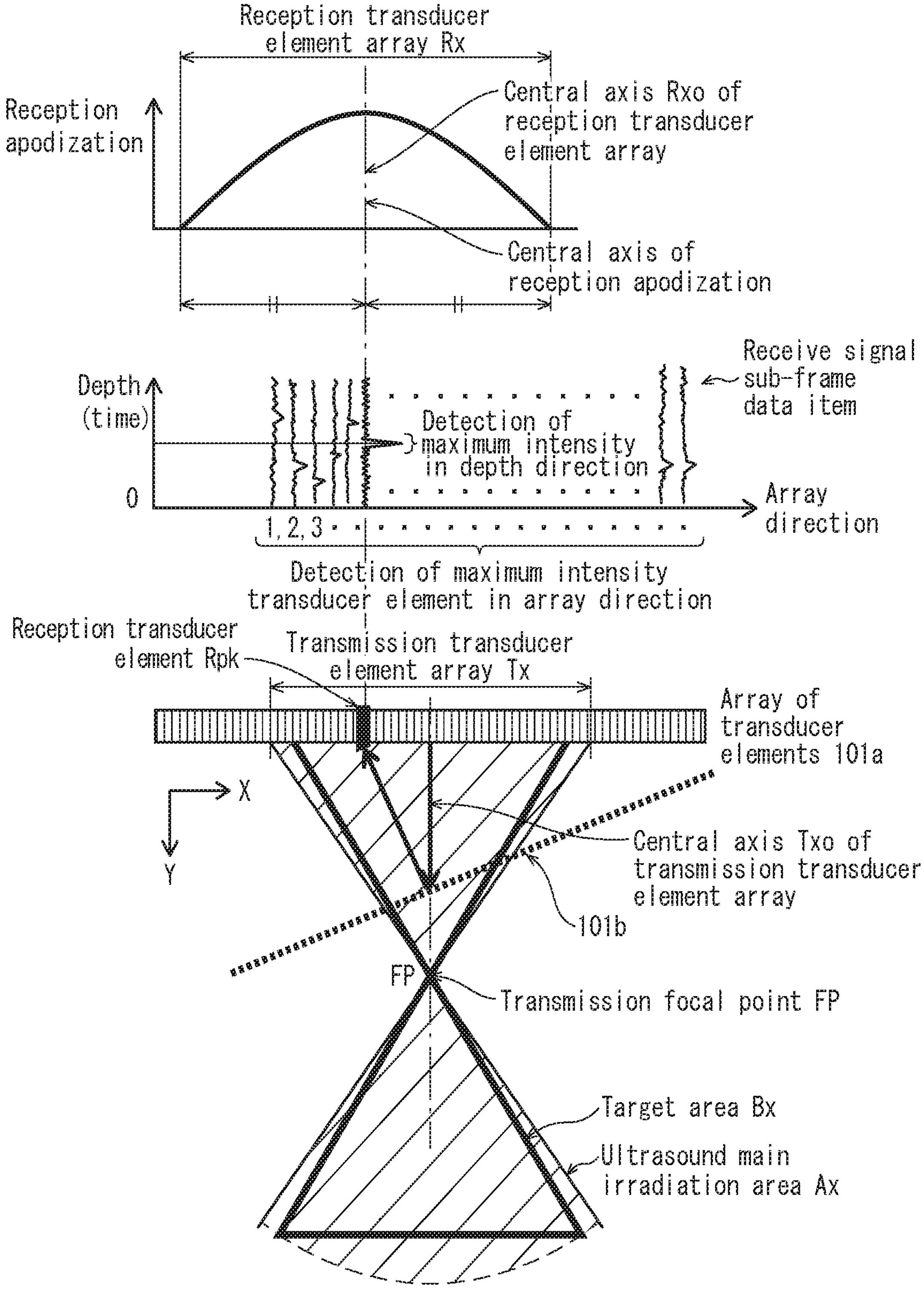
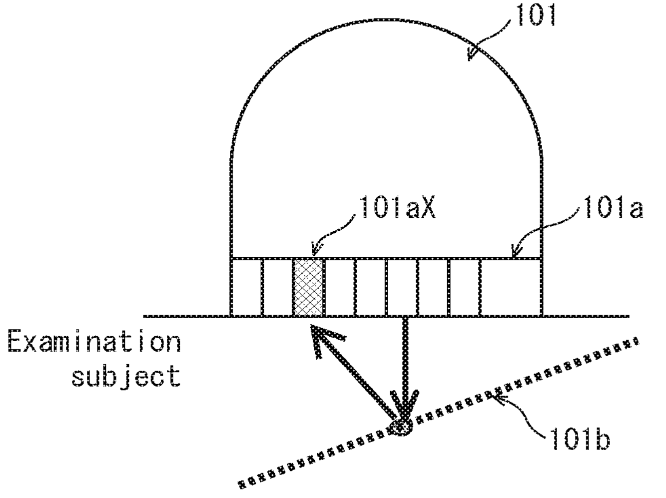
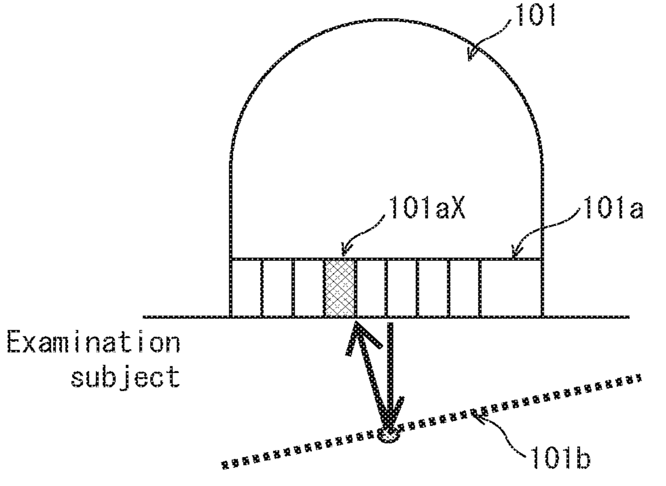

Reception transducer element array Rx
Reception apodization
Central axis Rxo of reception transducer element array
Central axis of reception apodization
Receive signal sub-frame data item
Depth (time)
Detection of maximum intensity in depth direction
0
Array direction
1, 2, 3
Detection of maximum intensity transducer element in array direction
Reception transducer element Rpk
Transmission transducer element array Tx
Array of transducer elements 101a
X
Y
Central axis Txo of transmission transducer element array
101b
FP
Transmission focal point FP
Target area Bx
Ultrasound main irradiation area Ax

FIG. 12A



Puncture needle inclination angle 30°

FIG. 12B



Puncture needle inclination angle 10°

FIG. 13A

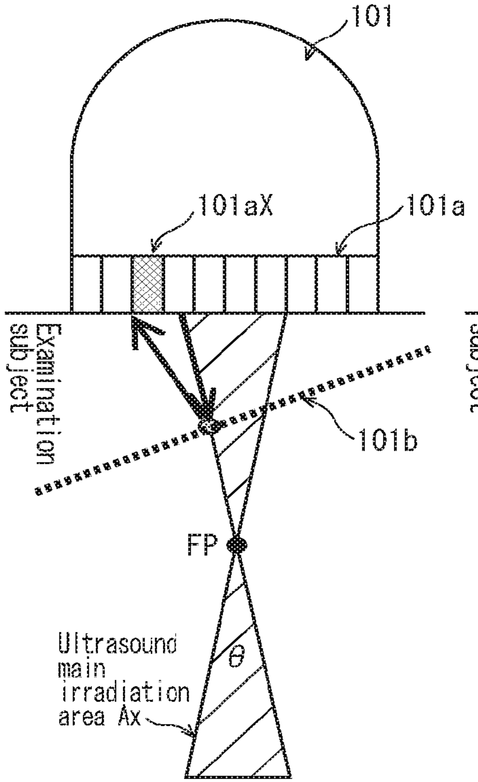


FIG. 13B

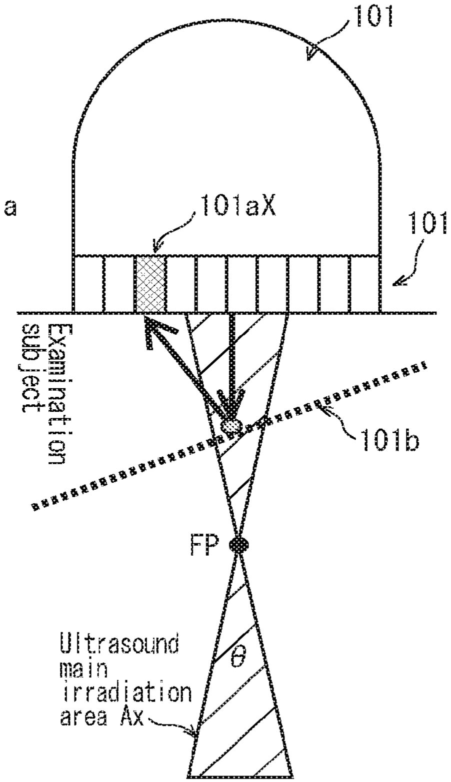


FIG. 13C

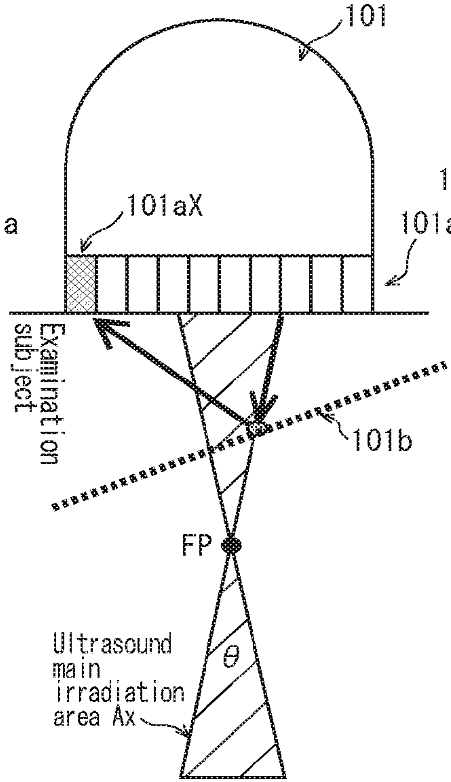


FIG. 13D

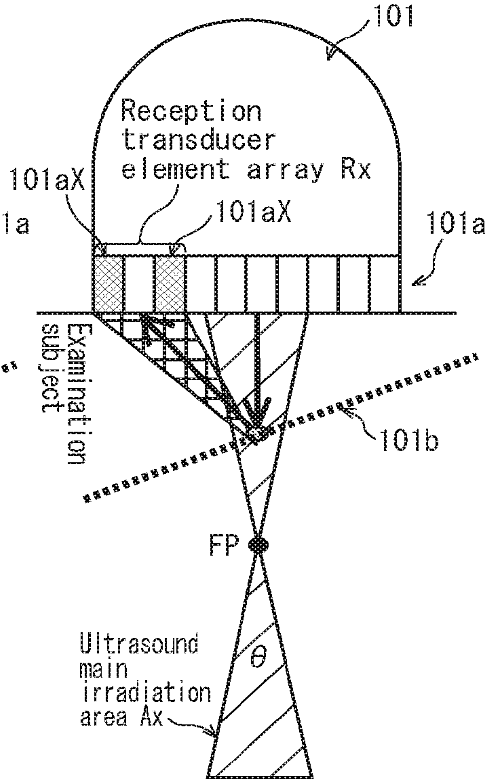


FIG. 14A

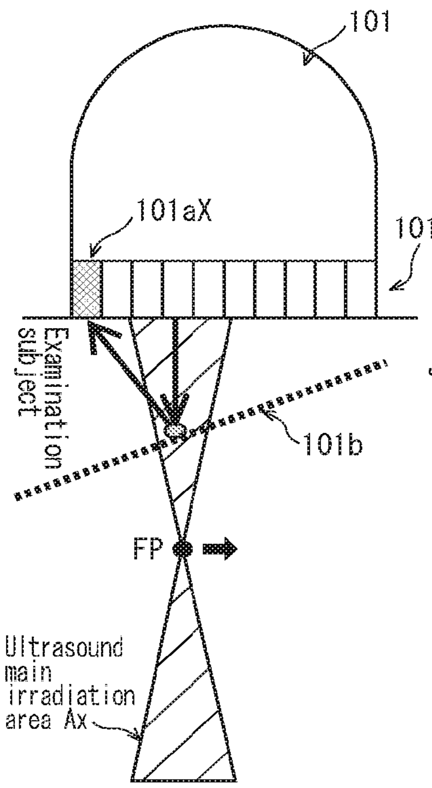


FIG. 14B

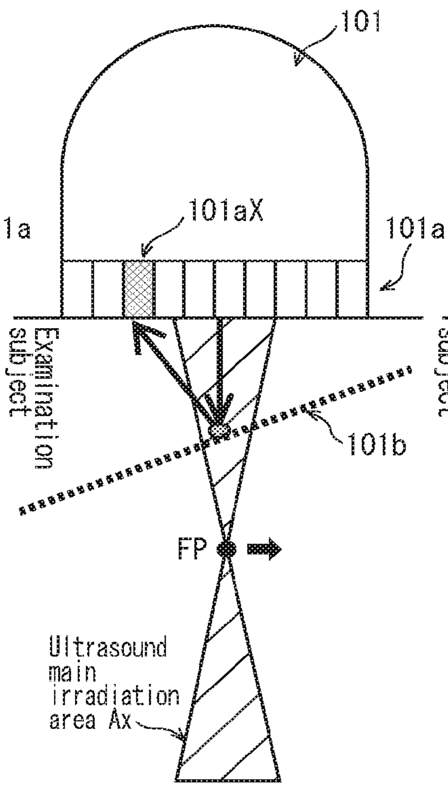


FIG. 14C

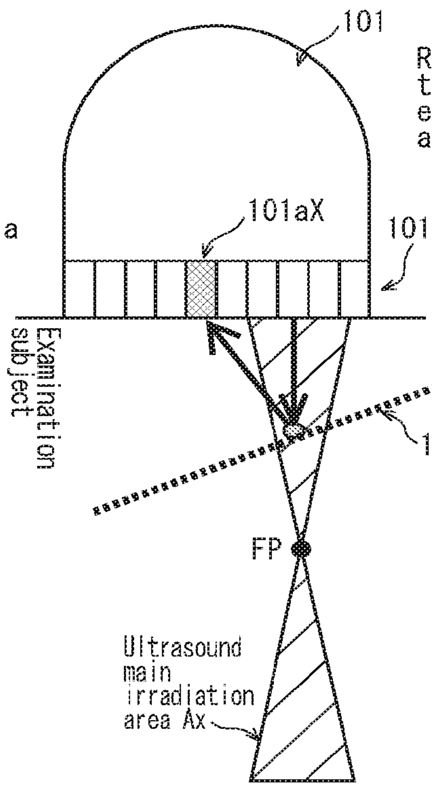


FIG. 14D

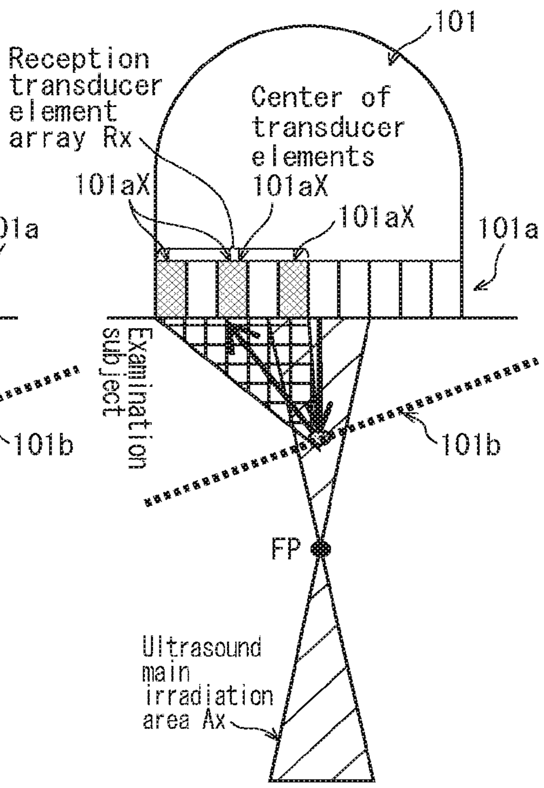


FIG. 15

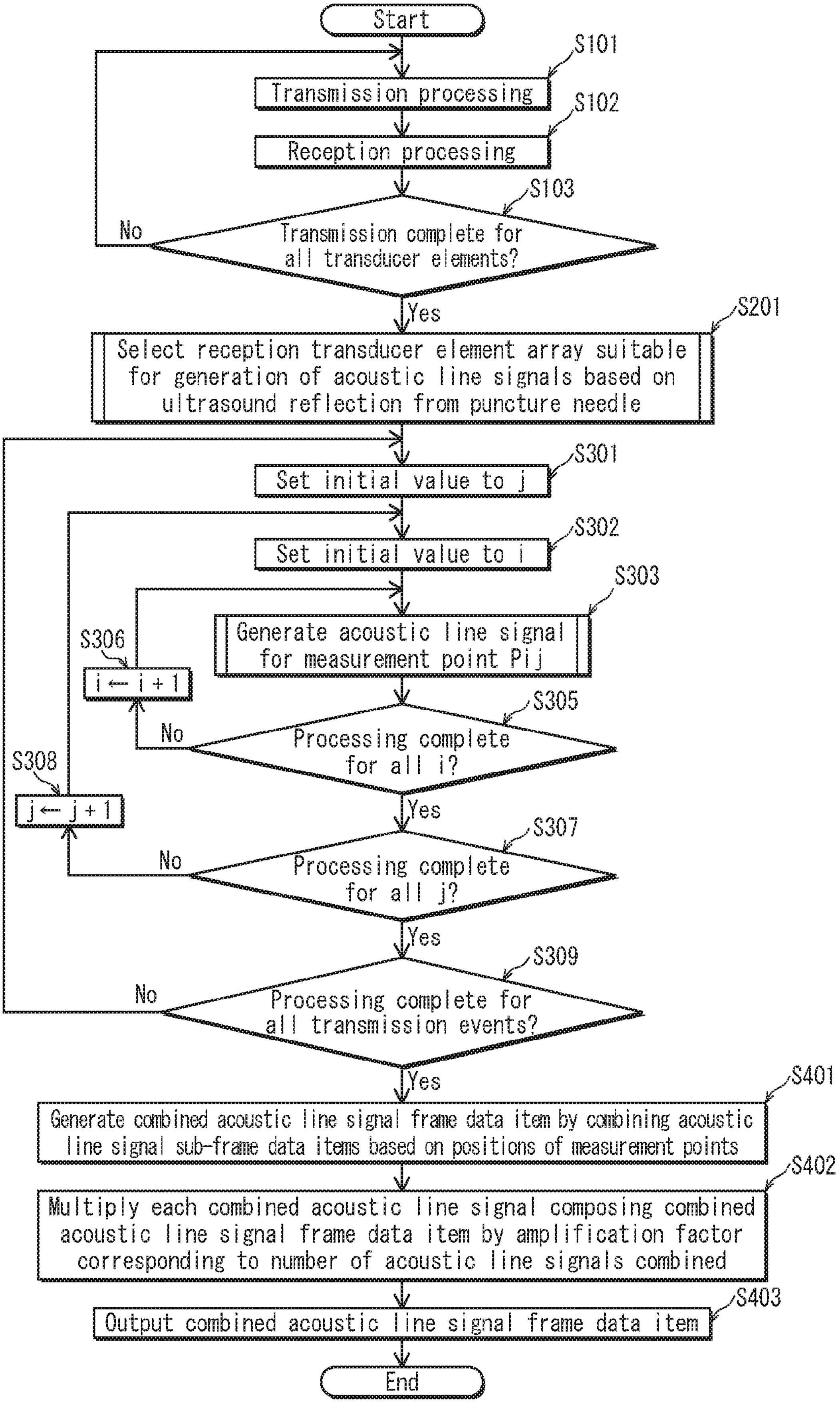

Start
S101
Transmission processing
S102
Reception processing
S103
Transmission complete for all transducer elements?
No
Yes
S201
Select reception transducer element array suitable for generation of acoustic line signals based on ultrasound reflection from puncture needle
S301
Set initial value to j
S302
Set initial value to i
S303
Generate acoustic line signal for measurement point Pij
S306
i ← i + 1
S305
Processing complete for all i?
No
Yes
S308
j ← j + 1
S307
Processing complete for all j?
No
Yes
S309
Processing complete for all transmission events?
No
Yes
S401
Generate combined acoustic line signal frame data item by combining acoustic line signal sub-frame data items based on positions of measurement points
S402
Multiply each combined acoustic line signal composing combined acoustic line signal frame data item by amplification factor corresponding to number of acoustic line signals combined
S403
Output combined acoustic line signal frame data item
End

FIG. 16

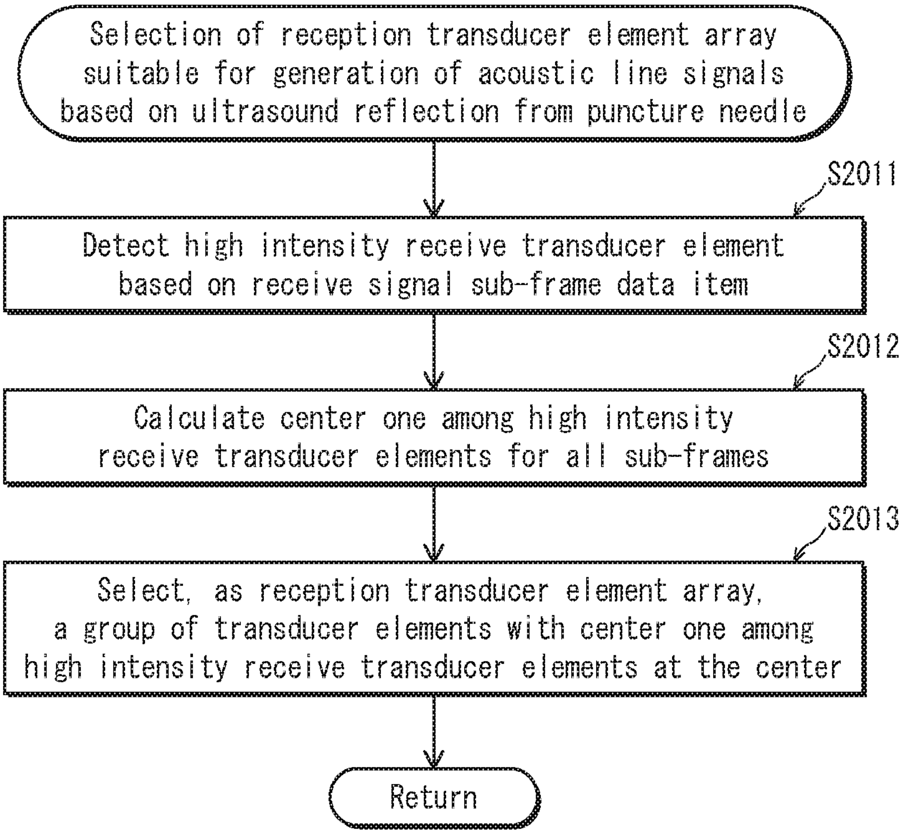

Selection of reception transducer element array suitable for generation of acoustic line signals based on ultrasound reflection from puncture needle
S2011
Detect high intensity receive transducer element based on receive signal sub-frame data item
S2012
Calculate center one among high intensity receive transducer elements for all sub-frames
S2013
Select, as reception transducer element array, a group of transducer elements with center one among high intensity receive transducer elements at the center
Return

FIG. 17

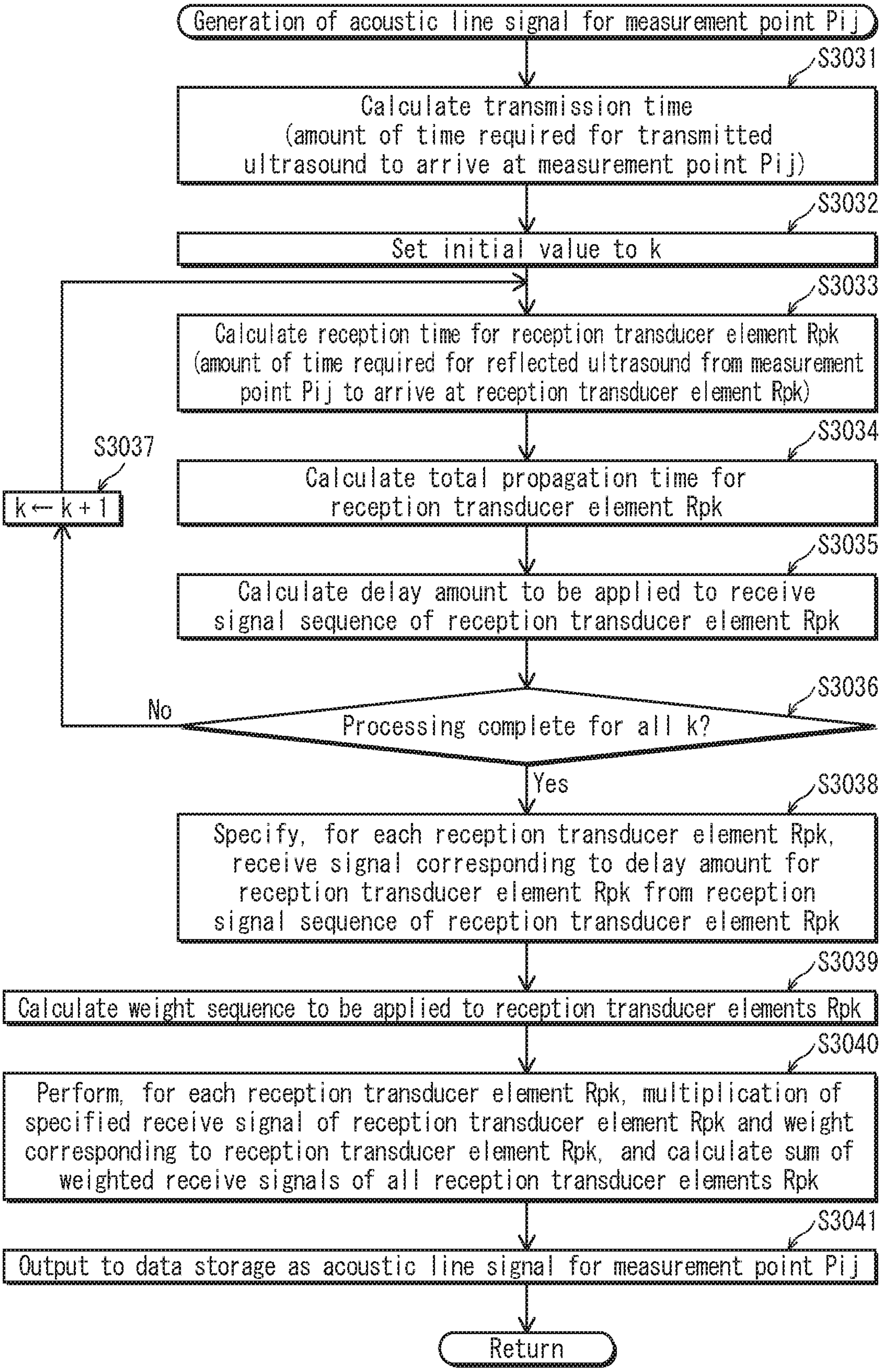

Generation of acoustic line signal for measurement point Pij
S3031
Calculate transmission time (amount of time required for transmitted ultrasound to arrive at measurement point Pij)
S3032
Set initial value to k
S3033
Calculate reception time for reception transducer element Rpk (amount of time required for reflected ultrasound from measurement point Pij to arrive at reception transducer element Rpk)
S3034
Calculate total propagation time for reception transducer element Rpk
S3035
Calculate delay amount to be applied to receive signal sequence of reception transducer element Rpk
S3036
Processing complete for all k?
No
S3037
k ← k + 1
Yes
S3038
Specify, for each reception transducer element Rpk, receive signal corresponding to delay amount for reception transducer element Rpk from reception signal sequence of reception transducer element Rpk
S3039
Calculate weight sequence to be applied to reception transducer elements Rpk
S3040
Perform, for each reception transducer element Rpk, multiplication of specified receive signal of reception transducer element Rpk and weight corresponding to reception transducer element Rpk, and calculate sum of weighted receive signals of all reception transducer elements Rpk
S3041
Output to data storage as acoustic line signal for measurement point Pij
Return

FIG. 18

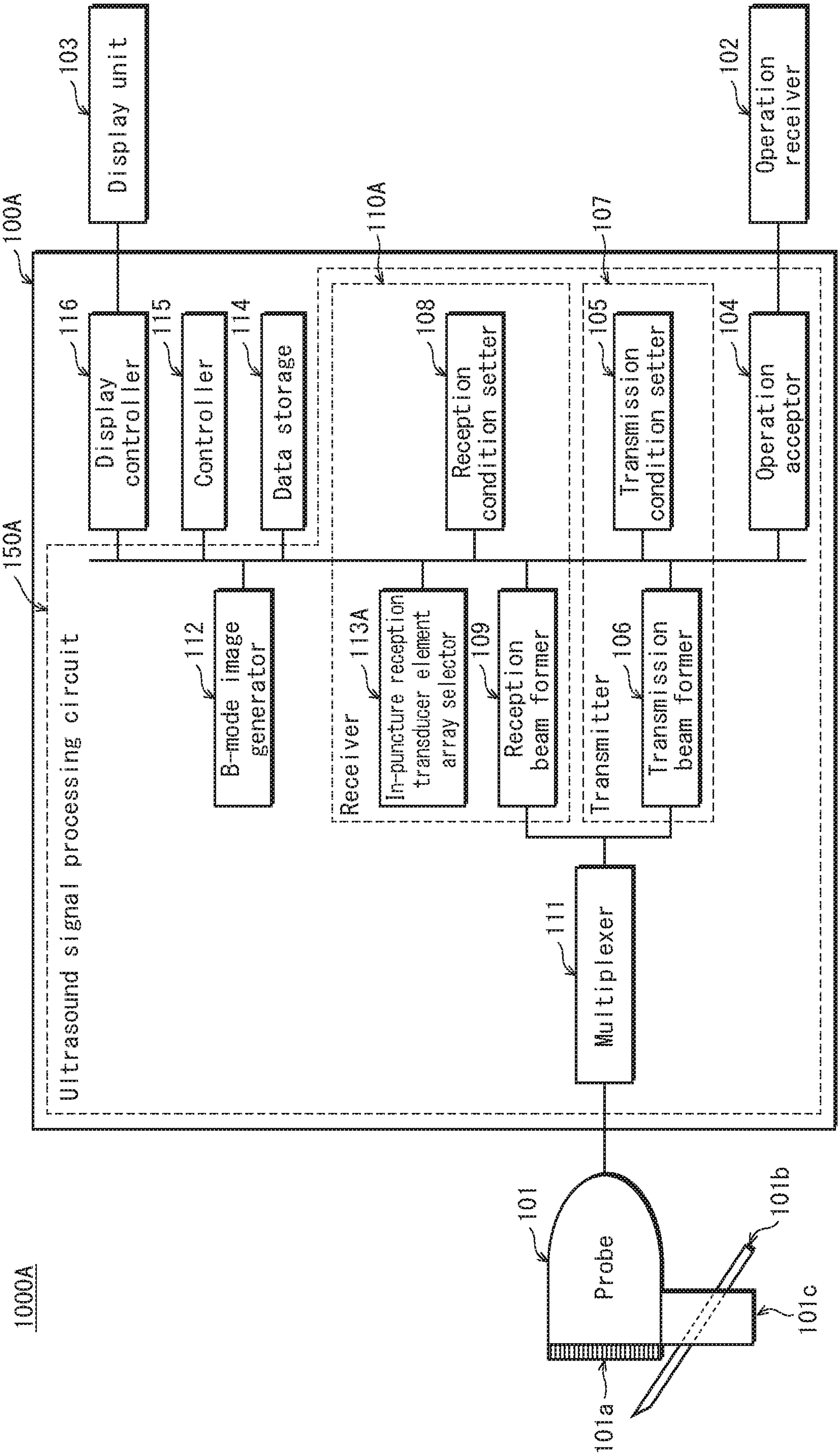

1000A
100A
Ultrasound signal processing circuit
150A
110A
107
103
Display unit
102
Operation receiver
116
Display controller
115
Controller
114
Data storage
108
Reception condition setter
105
Transmission condition setter
104
Operation acceptor
112
B-mode image generator
Receiver
113A
In-puncture reception transducer element array selector
109
Reception beam former
Transmitter
106
Transmission beam former
111
Multiplexer
101
Probe
101a
101b
101c

FIG. 19

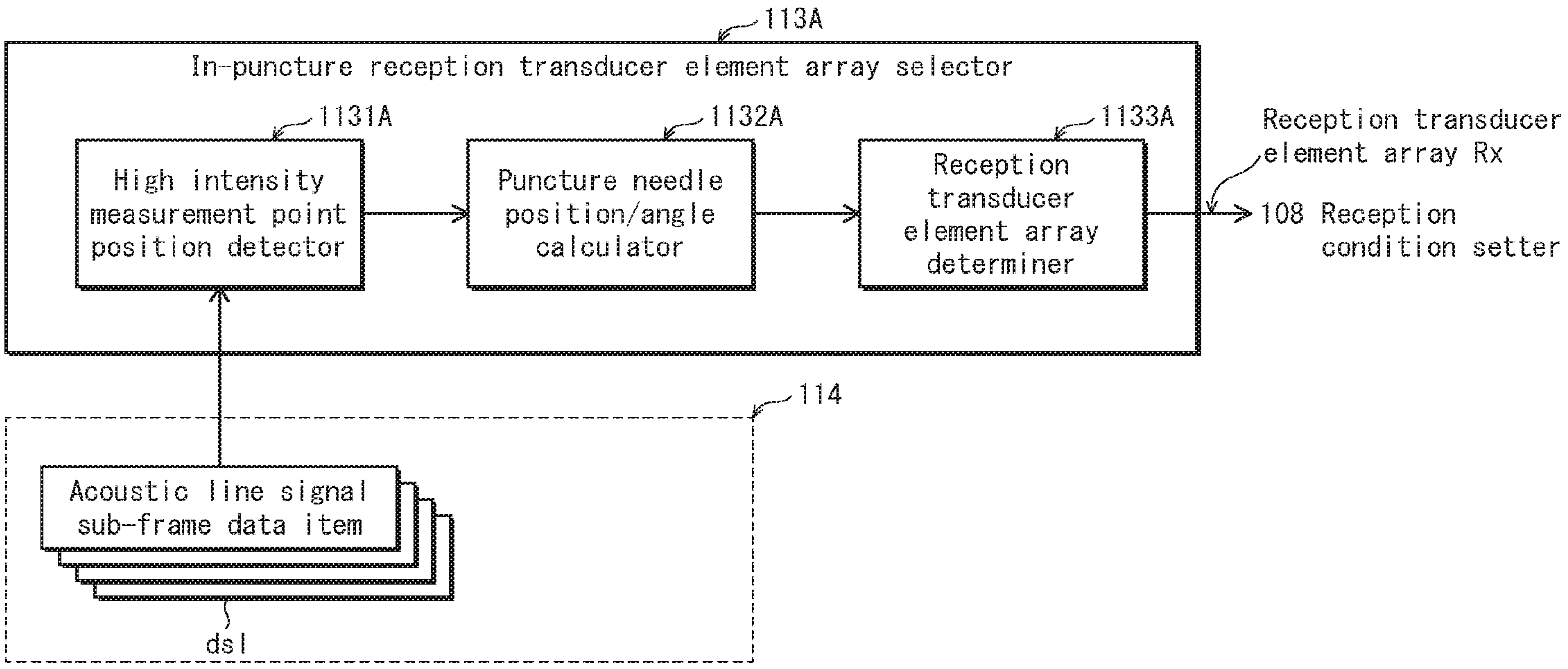

113A
In-puncture reception transducer element array selector
1131A
High intensity measurement point position detector
1132A
Puncture needle position/angle calculator
1133A
Reception transducer element array determiner
Reception transducer element array Rx
108 Reception condition setter
114
Acoustic line signal sub-frame data item
dsl

FIG. 20A

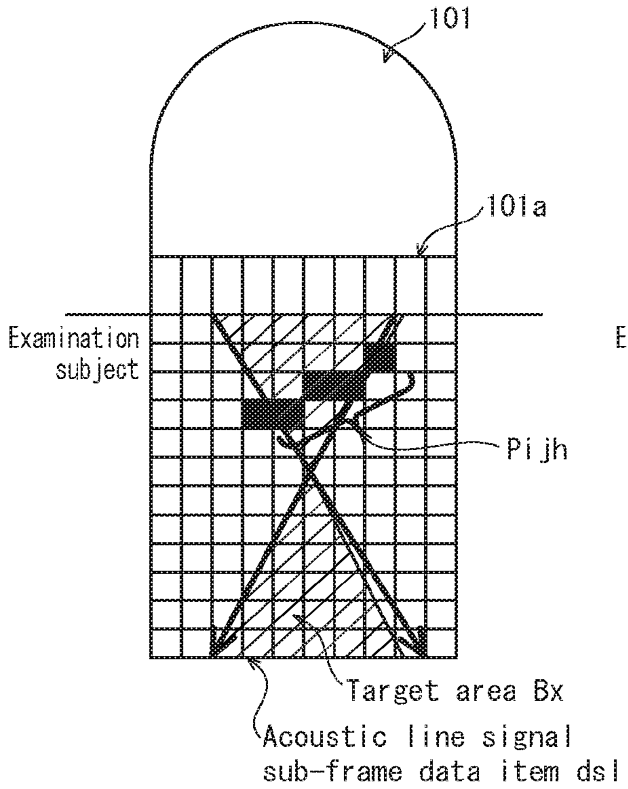


FIG. 20B

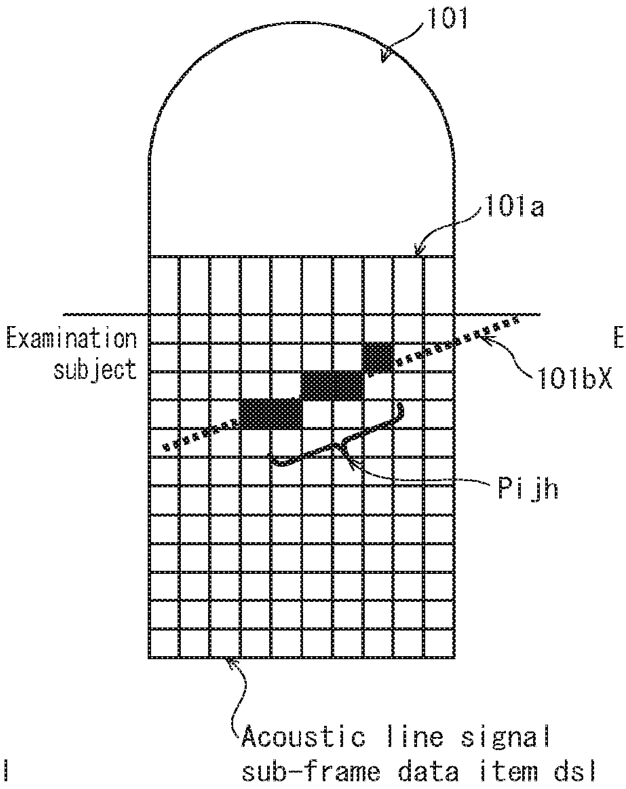


FIG. 20C

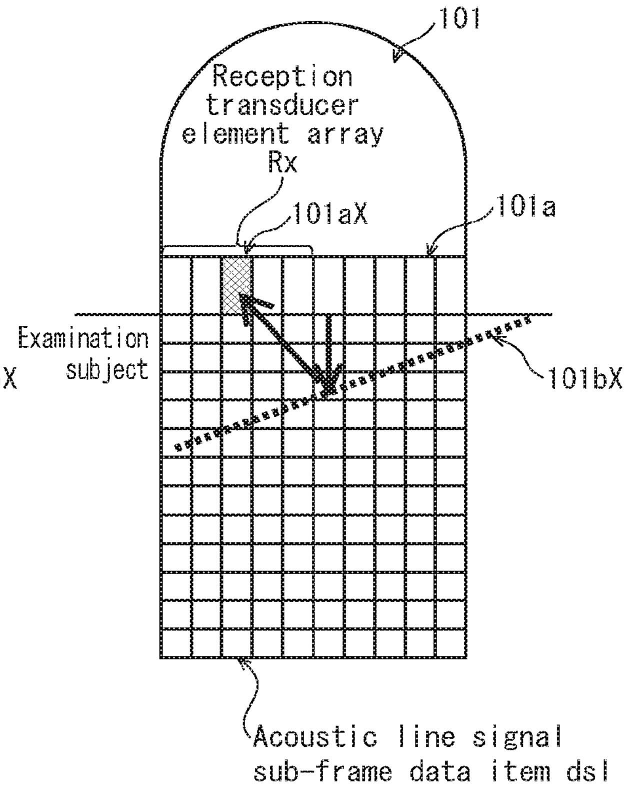


FIG. 21

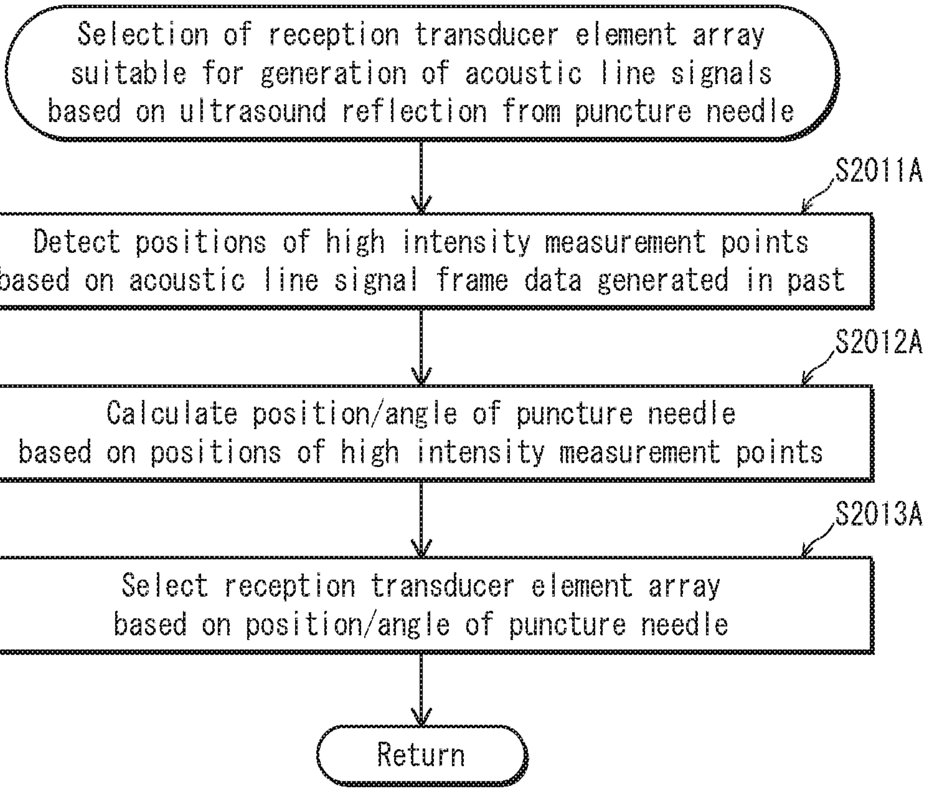

Selection of reception transducer element array suitable for generation of acoustic line signals based on ultrasound reflection from puncture needle
S2011A
Detect positions of high intensity measurement points based on acoustic line signal frame data generated in past
S2012A
Calculate position/angle of puncture needle based on positions of high intensity measurement points
S2013A
Select reception transducer element array based on position/angle of puncture needle
Return

FIG. 22

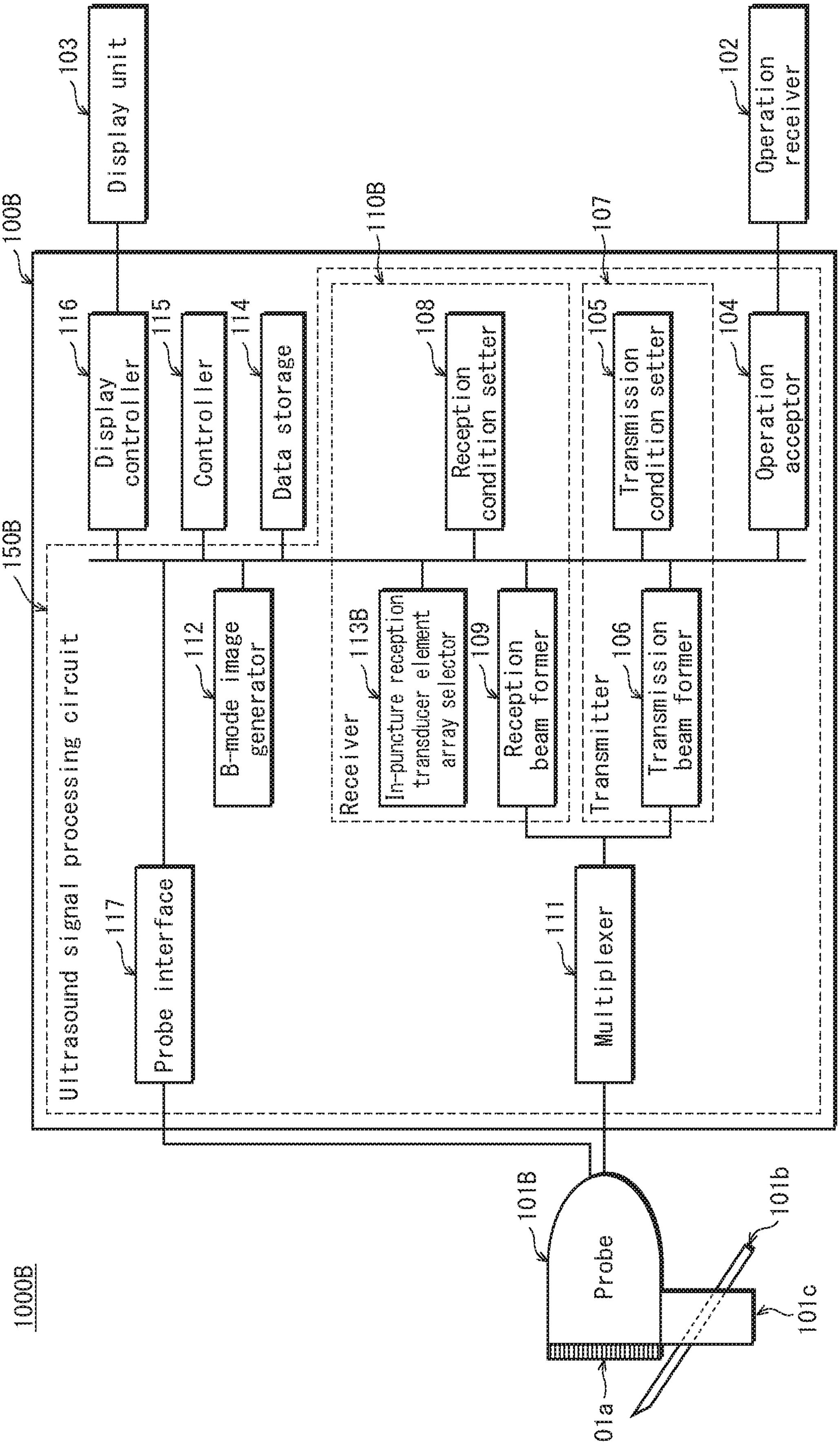

1000B
100B
150B
Ultrasound signal processing circuit
117
Probe interface
111
Multiplexer
112
B-mode image generator
110B
Receiver
113B
In-puncture reception transducer element array selector
109
Reception beam former
108
Reception condition setter
107
Transmitter
106
Transmission beam former
105
Transmission condition setter
104
Operation acceptor
116
Display controller
115
Controller
114
Data storage
103
Display unit
102
Operation receiver
101B
Probe
101a
101b
101c

FIG. 23

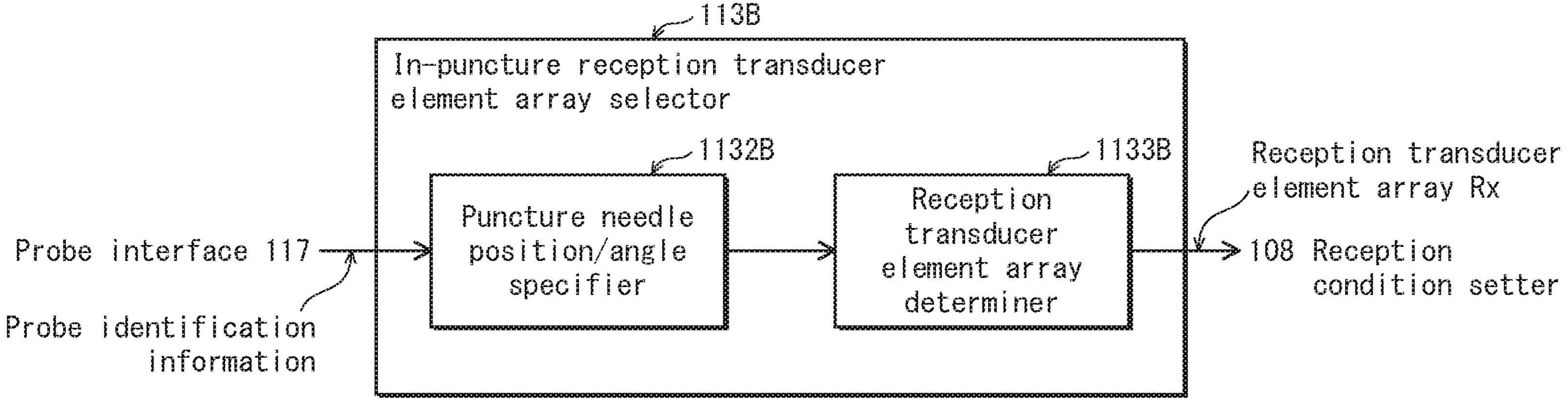

113B
In-puncture reception transducer element array selector
1132B
Puncture needle position/angle specifier
1133B
Reception transducer element array determiner
Probe interface 117
Probe identification information
Reception transducer element array Rx
108 Reception condition setter

FIG. 24A

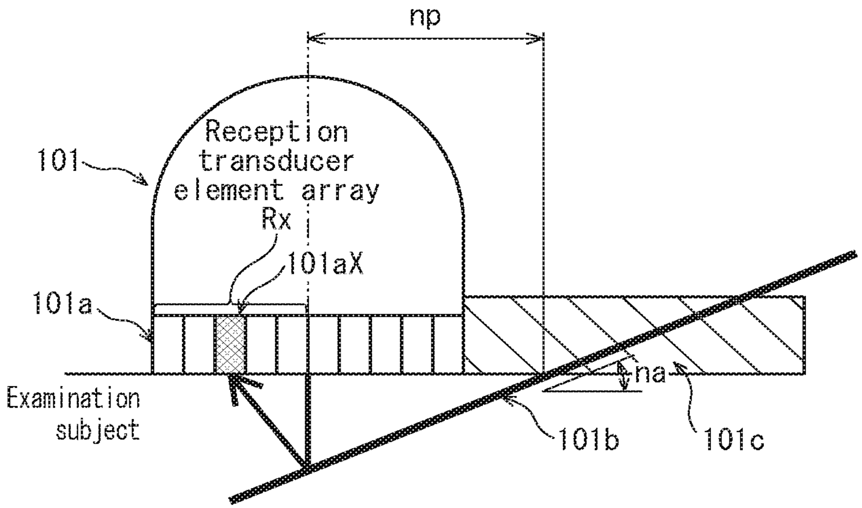


FIG. 24B

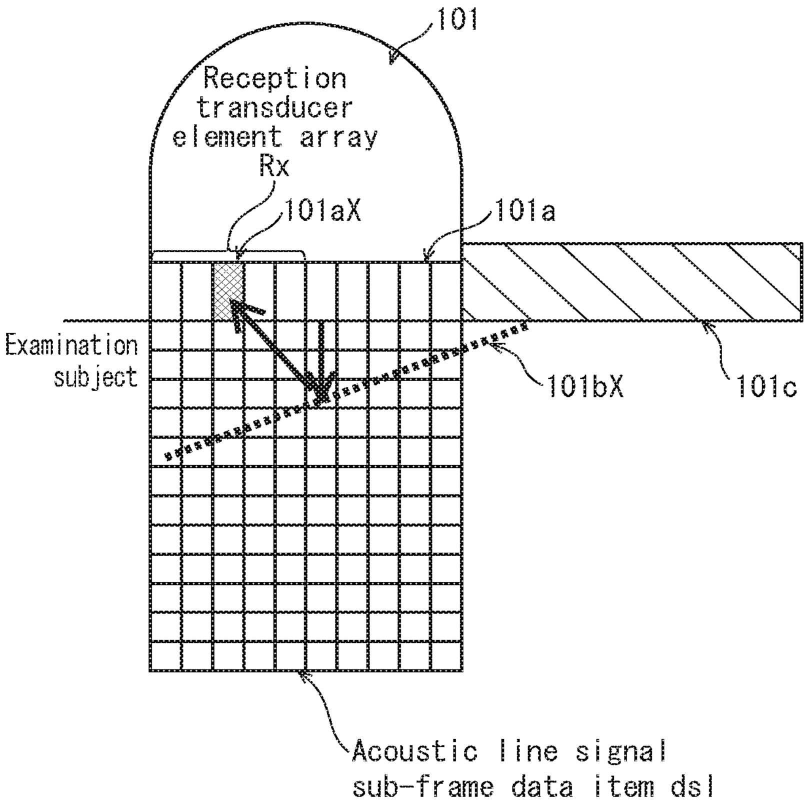


FIG. 25

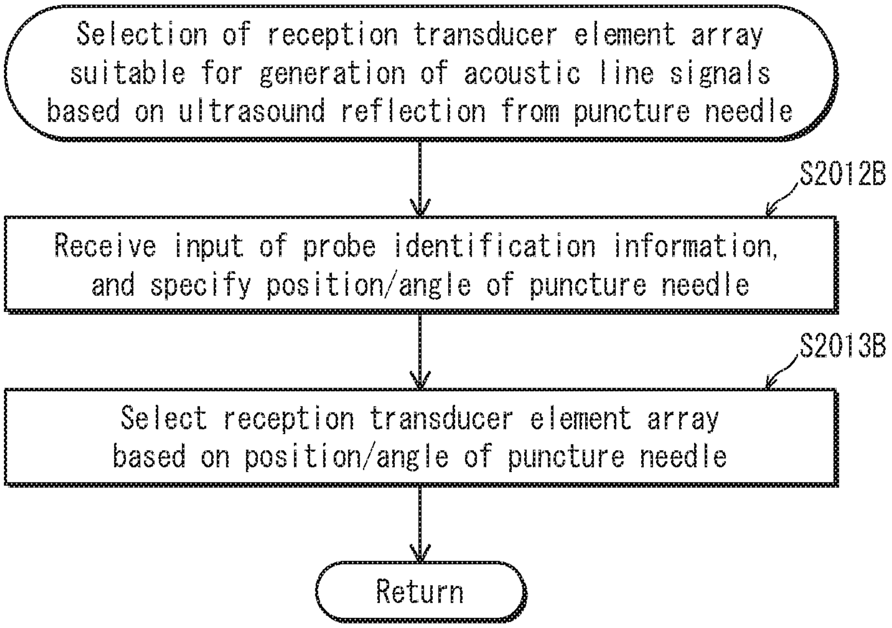

Selection of reception transducer element array suitable for generation of acoustic line signals based on ultrasound reflection from puncture needle
S2012B
Receive input of probe identification information, and specify position/angle of puncture needle
S2013B
Select reception transducer element array based on position/angle of puncture needle
Return

FIG. 26

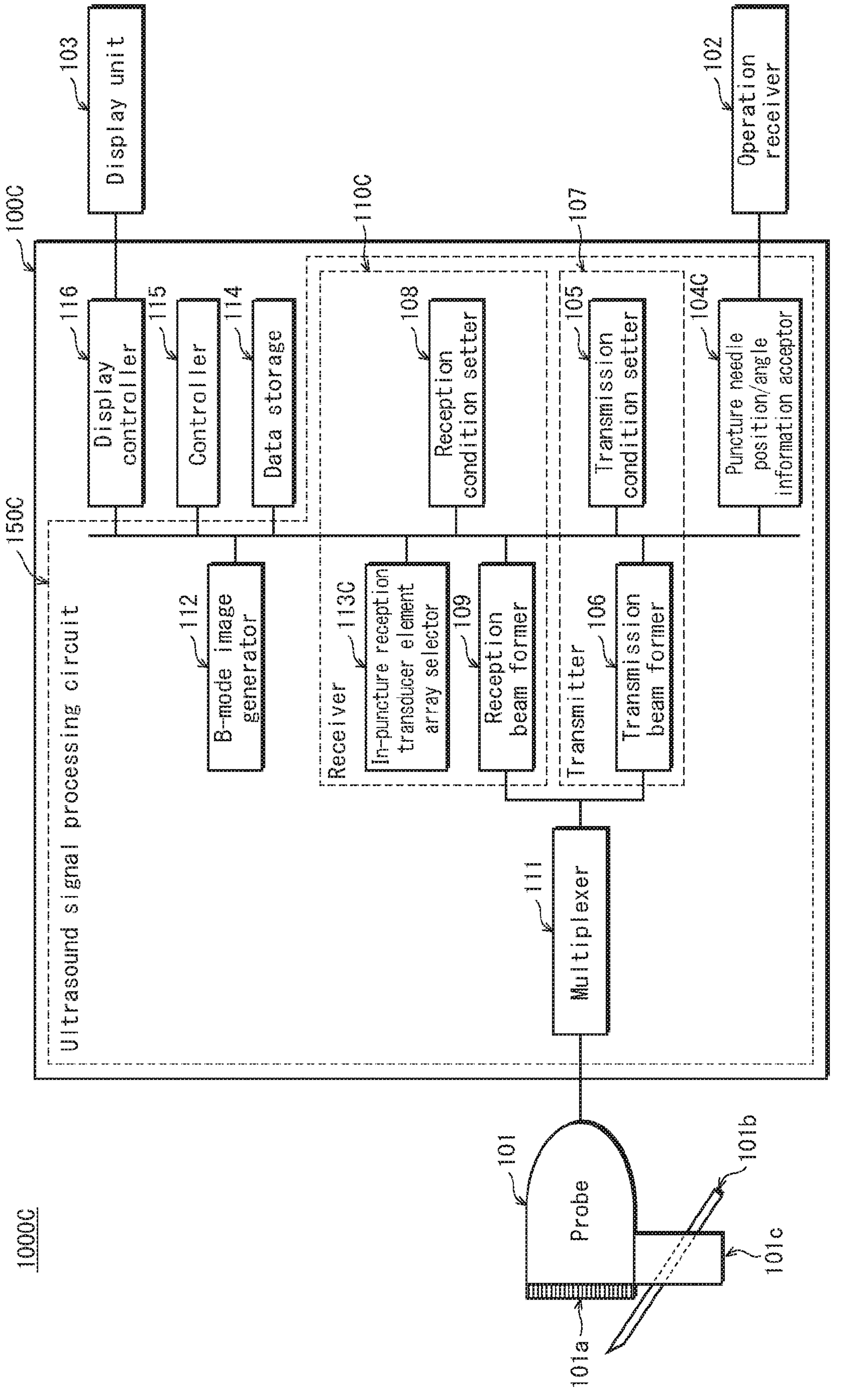

1000C
101a
101
Probe
101b
101c
100C
150C
Ultrasound signal processing circuit
111
Multiplexer
112
B-mode image generator
110C
Receiver
113C
In-puncture reception transducer element array selector
109
Reception beam former
108
Reception condition setter
107
Transmitter
106
Transmission beam former
105
Transmission condition setter
104C
Puncture needle position/angle information acceptor
116
Display controller
115
Controller
114
Data storage
103
Display unit
102
Operation receiver

FIG. 27

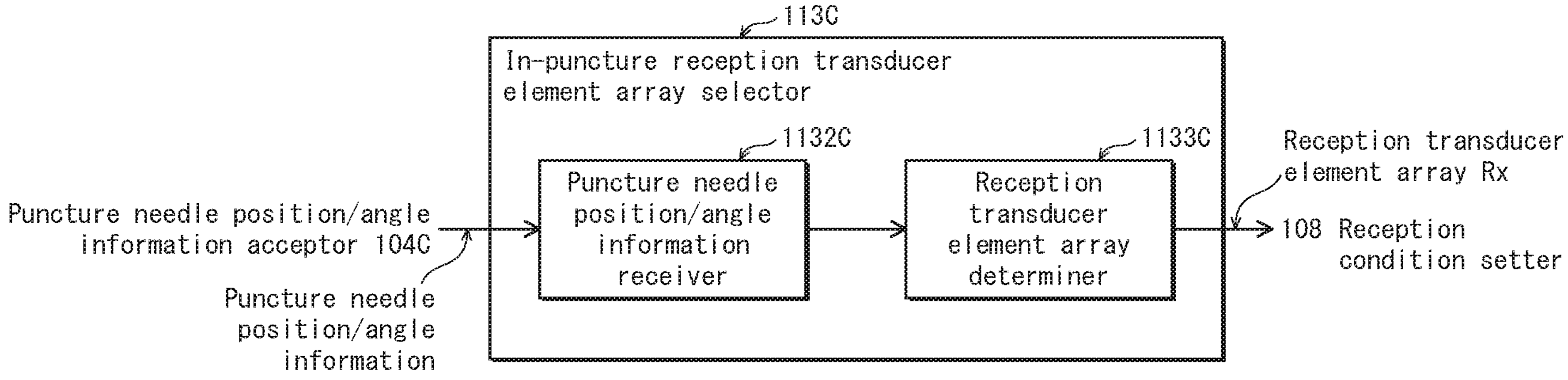

113C
In-puncture reception transducer element array selector
1132C
Puncture needle position/angle information receiver
1133C
Reception transducer element array determiner
Puncture needle position/angle information acceptor 104C
Puncture needle position/angle information
Reception transducer element array Rx
108 Reception condition setter

FIG. 28

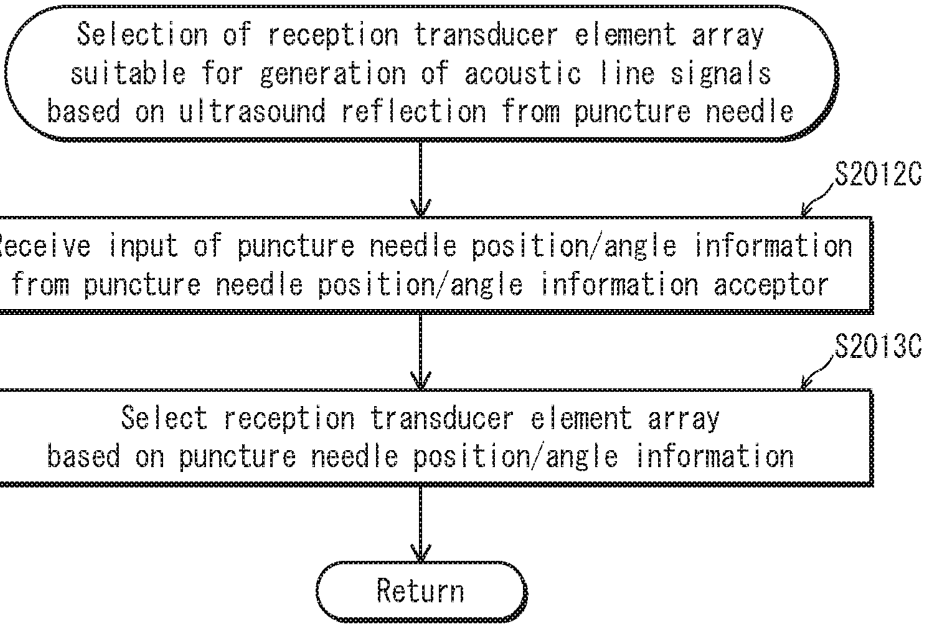
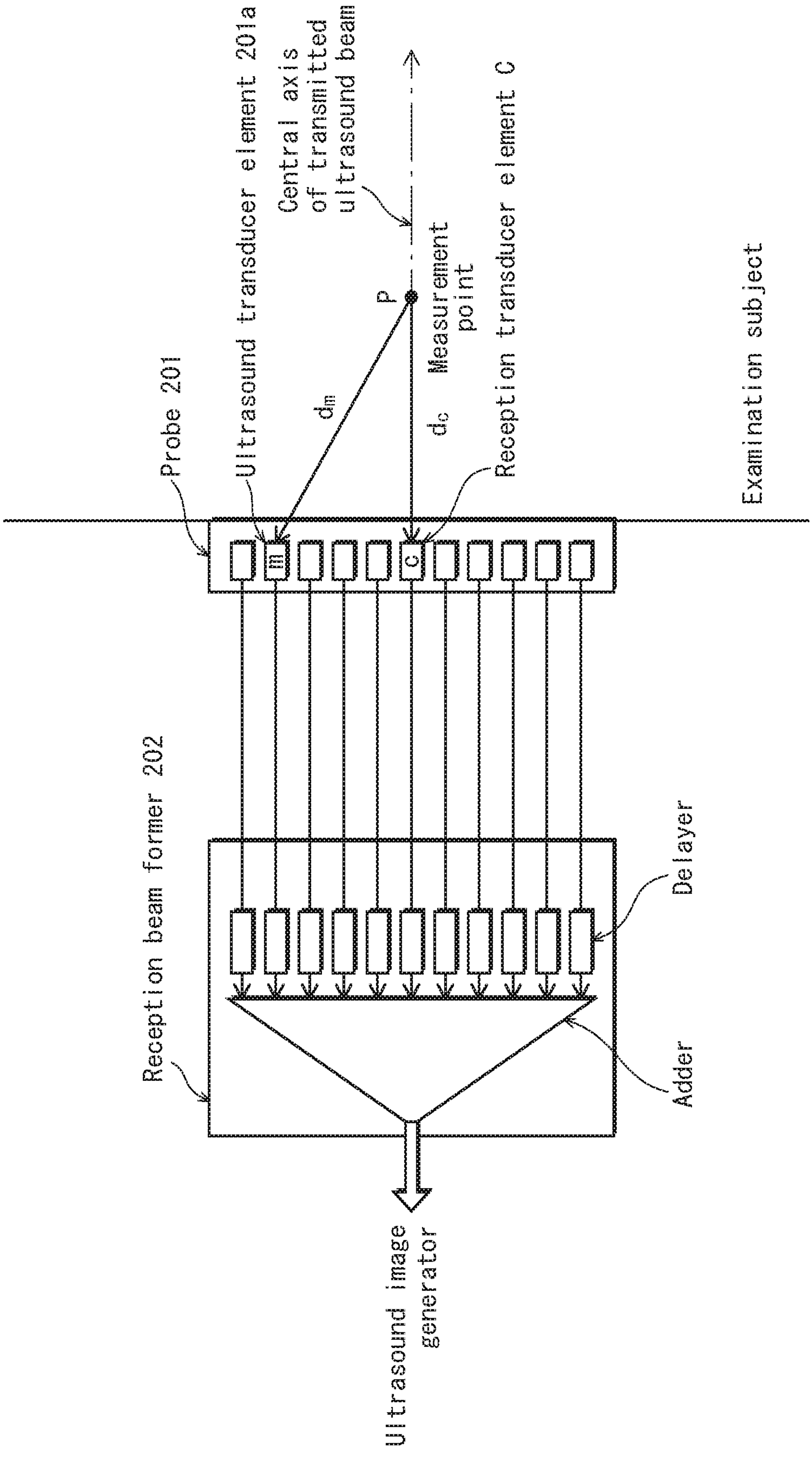

Selection of reception transducer element array suitable for generation of acoustic line signals based on ultrasound reflection from puncture needle
S2012C
Receive input of puncture needle position/angle information from puncture needle position/angle information acceptor
S2013C
Select reception transducer element array based on puncture needle position/angle information
Return

FIG. 29
Prior Art



# ULTRASOUND DIAGNOSTIC DEVICE AND ULTRASOUND SIGNAL PROCESSING METHOD

## CROSS-REFERENCE TO RELATED APPLICATION

**[0001]** This application is based on an application No. 2015-218241 filed in Japan, the contents of which are hereby incorporated by reference.

## BACKGROUND OF THE INVENTION

**[0002]** (1) Field of the Invention

**[0003]** The present disclosure relates to ultrasound diagnostic devices and ultrasound signal processing methods. In particular, the present disclosure relates to beam forming for ultrasound image diagnosis, adapted for the use of a puncture needle.

**[0004]** (2) Description of the Related Art

**[0005]** There exists a medical test called biopsy. In typical biopsy, a puncture needle is inserted into a body of a patient (an examination subject) to remove samples of body tissues and body fluids from the examination subject. Further, anesthesiology, which is practiced by anesthesiologists in intensive care units, pain clinics, etc., also involves the use of puncture needles. In such medical practices, a medical practitioner inserts a puncture needle into the examination subject while checking the position of the puncture needle in ultrasound images that are acquired by using an ultrasound probe (probe) and that show the inside of the examination subject. In inserting the puncture needle into the examination subject, the medical practitioner should be able to specify the puncture needle, particularly the position of the tip of the puncture needle, on a monitor. Thus, there is a demand for ultrasound diagnostic devices producing ultrasound images imaging a puncture needle with high visual perceptibility.

**[0006]** A conventional ultrasound diagnostic device causes transducer elements of a probe to transmit ultrasound towards the inside of the examination subject, in response to which the transducer elements receive, from the inside of the examination subject, ultrasound reflection (echoes) generated due to different body tissues of the examination subject having different levels of acoustic impedance. Based on electric signals acquired based on the ultrasound reflection received, the ultrasound diagnostic device generates ultrasound tomographic images showing the structure of body tissues of the examination subject and displays the ultrasound tomographic images on a monitor.

**[0007]** One method that a conventional ultrasound diagnostic device uses for the generation of signals from ultrasound reflection (for reception beam forming) is delay-and-sum processing. One example of delay-and-sum processing can be found disclosed in pages 42-45 of "Ultrasound Diagnostic Device", written by Masayasu Itou and Tsuyoshi Mochizuki and published by Corona Publishing Co., Ltd (Aug. 26, 2002). FIG. **29** is a schematic illustrating reception beam forming by a conventional ultrasound diagnostic device. The conventional ultrasound diagnostic device illustrated in FIG. **29** has a probe **201** connected thereto. The probe **201** has a plurality of ultrasound transducer elements (transducer elements) **201***a* that receive ultrasound reflection from inside the examination subject. Further, the conventional ultrasound diagnostic device has a reception beam former **202**. The reception beam former **202** is linked with the transducer elements **201***a*, and performs amplification, A/D conversion, and delaying (phase adjustment) on electric signals based on ultrasound reflection that the transducer elements **201***a* receives. Further, the reception beam former **202** multiplies the signals output as a result of such processing by weights (apodization), and outputs sums of the weighted signals as acoustic line signals. When using this reception beam forming method, the ultrasound diagnostic device usually causes the transducer elements **201***a* to transmit ultrasound (i.e., performs transmission beam forming) so that an ultrasound beam transmitted from the transducer elements **201***a* focuses at a predetermined depth of the examination subject. Further, the ultrasound diagnostic device sets measurement points P (points for which acoustic line signals are generated) along the central axis of the transmitted ultrasound beam, and calculates delay amounts for the transducer elements **201***a* with respect to each measurement point P based on the distance between the transducer elements **201***a* and the measurement point P.

**[0008]** Signal generation efficiency per ultrasound transmission is low with this method, since the ultrasound diagnostic device is only capable of generating, for each transmission of ultrasound, acoustic line signals for only one or a few lines of measurement points P along the central axis of the ultrasound beam. Further, with this method, an acoustic line signal generated for a measurement point P not in the vicinity of a transmission focal point has low resolution and low S/N ratio. Thus, the conventional ultrasound diagnostic device is not capable of producing ultrasound images imaging the inside of the examination subject with high visible perceptibility.

**[0009]** In view of such problems, another reception beam forming method is being proposed that utilizes the so-called synthetic aperture method to yield high resolution, high quality images not only from the vicinity of a transmission focal point but also from outside the vicinity of the transmission focal point. One example of such a reception beam forming method can be found disclosed in pages 395 through 405 of "Virtual Ultrasound Sources in High Resolution Ultrasound Imaging", S. I. Nikolov and J. A. Jensen, in Proc, SPIE—Progress in Biomedical Optics and Imaging, Vol. 3, 2002. According to this method, delaying is performed taking into consideration both propagation paths of ultrasound and the amount of time required for ultrasound reflection to arrive at transducer elements by travelling along the propagation paths. Thus, this method achieves reception beam forming making use of ultrasound reflection from both the vicinity of the transmission focal point and the outside of the vicinity of the transmission focal point in an ultrasound main transmission area. Thus, for each transmission of ultrasound, acoustic line signals can be generated for the entire ultrasound main irradiation area. In addition, the synthetic aperture method achieves setting a virtual focus on each measurement point by using multiple signals acquired from the measurement point as a result of multiple transmissions of ultrasound. Thus, reception beam forming method utilizing the synthetic aperture method produces ultrasound images that have higher resolution and higher S/N ratio and that image objects with higher visual perceptibility than those produced with the reception beam forming method disclosed in "Ultrasound Diagnostic Device".

## SUMMARY

### Problems to be Solved

**[0010]** Ultrasound diagnostic devices cause a probe to transmit an ultrasound beam towards the inside of the examination subject and visualize the ultrasound reflection acquired in response. Accordingly, in order for an ultrasound diagnostic device to be able to image a puncture needle being inserted into the examination subject with high visual perceptibility, the ultrasound diagnostic device should be able to accurately generate signals based on both ultrasound reflection from body tissues and ultrasound reflection from the puncture needle.

**[0011]** Here, it should be noted that a puncture needle produces specular ultrasound reflection, whereas body tissues produce diffuse ultrasound reflection. Thus, ultrasound reflection from a puncture needle has high directivity. This means that ultrasound reflection from a puncture needle has strong intensity in a certain direction, which changes depending upon the insertion angle of the puncture needle with respect to the examination subject and the position of the puncture needle relative to the probe. In other words, depending upon conditions such as the angle and the position of the puncture needle relative to the examination subject, ultrasound reflection that a transducer element of a probe receives from the puncture needle may have low intensity, which results in the puncture needle not being imaged with a sufficient level of visual perceptibility.

**[0012]** In particular, when employing the reception beam forming method disclosed in "Virtual Ultrasound Sources in High Resolution Ultrasound Imaging", which utilizes the synthetic aperture method, measurement points may be set over the entire ultrasound main irradiation area. Due to this, depending upon the position of the puncture needle relative to the measurement point for which a signal is to be generated and transducer elements whose ultrasound reflection is to be used in signal generation, a generated signal may barely show ultrasound reflection from the puncture needle. This results in the puncture needle being imaged with low visual perceptibility.

**[0013]** In view of these technical problems, the present disclosure aims to provide an ultrasound signal processing method and an ultrasound diagnostic device producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method.

### Means for Solving the Problems

**[0014]** One aspect of the present disclosure is an ultrasound diagnostic device to which an ultrasound probe having a plurality of transducer elements arrayed along an array direction is connectable, wherein the ultrasound diagnostic device: (i) repeatedly performs transmission events, each by selecting a first group of transducer elements from among the plurality of transducer elements and causing the first group to transmit ultrasound towards an examination subject having a puncture needle inserted therein; (ii) for each of the transmission events, generates a sub-frame data item based on ultrasound reflection received in response to the transmission event, the sub-frame data item including acoustic line signals; and (iii) combines sub-frame data items for the transmission events to generate a frame data item, the frame data item including combined acoustic line signals each being an aggregate of ones of the acoustic line signals, and the ultrasound diagnostic device includes an ultrasound signal processing circuit operating as: a transmitter that performs each of the transmission events by selecting the first group and causing the first group to transmit ultrasound focusing inside the examination subject, the transmitter gradually shifting the first group in the array direction between transmission events; and a receiver that: (i) for each of the transmission events, selects at least some of the plurality of transducer elements and generates a sequence of receive signals for each of the selected transducer elements based on ultrasound reflection that the selected transducer element has received from the examination subject in response to the transmission event; (ii) selects a second group of transducer elements, the transducer elements in the second group being ones among the plurality of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity; (iii) for each of the transmission events, sets a target area for generating the sub-frame data item inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generates the sub-frame data item by performing, for each of a plurality of measurement points in the target area, delay-and-sum processing on receive signals, for the transducer elements in the second group, based on ultrasound reflection from the measurement point; and (iv) generates the frame data item by combining the sub-frame data items for the transmission events.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]** These and the other objects, advantages and features of the technology pertaining to the present disclosure will become apparent from the following description thereof taken in conjunction with the accompanying drawings, which illustrate specific embodiments of the technology pertaining to the present disclosure.

**[0016]** In the drawings:

**[0017]** FIG. **1** illustrates functional blocks of an ultrasound diagnostic system **1000** including an ultrasound diagnostic device **100** pertaining to embodiment 1;

**[0018]** FIG. **2** is a schematic illustrating a propagation path of ultrasound transmitted by a transmitter **107**;

**[0019]** FIG. **3** illustrates functional blocks of a transmission beam former **106**;

**[0020]** FIG. **4** illustrates functional blocks of a reception beam former **109**;

**[0021]** FIG. **5** is a schematic illustrating, based on one transmission event, the relationship between a transmission transducer element array Tx, an ultrasound main irradiation area Ax, a target area Bx, a reception transducer element array Rx, and a reception apodization;

**[0022]** Each of FIGS. **6**A and **6**B is a schematic illustrating an overview of calculation of ultrasound propagation path, performed by a delay processor **10921** of a delay-and-sum calculator **1092**;

**[0023]** Each of FIGS. **7**A and **7**B is a schematic illustrating generation of an acoustic line signal for a measurement point Pij, performed by the delay-and-sum calculator **1092**;

**[0024]** FIG. **8** is a schematic illustrating combining of acoustic line signal sub-frame data items, performed by a sub-frame combiner **10931**;

**[0025]** Each of FIGS. **9**A and **9**B is a schematic illustrating amplification performed by a synthesizer **1093**;

**[0026]** FIG. **10** illustrates functional blocks of an in-puncture reception transducer element array selector **113**;

**[0027]** FIG. **11** is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**;

**[0028]** Each of FIGS. **12**A and **12**B is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**;

**[0029]** Each of FIGS. **13**A through **13**D is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**;

**[0030]** Each of FIGS. **14**A through **14**D is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**;

**[0031]** FIG. **15** is a flowchart illustrating beam forming performed by the ultrasound diagnostic device **100**;

**[0032]** FIG. **16** is a flowchart illustrating selection of a reception transducer element array Rx, performed by the in-puncture reception transducer element array selector **113**;

**[0033]** FIG. **17** is a flowchart illustrating generation of an acoustic line signal for a measurement point Pij, performed by the delay-and-sum calculator **1092**;

**[0034]** FIG. **18** illustrates functional blocks of an ultrasound diagnostic system **1000**A including an ultrasound diagnostic device **100**A pertaining to embodiment 2;

**[0035]** FIG. **19** illustrates functional blocks of an in-puncture reception transducer element array selector **113**A;

**[0036]** Each of FIGS. **20**A through **20**C is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**A, with an acoustic line signal sub-frame data item illustrated over a corresponding position within an examination subject;

**[0037]** FIG. **21** is a flowchart illustrating selection of a reception transducer element array Rx, performed by the in-puncture reception transducer element array selector **113**A;

**[0038]** FIG. **22** illustrates functional blocks of an ultrasound diagnostic system **1000**B including an ultrasound diagnostic device **100**B pertaining to embodiment 3;

**[0039]** FIG. **23** illustrates functional blocks of an in-puncture reception transducer element array selector **113**B;

**[0040]** Each of FIGS. **24**A and **24**B is a schematic illustrating processing by the in-puncture reception transducer element array selector **113**B;

**[0041]** FIG. **25** is a flowchart illustrating selection of a reception transducer element array Rx, performed by the in-puncture reception transducer element array selector **113**B;

**[0042]** FIG. **26** illustrates functional blocks of an ultrasound diagnostic system **1000**C including an ultrasound diagnostic device **100**C pertaining to embodiment 4;

**[0043]** FIG. **27** illustrates functional blocks of an in-puncture reception transducer element array selector **113**C;

**[0044]** FIG. **28** is a flowchart illustrating selection of a reception transducer element array Rx, performed by the in-puncture reception transducer element array selector **113**C; and

**[0045]** FIG. **29** is a schematic illustrating reception beam forming by a conventional ultrasound diagnostic device.

## DESCRIPTION OF PREFERRED EMBODIMENTS

**[0046]** The following describes embodiments of the technology pertaining to the present disclosure.

## Embodiment 1

### <Ultrasound Diagnostic System **1000**>

### 1. Overview of Structure

**[0047]** The following describes an ultrasound diagnostic system **1000** with reference to the accompanying drawings. The ultrasound diagnostic system **1000** includes an ultrasound diagnostic device **100** pertaining to embodiment 1. FIG. **1** illustrates functional blocks of the ultrasound diagnostic system **1000**. As illustrated in FIG. **1**, the ultrasound diagnostic system **1000** includes, in addition to the ultrasound diagnostic device **100**, an ultrasound probe **101** (probe **101**), an operation receiver **102**, and a display unit **103**. The probe **101** has a plurality of transducer elements **101***a* arrayed at a front tip surface thereof. The transducer elements **101***a* are capable of transmitting ultrasound towards an examination subject and receiving ultrasound reflection from the examination subject. The ultrasound diagnostic device **100** causes the probe **101** to perform transmission and reception of ultrasound, and generates ultrasound images based on signals output from the probe **101**. The operation receiver **102** receives input operations performed by an examiner. The display unit **103** displays ultrasound images on a screen. Each of the probe **101**, the operation receiver **102**, and the display unit **103** can be connected to the ultrasound diagnostic device **100** or disconnected from the ultrasound diagnostic device **100**. FIG. **1** illustrates the ultrasound diagnostic device **100** with the probe **101**, the operation receiver **102**, and the display unit **103** connected thereto. Alternatively, the probe **101**, the operation receiver **102**, and the display unit **103** may be incorporated into the ultrasound diagnostic device **100**.

**[0048]** The following describes each of the probe **101**, the operation receiver **102**, and the display unit **103**, which are external components connectable to the ultrasound diagnostic device **100**.

### 2. Probe **101**

**[0049]** The probe **101** has transducer elements **101***a* that are, for example, arrayed along one direction (array direction). The probe **101** receives a pulsar electric signal (transmission signal) from a later-described transmission beam former **106** of the ultrasound diagnostic device **100**, and converts the pulsar electric signal into ultrasound pulses. Here, while the probe **101** is described as converting a pulsar signal into ultrasound pulses for the sake of simplicity, the input and output of the probe **101** are not limited to being pulsar in such a manner. The probe **101**, with an outer surface thereof where the transducer elements **101***a* are arranged in contact with a skin surface of the examination subject, transmits an ultrasound beam towards the examination subject. Here, an ultrasound beam is considered as an aggregate of ultrasound transmitted from a plurality of transducer elements **101***a*. Further, the probe **101** receives ultrasound reflection from the examination subject by using a plurality of transducer elements **101***a*. The transducer elements **101***a* receiving ultrasound reflection convert the ultrasound reflection into electric signals, and the probe **101** supplies these electric signals to a later-described reception beam former **109** of the ultrasound diagnostic device **100**.

**[0050]** Further, the probe **101** has a puncture guide **101***c* attached thereto. The puncture guide **101***c* holds a puncture needle **101***b*. Specifically, the puncture guide **101***c* has an undepicted guide member that, when the probe **101** is put in contact with the skin surface of the examination subject, guides the puncture needle **101***b* into the examination subject at a predetermined insertion angle. Further, a configuration may be made such that the angle of the puncture guide **101***c* relative to the probe **101** is changeable, which enables adjusting the insertion angle of the puncture needle **101***b* with respect to the examination subject.

### 3. Operation Receiver **102**

**[0051]** The operation receiver **102** receives an input operation that the examiner performs in operating the ultrasound diagnostic device **100**, and outputs the input operation to be received by a later-described controller **115** of the ultrasound diagnostic device **100** via a later described operation acceptor **104** of the ultrasound diagnostic device **100**. The input operation may be, for example, an input operation for changing a setting of the ultrasound diagnostic device **100** or an input operation for controlling the ultrasound diagnostic device **100**. Further, a configuration may be made, for example, such that the operation receiver **102** is capable of receiving, from the examiner, manual input for setting the insertion angle of the puncture needle **101***b* with respect to body tissues of the examination subject and the position of the puncture needle **101***b* relative to the transducer elements **101**, as described later in detail in embodiment 4.

**[0052]** Note that the combination of the operation receiver **102** and the display unit **103** may be implemented by using a touch panel. With this configuration, the examiner can change settings of the ultrasound diagnostic device **100** and control the ultrasound diagnostic device **100** by performing touch input, drag input, etc., by using one or more operation keys displayed on the display unit **103**. Alternatively, the operation receiver **102** may be, for example, a keyboard having keys that the examiner can use to perform various operations, or an operation panel having one or more buttons, one or more levers, and/or the like that the examiner can use to perform various operations. Alternatively, the operation receiver **102** may be, for example, a trackball, a mouse, or a flat pad that the examiner can use to control a cursor displayed on the display unit **103**. Further, the operation receiver **102** may be a combination of two or more of such devices. Also, a plurality of operation receivers **102** may be provided, each being one of such devices.

### 4. Display Unit **103**

**[0053]** The display unit **103** is an image display device, and has a screen for displaying images output from a later-described display controller **116** of the ultrasound diagnostic device **100**. The display unit **103** may be, for example, a liquid crystal display (LCD), a cathode ray tube (CRT), or an organic electroluminescence (EL) display.

## <Overview of Structure of Ultrasound Diagnostic Device **100**>

**[0054]** The following describes the ultrasound diagnostic device **100** pertaining to embodiment 1.

**[0055]** The ultrasound diagnostic device **100** includes: a transmission condition setter **105**; a transmission beam former **106**; a reception condition setter **108**; a reception beam former **109**; a multiplexer **111**; and an in-puncture reception transducer element array selector **113**. The transmission condition setter **105** generates information indicating a group of transducer elements **101***a* that are to perform ultrasound transmission, and outputs the information to the transmission beam former **106**. In the following, the transducer elements **101***a* that perform ultrasound transmission are referred to as transmission transducer elements **101***a*, and the group of the transmission transducer elements **101***a* is referred to as a transmission transducer element array Tx. The transmission beam former **106** determines when a high voltage triggering ultrasound transmission is to be applied to the transmission transducer elements **101***a*. The reception condition setter **108** generates information indicating a group of transducer elements **101***a* whose receive signals are to be used for the generation of acoustic line signals, and outputs the information to the reception beam former **109**. In the following, the transducer elements **101***a* whose receive signals are used for the generation of acoustic line signals are referred to as reception transducer elements **101***a*, and the group of the reception transducer elements **101***a* is referred to as a reception transducer element array Rx. The multiplexer **111** is capable of connecting to either the transmission transducer elements **101***a* or the reception transducer elements **101***a*, and provides the transducer elements **101***a* to which it is connected with input and receives output from the transducer elements **101***a* to which it is connected. The in-puncture reception transducer element array selector **113** selects, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity.

**[0056]** The ultrasound diagnostic device **100** further includes a B-mode image generator **112**. The B-mode image generator **112** generates ultrasound images (B-mode images) one after another by using acoustic line signals that the reception beam former **109** generates and outputs based on ultrasound transmission by the transmission beam former **106**.

**[0057]** The ultrasound diagnostic device **100** further includes: an operation acceptor **104**; a data storage **114**; a display controller **116**; and a controller **115**. The operation acceptor **104** receives, from the operation receiver **102**, information related to the manual input operation that the examiner has performed on the operation receiver **102**. The data storage **114** stores, for example, receive signals and acoustic line signals output from the reception beam former **109**, and B-mode images output from the B-mode image generator **112**. The display controller **116** forms display images and causes the display unit **103** to display the display images. The controller **115** controls the components of the ultrasound diagnostic device **100**.

**[0058]** Among the components of the ultrasound diagnostic device **100**, the operation acceptor **104**, the transmission condition setter **105**, the transmission beam former **106**, the reception condition setter **108**, the reception beam former **109**, the multiplexer **111**, the B-mode image generator **112**, and the in-puncture reception transducer element array selector **113** form an ultrasound signal processing circuit **150**. Further, the transmission condition setter **105** and the transmission beam former **106** form a transmitter **107**, and the reception condition setter **108**, the reception beam former **109**, and the in-puncture reception transducer element array selector **113** form a receiver **110**.

**[0059]** The controller **115**, the display controller **116**, and the components of the ultrasound signal processing circuit

**150** are each implemented by using, for example, a hardware circuit such as a field-programmable gate array (FPGA) or an application-specific integrated circuit (ASIC). Alternatively, such components may each be implemented by using a combination of software and a programmable device such as a central processing unit (CPU), a General-purpose computing on graphics processing unit (GPGPU), or any processor. Such components may each be implemented as one circuit component, or as an aggregate of a plurality of circuit components. Further, a plurality of such components may be implemented by using one circuit component, or as an aggregate of a plurality of circuit components.

**[0060]** The data storage **114** is a computer-readable recording medium. For example, the data storage **114** may be implemented by using a flexible disk, a hard disk, an MO, a DVD, a DVD-RAM, or a semiconductor memory. Alternatively, the data storage **114** may be an external storage device connected to the ultrasound diagnostic device **100**.

**[0061]** Note that the ultrasound diagnostic device **100** need not have the structure illustrated in FIG. **1**. For example, the ultrasound diagnostic device **100** may not include the multiplexer **111**. Further, the probe **101** may include a part or the entirety of, for example, at least one of the transmission beam former **106** and the reception beam former **109**.

## <Structures of Components of Ultrasound Diagnostic Device **100**>

**[0062]** The ultrasound diagnostic device **100** is characterized for including the transmitter **107** and the receiver **110**. The transmitter **107** causes transmission transducer elements **101***a* to perform ultrasound transmission. The receiver **110** performs computation on electric signals that the probe **101** acquires through the reception of ultrasound reflection, and generates acoustic line signals used for forming ultrasound images. Due to this, the following description focuses on the structures and functions of the components included in the transmitter **107** and the receiver **110**. Note that components other than those included in the transmitter **107** and the receiver **110** may have structures and functions similar to those in conventional ultrasound diagnostic devices. In other words, the ultrasound diagnostic device **100** may be implemented by replacing a transmitter and a receiver of a conventional ultrasound diagnostic device with the transmitter **107** and the receiver **110** pertaining to the present embodiment, respectively.

## 1. Transmitter **107**

**[0063]** The transmitter **107** is connected to the probe **101**, via the multiplexer **111**. The transmitter **107** determines when a high voltage pulse is to be applied to each of some of the transducer elements **101***a* of the probe **101** (i.e., each of the transmission transducer elements **101***a*) to trigger ultrasound transmission from the probe **101**. The transmitter **107** repeatedly performs transmissions of ultrasound while gradually shifting the transmission transducer element array Tx in the array direction each time. Consequently, all transducer elements **101***a* of the probe **101** perform ultrasound transmission. In the following, a single transmission of ultrasound that the transmitter **107** performs by using one transmission transducer element array Tx is referred to as a transmission event.

**[0064]** The transmitter **107** includes the transmission condition setter **105** and the transmission beam former **106**.

### 1.1. Transmission Condition Setter **105**

**[0065]** For each transmission event, the transmission condition setter **105** supplies the transmission beam former **106** with a transmission control signal. The transmission control signal causes the transmission transducer elements **101***a* for the transmission event to transmit an ultrasound beam focusing at a transmission focal point FP set at a predetermined depth (focal depth) in the examination subject. A transmission control signal for a transmission event includes the following information for example: (i) information indicating positions of the transmission transducer elements **101***a* for the transmission event among the transducer elements **101***a* of the probe **101**; (ii) information indicating the position of the transmission focal point FP for the transmission event; and (iii) information indicating a pulse width of ultrasound pulse to be transmitted.

**[0066]** FIG. **2** is a schematic illustrating a propagation path of ultrasound that the transmitter **107** causes the transmission transducer elements **101***a* to transmit. FIG. **2** illustrates a transmission transducer element array Tx for one transmission event, which is a group of transducer elements **101***a* that contribute to the transmission event. For example, supposing that the probe **101** has one hundred and ninety two (**192**) transducer elements **101***a* in total, the number of transmission transducer elements **101***a* included in each transmission transducer element array Tx may be twenty (**20**) to one hundred (**100**).

**[0067]** Further, the transmission beam former **106** controls when the transmission transducer elements **101***a* perform ultrasound transmission such that the closer a transmission transducer element **101***a* is to the center position of the transmission transducer element array Tx in the array direction, the later the transmission transducer element **101***a* transmits ultrasound in the transmission event. Consequently, the wavefront of ultrasound transmitted from the transmission transducer elements **101***a* focuses at one point at the focal depth, and thus, the ultrasound beam transmitted from the transmission transducer element array Tx focuses at the transmission focal point FP. Note that the focal depth (i.e., the depth of the transmission focal point FP) can be set as desired or required.

**[0068]** After focusing at the transmission focal point FP, the wavefront of the transmitted ultrasound spreads out as before focusing at the transmission focal point FP. Thus, the transmitted ultrasound mainly propagates through an hourglass-shaped area which has a base defined by the transmission transducer element array Tx and which is partitioned from other areas inside the examination subject by two straight lines intersecting at the transmission focal point FP. Specifically, the ultrasound transmitted from the transmission transducer element array Tx propagates in the following manner. As the ultrasound advances deeper inside the examination subject from the transmission transducer element array Tx, the width thereof (length along X axis in FIG. **2**) gradually decreases until reaching the minimum width at the transmission focal point FP. Then, as the ultrasound advances deeper beyond the transmission focal point FP (i.e., as the ultrasound advances in the downward direction in FIG. **2**), the width thereof increases (i.e., the ultrasound spreads out). In the following, this hourglass-shaped area described above (indicated by diagonal hatching in FIG. **2**) is referred to as an ultrasound main irradiation area Ax.

**[0069]** Further, the F number of transmitted ultrasound (i.e., the ratio of the depth of the transmission focal point FP to the length of the transmission transducer element array Tx) set to the transmission beam former **103** may for example be greater than or equal two and smaller than or equal to four. With this F number, the angle θ at which the two straight lines that define the boundary of the ultrasound main irradiation area Ax intersect at the transmission focal point FP is approximately greater than or equal to 14° and smaller than or equal to 28°.

**[0070]** Note that in the present disclosure, a focused ultrasound beam generated by ultrasound transmission need not focus at a single point as described above, as long as the area that the ultrasound beam irradiates decreases starting from the point of transmission to reach a minimum at the focal depth. When the focused ultrasound beam does not focus at a single point, the transmission focal point FP is the center position of the ultrasound beam at the focal depth.

### 1.2 Transmission Beam Former **106**

**[0071]** The transmission beam former **106** is connected to the probe **101**, via the multiplexer **111**. The transmission beam former **106** receives the transmission control signal from the transmission condition setter **105**, and based on the transmission control signal, outputs a high voltage to each transmission transducer element **101***a* to trigger ultrasound transmission from the probe **101**.

**[0072]** FIG. **3** is a functional block diagram illustrating the structure of the transmission beam former **106**. As illustrated in FIG. **3**, the transmission beam former **106** includes: a drive signal generator **1061**; a delay profile generator **1062**; and a drive signal transmitter **1063**.

### (1) Drive Signal Generator **1061**

**[0073]** The drive signal generator **1061** is a circuit that, based on information in the transmission control signal indicating a transmission transducer element array Tx and a pulse width, generates a pulse signal sp for causing some or all of the transducer elements **101***a* of the probe **101** (i.e., the transmission transducer element array Tx) to transmit an ultrasound beam.

### (2) Delay Profile Generator **1062**

**[0074]** The delay profile generator **1062** is a circuit that, based on information in the transmission control signal indicating a transmission transducer element array Tx and a position of a transmission focal point FP, specifies and outputs a delay time tpk for each transmission transducer element **101***a* (k denotes a natural number between one and m, inclusive, and m denotes a natural number indicating the total number of transmission transducer elements **101***a* for a transmission event). The delay time tpk for a transmission transducer element **101***a* specifies when the transmission transducer element **101***a* performs ultrasound transmission. Thus, the delay time tpk delays ultrasound transmission by a corresponding transmission transducer element **101***a*, which results in the generation of a focused ultrasound beam.

### (3) Drive Signal Transmitter **1063**

**[0075]** The drive signal transmitter **1063** is a circuit that performs, for each transmission transducer element **101***a*, transmission processing of supplying a transmission signal sck to the transmission transducer element **101***a* based on the pulse signal sp from the drive signal generator **1061** and the delay time tpk from the delay profile generator **1062**. A transmission signal sck supplied to a transmission transducer element **101***a* causes the transmission transducer element **101***a* to perform ultrasound transmission. Note that the transmission beam former **106** is connected to the transmission transducer element array Tx via the multiplexer **111**.

**[0076]** The transmission beam former **106**, based on transmission control signals from the transmission condition setter **105**, repeatedly performs transmission events while gradually shifting the transmission transducer element array Tx in the array direction each time. Consequently, all transducer elements **101***a* of the probe **101** perform ultrasound transmission. Further, the transmission beam former **106**, by repeatedly performing transmission events while gradually shifting the transmission transducer element array Tx in the array direction each time, also gradually shifts the transmission focal point FP in the array direction. Thus, the transmission beam former **106** causes transmitted ultrasound to propagate over the entirety of an examination subject area of the examination subject.

### 2. Receiver **110**

**[0077]** The receiver **110** generates acoustic line signals based on electric signals that a plurality of transducer elements **101***a* have acquired based on ultrasound reflection received by the probe **101**. As illustrated in FIG. **1**, the receiver **110** includes: the reception condition setter **108**; the reception beam former **109**; and the in-puncture reception transducer element array selector **113**.

**[0078]** The following describes the structure of the components of the receiver **110**.

### 2.1. Reception Condition Setter **108**

**[0079]** For each transmission event, the reception condition setter **108** generates a reception control signal and supplies the reception beam former **109** with the reception control signal. The reception control signal causes the reception beam former **109** to generate acoustic line signals based on electric signals that a plurality of transducer elements **101***a* acquire based on ultrasound reflection received by the probe **101** in response to the transmission event. For example, the reception control signal includes information indicating a reception transducer element array Rx and information indicating a target area Bx for which acoustic line signals are to be generated. In addition, the reception control signal may include information indicating a reception apodization.

### a) Setting of Target Area Bx

**[0080]** For each transmission event, the reception condition setter **108** acquires information indicating a transmission transducer element array Tx and information indicating the position of a transmission focal point FP from the transmission condition setter **105**. Using such information, the reception condition setter **108** sets a target area Bx for the transmission event. In the present disclosure, a target area

Bx is a signal area that is set for each transmission event and that includes a plurality of measurement points Pij, for each of which an acoustic line signal is to be generated. In other words, for each transmission event, acoustic line signals are generated for measurement points Pij included in a target area Bx. Thus, a target area Bx is a group of measurement points Pij for which acoustic line signals are to be generated, and is set for each transmission event for the sake of calculation.

**[0081]** FIG. **5** is a schematic illustrating, based on one transmission event, the relationship between a transmission transducer element array Tx, an ultrasound main irradiation area Ax, a target area Bx, a reception transducer element array Rx, and a reception apodization. As illustrated in FIG. **5**, in the present disclosure, a target area Bx is an hourglass-shaped area that is internally tangent to two straight lines passing through the transmission focal point FP and different ends of the transmission transducer element array Tx. As such, the target area Bx is substantially equivalent to the ultrasound main irradiation area Ax.

### b) Setting of Reception Transducer Element Array Rx

**[0082]** The reception condition setter **108** also specifies a reception transducer element array Rx. In the present disclosure, a reception transducer element array Rx is, as illustrated in FIG. **5**, a group of transducer elements **101***a* (reception transducer elements **101***a*) whose sequences of receive signals are used in delay-and-sum processing for generating acoustic line signals for measurement points Pij.

**[0083]** Specifically, when receiving information indicating a group of transducer elements **101***a* suitable for generation of acoustic line signals from the puncture needle **101***b* from the in-puncture reception transducer element array selector **113**, the reception condition setter **108** sets the group of transducer elements **101***a* as a reception transducer element array Rx. Meanwhile, when not receiving information indicating a group of transducer elements **101***a* suitable for generation of acoustic line signals from the puncture needle **101***b* from the in-puncture reception transducer element array **113**, the reception condition setter **108** sets a reception transducer element array Rx according to a predetermined method. For example, the predetermined method may be (i) a method of setting, for each transmission event, a reception transducer element array Rx such that the center position of the reception transducer element array Rx in the array direction matches the center position of the transmission transducer element array Tx in the array direction, or (ii) a method of setting, for each measurement point Pij, a reception transducer element array Rx such that the center position of the reception transducer element array Rx in the array direction matches the position of the measurement point Pij in the array direction. Here, when setting a reception transducer element array Rx according to a predetermined method as described above, it is preferable that the reception condition setter **108** set the reception transducer element array Rx such that the reception transducer element array Rx has a greater array-direction length than the transmission transducer element array Tx for a corresponding transmission event. For example, the number of transducer elements **101***a* included in the reception transducer element array Rx may be 32, 64, 96, 128, 192, and so on.

### c) Setting of Reception Apodization

**[0084]** In addition to setting a reception transducer element array Rx, the reception condition setter **108** may also set a reception apodization for the reception transducer element array Rx. In the present disclosure, a reception apodization is information indicating a distribution of weights to be used in delay-and-sum processing. Specifically, the reception apodization is a numerical sequence composed of weight coefficients that are to be applied to sequences of receive signals for the reception transducer elements **101***a* included in the reception transducer element array Rx. Further, the reception apodization is set so that the maximum weight is set with respect to the reception transducer element **101***a* located at the center position of the reception transducer element array Rx in the array direction. Thus, as illustrated in FIG. **5**, the reception apodization is set so that the central axis of the reception apodization in the array direction matches the central axis Rxo of the receive transducer element array Rx in the array direction. The reception apodization may indicate a weight distribution of any shape, including but not limited to a hamming window, a hanning window, and a rectangular window.

### d) Other Matters

**[0085]** The reception condition setter **108** generates a reception control signal for each transmission event performed. Due to this, the number of times the generation of the reception control signal is performed is equal to the number of transmission events performed. Note that the reception condition setter **108** may perform the generation of reception control signals for transmission events such that a reception control signal is generated each time a transmission event is performed, or alternatively, such that reception control signals for all transmission events are generated at once upon completion of the transmission events.

**[0086]** In the present embodiment, the target area Bx is set to have a shape similar to the shape of the ultrasound main irradiation area Ax. Thus, the target area Bx is an hourglass-shaped area whose base is set along the surface of the examination subject that is in contact with the transmission transducer element array Tx. Setting such a target area Bx enables distributing measurement points over substantially the entire ultrasound main irradiation area Ax, and thereby improves the efficiency of signal generation for each transmission event.

**[0087]** However, the target area Bx need not have an hourglass shape and may have other shapes. For example, when a configuration is made such that transmission transducer elements transmit parallel ultrasound waves, the target area Bx may be configured as a rectangular-shaped area whose base is set along the surface of the examination subject that is in contact with the transmission transducer element array Tx. This configuration also enables distributing measurement points over substantially the entire ultrasound main irradiation area Ax, and thereby improves the efficiency of signal generation for each transmission event.

**[0088]** The reception condition setter **108** outputs the reception control signals to the reception beam former **109**.

### 2.2 Reception Beam Former **109**

**[0089]** The reception beam former **109** generates an acoustic line signal sub-frame data item dsl for each transmission event, and generates a combined acoustic line signal frame data item ds by combining acoustic line signal sub-frame data items dsl for transmission events. Specifically, for each transmission event, the reception beam former **109**

generates an acoustic line signal sub-frame data item dsl by generating an acoustic line signal for each measurement point Pij in the target area Bx. As described above, the target area Bx is set for each transmission event, and the target area Bx for a given transmission event is included in the ultrasound main irradiation area Ax for the transmission event. Further, the reception beam former **109** generates acoustic line signals based on ultrasound reflection that a plurality of transducer elements **101***a* receive in response to each transmission event.

**[0090]** Specifically, the reception beam former **109** generates, for each transmission event having been performed, acoustic line signals based on electric signals acquired by a plurality of transducer elements **101***a* based on ultrasound reflection received by the probe **101** in response to the transmission event. In the present disclosure, an acoustic line signal is generated for each measurement point Pij, through delay-and-sum processing of receive signals corresponding to the measurement point Pij.

**[0091]** Further, the reception beam former **109** specifies, as an acoustic line signal sub-frame data item dsl for the transmission event, a set of acoustic lines signals each corresponding to a different one of the measurement points Pij included in the target area Bx for the transmission event. By repeating this process for each transmission event, the reception beam former **109** generates an acoustic line signal sub-frame data item dsl for each transmission event.

**[0092]** Here, note that 1 denotes a natural number between 1 and n, and n denotes the total number of transmission events that are performed. The reception beam former **109** outputs the acoustic line signal sub-frame data items dsl for the transmission events to be stored in the data storage **114**.

**[0093]** Further, the reception beam former **109** generates a combined acoustic line signal frame data item ds by combining the acoustic line signal sub-frame data items dsl for the different transmission events. The reception beam former **109** outputs the combined acoustic line signal frame data item ds to be stored in the data storage **114**.

**[0094]** Further, the reception beam former **109** generates a sequence of combined acoustic line signal frame data items ds by repeatedly performing the generation of the combined acoustic line signal frame data item ds. The reception beam former **109** outputs the sequence of combined acoustic line signal frame data items ds to be stored in the data storage **114**.

**[0095]** FIG. **4** illustrates functional blocks of the reception beam former **109**. The reception beam former **109** includes: an input unit **1091**; a delay-and-sum calculator **1092**; and a synthesizer **1093**.

### (1) Input Unit **1091**

**[0096]** The input unit **1091** is connected to the probe **101**, via the multiplexer **111**. The input unit **1091** is a circuit that generates receive signal sequences (RF signals) based on ultrasound reflection that the probe **101** receives. Specifically, each sequence of receive signals that the input unit **1091** generates corresponds to one transducer element **101***a*. Specifically, the input unit **1091** generates sequence of receive signals for a transducer element **101***a* by performing A/D conversion on an electric signal that the transducer element **101***a* has generated by converting ultrasound reflection received in response to a transmission event. Thus, an RF signal is a digital signal that is a sequence of signals (receive signals rf) along the ultrasound transmission direction (depth direction of examination subject).

**[0097]** For each transmission event, the input unit **1091** generates a sequence of receive signals rf for each of a plurality of transducer elements **101***a* used to receive ultrasound reflection in response to the transmission event. In the following, the transducer elements **101***a* that are used to receive ultrasound reflection in response to a transmission event are referred to as receive transducer elements **101***a,* and the group of the receive transducer elements **101***a* is referred to as a receive transducer element array. Further, the receive transducer element array is selected for each transmission event. Specifically, the receive transducer element array is a group of some or all of the transducer elements **101***a* of the probe **101**, and is selected for each transmission event based on an instruction from the controller **115**. Further, the reception beam former **109** is connected to the receive transducer element array, via the multiplexer **111**. Here, it is preferable that the receive transducer element array include a greater number of transducer elements than a transmission transducer element array Tx. Further, the present embodiment is based on a configuration where the receive transducer element array for every transmission event includes all of the transducer elements **101***a* of the probe **101**. Accordingly, for each transmission event, all the transducer elements **101***a* of the probe **101** are used for receiving ultrasound reflection in response to the transmission event, and a sequence of receive signals rf is generated for each transducer element **101***a* of the probe **101**.

**[0098]** For each transmission event, the input unit **1091** generates a receive signal sub-frame data item rfl (a set of sequences of receive signals rf it has generated based on ultrasound reflection received in response to the transmission event), and outputs the receive signal sub-frame data item rfl to be stored in the data storage **114**. Thus, the data storage **114** stores a sequence of receive signal sub-frame data items rfl.

### (2) Delay-and-Sum Calculator **1092**

**[0099]** The delay-and-sum calculator **1092** generates an acoustic line signal sub-frame data item dsl for each transmission event. Specifically, the delay-and-sum calculator **1092** generates an acoustic line signal sub-frame data item dsl for a transmission event by generating an acoustic line signal for each measurement point Pij in the target area Bx for the transmission event. The delay-and-sum calculator **1092** generates an acoustic line signal for a measurement point Pij by performing delay processing on receive signals rf corresponding to the measurement point Pij that have been generated for a plurality of reception transducer elements Rpk, which are included in the receive transducer element array, and by summing the delayed receive signals rf. For each transmission event, the delay-and-sum calculator **1092** selects a reception transducer element array Rx based on the reception control signal from the reception condition setter **108**. As already described above, the reception transducer element array Rx includes some of the transducer elements **101***a* of the probe **101**, and the transducer elements **101***a* included in the reception transducer element array Rx are each referred to as a reception transducer element Rpk.

**[0100]** The delay-and-sum calculator **1092** includes a delay processor **10921** performing delay processing on receive signals rf, and a sum calculator **10922**.

(2-1) Delay Processor **10921**

**[0101]** The delay processor **10921** is a circuit that, for each reception transducer element Rpk included in a reception transducer element array Rx, specifies a receive signal rf based on ultrasound reflection from a measurement point Pij, from among the sequence of receive signals rf for the reception transducer element Rpk. Specifically, the delay processor **10921** performs the specification of receive signals rf for the measurement point Pij by performing compensation by using delay amounts for the reception transducer elements Rpk. The delay amounts indicate the difference among the reception transducer elements Rpk in terms of the amount of time required for ultrasound reflection from the measurement point Pij to reach the reception transducer elements Rpk. Specifically, the delay processor **10921** calculates a delay amount for each reception transducer element Rpk by dividing the distance between the measurement point Pij and the reception transducer element Rpk by ultrasound velocity. FIGS. **6**A and **6**B are schematics illustrating how the delay processor **10921** calculates ultrasound propagation paths. FIG. **6**A illustrates an example where the measurement point Pij is deeper than the transmission focal point FP, and FIG. **6**B illustrates an example where the measurement point Pij is shallower than the transmission focal point FP. Each of FIGS. **6**A and **6**B illustrates a propagation path of ultrasound that is transmitted from the transmission transducer element array Tx and is reflected at a measurement point Pij before reaching a reception transducer element Rpk. As described above, the measurement point Pij is included in the target area Bx, which is set inside the ultrasound main irradiation area Ax.

a) Calculation of Transmission Time

**[0102]** For each transmission event, the delay processor **10921** calculates a transmission time for each measurement point Pij set in the target area Bx for the transmission event, by calculating a transmission path through which transmitted ultrasound travels in the examination subject to reach the measurement point Pij, and dividing the transmission path by ultrasound velocity. The delay processor **10921** performs the calculation of the transmission time by using the following information, which the delay processor **10921** acquires from the transmission condition setter **105** for each transmission event: (i) the information indicating the transmission transducer elements **101***a* for the transmission event; (ii) the information indicating the transmission focal point FP for the transmission event; and (iii) the information indicating the position of the target area Bx inside the ultrasound main irradiation area Ax.

**[0103]** First, description is provided based on the transmission path illustrated in FIG. **6**A. In FIG. **6**A, ultrasound transmitted from the transmission transducer element array Tx first travels along path **401** to reach the transmission focal point FP, where the wavefront of the transmitted ultrasound focuses. Then, the transmitted ultrasound travels along path **402** to reach the measurement point Pij, which is deeper than the transmission focal point FP. Thus, the transmission time for the transmission path illustrated in FIG. **6**A is the total of the time required for the transmitted ultrasound to travel through path **401** and the time required for the transmitted ultrasound to travel through path **402**. Specifically, the transmission time for the transmission path illustrated in FIG. **6**A can be calculated, for example, by dividing the total of the lengths of the paths **401** and **402** by ultrasound velocity inside the examination subject.

**[0104]** Next, description is provided based on the transmission path illustrated in FIG. **6**B. In FIG. **6**B, ultrasound transmitted from the transmission transducer element array Tx travels along path **404** to reach the measurement point Pij, which is shallower than the transmission focal point FP. The transmission time for the transmission path illustrated in FIG. **6**B, where the measurement point Pij is shallower than the transmission focal point FP, is calculated assuming that the time required for the transmitted ultrasound to first travel along path **404** to reach the measurement point Pij and then travel along path **402** from the measurement point Pij to reach the transmission focal point FP is equal to the time required for the transmitted ultrasound to reach the transmission focal point FP by traveling along path **401**. Thus, the transmission time required for transmitted ultrasound to travel through path **404** is the difference when subtracting the time required for the transmitted ultrasound to travel through path **402** from the time required for the transmitted ultrasound to travel through path **401**. Specifically, the transmission time for the transmission path illustrated in FIG. **6**B can be calculated, for example, by dividing the difference calculated by subtracting the length of path **402** from the length of path **401** by ultrasound velocity inside the examination subject.

**[0105]** The transmission condition setter **105** has set thereto preset values for the transmission focal point F. Thus, the length of the path **402** from the transmission focal point F to the measurement point Pij can be calculated geometrically.

b) Calculation of Reception Time

**[0106]** Further, the delay processor **10921** calculates a reception time for each reception transducer element Rpk in the reception transducer element array Rx, by calculating a reception path through which transmitted ultrasound travels after being reflected at a measurement point P to reach the reception transducer element Rpk, and dividing the reception path by ultrasound velocity. The delay processor **10921** performs the calculation of the reception time by using the following information, which the delay processor **10921** acquires from the data storage **114** for each transmission event: information indicating the position of the reception transducer element array Rx for the transmission event.

**[0107]** Specifically, the delay processor **10921** performs the calculation of reception time for each reception transducer element Rpk supposing that ultrasound reflection is generated at the measurement point Pij due to a change in acoustic impedance at the measurement point Pij, and thus, based on a reception path where ultrasound reflection from the measurement point Pij travels along path **403** to return to the reception transducer element Rpk.

**[0108]** Since information indicating the positions of the reception transducer elements Rpk of the reception transducer element array Rx is acquired from the controller **115**, the length of the path **403** from the measurement point Pij to each reception transducer element Rpk can be calculated geometrically.

c) Calculation of Delay Amounts

**[0109]** Further, the delay processor **10921** calculates a total propagation time for each reception transducer element

Rpk, based on the transmission time and the reception time for the reception transducer element Rpk. Further, the delay processor **10921**, based on the total propagation time, calculates a delay amount to be applied to the sequence of receive signals rf for the reception transducer element Rpk. Specifically, for each reception transducer element Rpk, the delay processor **10921** calculates a total propagation time, which is the amount of time required for transmitted ultrasound to reach the reception transducer element Rpk after being reflected at the measurement point Pij. Further, based on the differences between the total propagation times for the reception transducer elements Rpk, the delay processor **10921** calculates, for each of the reception transducer elements Rpk, a delay amount to be applied to the sequence of receive signals rf for the reception transducer element Rpk.

### d) Delay Processing

**[0110]** FIGS. **7**A and **7**B are schematics illustrating the generation of an acoustic line signal for a measurement point Pij, performed by the delay-and-sum calculator **1092**. FIG. **7**A illustrates an example where the measurement point Pij is deeper than the transmission focal point FP, and FIG. **7**B illustrates an example where the measurement point Pij is shallower than the transmission focal point FP. For each reception transducer element Rpk in the reception transducer element array Rx, the delay processor **10921** specifies a receive signal rf corresponding to the delay amount for the reception transducer element Rpk from among the sequence of receive signals rf for the reception transducer element Rpk. Further, the delay processor **10921** sets, for the reception transducer element Rpk, the specified receive signal rf as a receive signal rf based on ultrasound reflection from the measurement point Pij. For each transmission event, the delay processor **10921** performs the processing described above for each measurement point Pij included in the target area Bx for the transmission event by using sequences of receive signals rf acquired from the data storage **114** as input, as illustrated in FIGS. **7**A and **7**B.

### (2-2) Sum Calculator 10922

**[0111]** The sum calculator **10922** is a circuit that, for each measurement point Pij, generates a delayed-and-summed acoustic line signal for the measurement point Pij by using as input the receive signals rf for the reception transducer elements Rpk, which have been specified and output by the delay processor **10921**, and summing the receive signals rf.

**[0112]** Alternatively, for each measurement point Pij, the sum calculator **10922** may generate a delayed-and-summed acoustic line signal for the measurement point Pij by multiplying the receive signals rf for the reception transducer elements Rpk by the weights for the reception transducer elements Rpk included in the reception apodization (sequence of weights), and summing the weighted receive signals rf. As already described above, a reception apodizaton for a reception transducer element array Rx is a numerical sequence of weight coefficients that are to be applied to receive signals rf for the respective reception transducer elements Rpk in the reception transducer element array Rx.

**[0113]** For each transmission event, the sum calculator **10922** performs the processing described above for each measurement point Pij in the target area Bx for the transmission event, as illustrated in FIGS. **7**A and **7**B, and thereby generates an acoustic line signal for each measurement point Pij in the target area Bx. For each transmission event, the sum calculator **10922** generates a plurality of acoustic line signals, each corresponding to a different one of the measurement points Pij in the target area Bx for the transmission event. The plurality of acoustic line signals generated in response to a single transmission event are collectively referred to as an acoustic line signal sub-frame data item dsl. Further, in the present disclosure, the term “sub-frame” is used to refer to a unit of signals that are generated in response to one transmission event and that correspond to a plurality of measurement points Pij included in a target area Bx.

**[0114]** The sum calculator **10922** sums the receive signals rf for the reception transducer elements Rpk, after the phases of the receive signals rf have been adjusted by the delay processor **10921**. Due to this, the sum calculator **10922** is capable of increasing signal S/N ratio by combining receive signals rf based on ultrasound reflection from the same measurement point Pij, generated for different reception transducer elements Rpk. Thus, the sum calculator **10922** is capable of extracting a reception signal based on ultrasound reflection from the measurement point Pij.

### (3) Synthesizer 1093

**[0115]** As described above, transmission events are repeatedly performed while gradually shifting the transmission transducer element array Tx in the array direction each time, such that consequently, all transducer elements **101***a* of the probe **101** perform ultrasound transmission. The synthesizer **1093** is a circuit that generates a combined acoustic line signal frame data item ds by combining a plurality of acoustic line signal sub-frame data items dsl generated for transmission events. Further, the synthesizer **1093** repeatedly performs the generation of the combined acoustic line signal frame data item ds, and thereby generates a sequence of combined acoustic line signal frame data items ds. As illustrated in FIG. **4**, the synthesizer **1093** includes a sub-frame combiner **10931** and an amplifier **10932**.

### (3-1) Sub-Frame Combiner 10931

**[0116]** The sub-frame combiner **10931** reads out the acoustic line signal sub-frame data items dsl stored in the data storage **114**. Further, the sub-frame combiner **10931** generates a combined acoustic line signal frame data item ds by combining the acoustic line signal sub-frame data items dsl. The combining of the acoustic line signal sub-frame data items dsl is performed according to the positions of measurement points Pij from which the acoustic line signals included in the acoustic line signal sub-frame data items dsl have been generated, such that in the process, a combined acoustic line signal is generated for each of the measurement points Pij. Specifically, the sub-frame combiner **10931** generates a combined acoustic line signal for each measurement point Pij by combining acoustic line signals corresponding to the measurement point Pij that are included in different acoustic line signal sub-frame data items dsl.

**[0117]** FIG. **8** is a schematic illustrating the combining of acoustic line signal sub-frame data items dsl, performed by the sub-frame combiner **10931**. As already described above, transmission events are repeatedly performed while gradually shifting the transmission transducer element array Tx in the array direction each time. Due to this, the position of the target area Bx, which is set within the ultrasound main irradiation area Ax of each transmission event, also shifts in the array direction from one transmission event to another. In view of this, the sub-frame combiner **10931** generates a combined acoustic line signal frame data item ds covering target areas Bx for all transmission events, by combining acoustic line signal sub-frame data items dsl based on the positions of the measurement points Pij from which the acoustic lines signals included in the acoustic line signal sub-frame data items dsl have been generated.

**[0118]** Further, the sub-frame combiner **10931** generates combined acoustic line signals for the measurement points such that for a measurement point Pij that is included in multiple target areas Bx, values of acoustic line signals in different acoustic line signal sub-frame data items dsl for the same measurement point Pij are summed. Thus, some combined acoustic line signals may have a great value, depending upon the number of target areas Bx in which the corresponding measurement point Pij is included. In the following, the number of different target areas Bx in which a given measurement point Pij is included is referred to as an overlap count of the measurement point Pij, and the maximum value of the overlap count in the array direction is referred to as a maximum overlap count.

**[0119]** FIGS. **9**A and **9**B are schematics illustrating amplification performed by the synthesizer **1093**. FIG. **9**A illustrates a depth-direction variance among maximum overlap counts of combined acoustic line signals. Since the target areas Bx are hourglass-shaped areas, variance in the depth direction is observed among maximum overlap counts. Further, the intensity value of each combined acoustic line signal is dependent upon the maximum overlap count of the corresponding measurement point. Consequently, a variance in the depth direction is also observed among intensity values of combined acoustic line signals.

**[0120]** The sub-frame combiner **10931** outputs the combined acoustic line signal frame data item ds to the amplifier **10932**.

### (3-2) Amplifier **10932**

**[0121]** As already described above, a depth-direction variance is observed among the intensity values of combined acoustic line signals. In order to compensate for this depth-direction variance, the amplifier **10932** performs amplification by multiplying the combined acoustic line signals by amplification factors. The amplifier **10932** determines an amplification factor for a given combined acoustic line signal according to the number of acoustic line signals combined to yield the combined acoustic line signal, for generating the combined acoustic line signal frame data ds.

**[0122]** FIG. **9**B illustrates a depth-direction variance among amplification factors used in the amplification. As described above, a depth-direction variance is observed among maximum overlap counts. Thus, to compensate for this variation among maximum overlap counts, the amplifier **10932** multiplies the combined acoustic line signals by respective amplification factors that are determined based on the maximum overlap counts and vary in the depth direction. The amplification with these amplification factors eliminates the depth-direction variance among values of combined acoustic line signals, which derives from the depth-direction variance among overlap counts. Thus, the amplified combined acoustic line signals have values that are averaged out somewhat in the depth direction. Here, a combined acoustic line signal frame data item ds is a group of combined acoustic line signals amplified in such a manner, each generated from a different measurement point Pij. Note that the present disclosure intends no limitation regarding how the above-described amplification factors are determined.

### 2.3 In-Puncture Reception Transducer Element Array Selector **113**

**[0123]** The in-puncture reception transducer element array selector **113** is a circuit that selects, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals based on ultrasound reflection from the puncture needle **101***b* have relatively strong intensity, among the transducer elements **101***a* of the probe **101**. The in-puncture reception transducer element array selector **113** performs the selection of this group of transducer elements **101***a* based on one or more receive signal sub-frame data items rfl. Here, the group of transducer elements **101***a* selected by the in-puncture reception transducer element array selector **113** is a group of transducer elements **101***a* whose receive signals based on ultrasound reflection from the puncture needle actually have or are expected to have stronger intensity than transducer elements **101***a* not selected by the in-puncture reception transducer element array selector **113**.

**[0124]** Specifically, in the present embodiment, the in-puncture reception transducer element array selector **113** detects, from among sequences of receive signals rf for a plurality of transducer elements **101***a*, a sequence of receive signals rf including a receive signal with high intensity, and specifies a transducer element **101***a* corresponding to the detected sequence of receive signals rf as a high intensity receive transducer element **101***a*. Further, the in-puncture reception transducer element array selector **113** selects a group of transducer elements **101***a* including the specified high intensity receive transducer element **101***a* as a reception transducer element array Rx.

**[0125]** FIG. **10** illustrates functional blocks of the in-puncture reception transducer element array selector **113**. Further, each of the following drawings is a schematic illustrating operations of the in-puncture reception transducer element array selector **113**: FIG. **11**, FIGS. **12**A and **12**B, FIGS. **13**A through **13**D, and FIGS. **14**A through **14**D. As illustrated in FIG. **10**, the in-puncture reception transducer element array selector **113** includes: a depth-direction high-intensity signal detector **1131**; an array-direction maximum intensity transducer element detector **1132**; and a reception transducer element array determiner **1133**.

**[0126]** (1) Depth-Direction High-Intensity Signal Detector **1131**

**[0127]** The in-puncture reception transducer element array selector **113** reads out one or more receive signal sub-frame data items rfl from the data storage **114**.

**[0128]** The depth-direction high-intensity signal detector **1131** performs analysis of the plurality of sequences of receive signals rf included in a receive signal sub-frame data item rfl. In this analysis, the depth-direction high-intensity signal detector **1131** determines whether or not each sequence of receive signals rf includes a signal portion (i.e., a receive signal rf) with an intensity higher than or equal to a predetermined threshold, to detect sequences of receive signals rf including receives signals rf with intensities higher than or equal to a predetermined threshold, as illustrated in the middle portion of FIG. **11**. As already described above, the puncture needle **101***b* generates specular ultrasound reflection. Thus, signals based on ultrasound reflection from the puncture needle **101***b* have extremely higher intensity than signals based on ultrasound reflection from body tissues. The predetermined threshold is set to distinguish signals based on ultrasound reflection from the puncture needle **101***b* from signals based on ultrasound reflection from body tissues. Accordingly, a transducer element **101***a* having received ultrasound reflection from the puncture needle **101***b* can be detected by detecting a sequence of receive signals rf including a receive signal rf with an intensity higher than or equal to the predetermined threshold.

**[0129]** The depth-direction high-intensity signal detector **1131** performs the extraction, from sequences of receive signals rf, of receives signals rf with intensities higher than or equal to the predetermined threshold, for each receive signal sub-frame data item rfl that is read out.

(2) Array-Direction Maximum Intensity Transducer Element Detector **1132**

**[0130]** As illustrated in the middle portion of FIG. **11**, the array-direction maximum intensity transducer element detector **1132** detects, from among sequences of receive signals rf detected as including receive signals rf with intensities higher than or equal to the predetermined threshold in a receive signal sub-frame data item rfl, a sequence of receives signals rf that includes the greatest or close-to-greatest receive signal rf among the receive signals rf with intensities higher than or equal to the predetermined threshold. Further, the array-direction maximum intensity transducer element detector **1132** specifies a transducer element **101***a* corresponding to the detected sequence of receive signals rf as a high intensity receive transducer element **101***a*X. By detecting a transducer element **101***a* corresponding to the greatest or close-to-greatest one among the receive signals rf with intensities higher than or equal to the predetermined threshold, a transducer element **101***a* whose receive signal rf based on ultrasound reflection from the puncture needle **101***b* has relatively high intensity (i.e., a high intensity receive transducer element **101***a*X) can be detected.

**[0131]** The array-direction maximum intensity transducer element detector **1132** performs the specification of a high intensity receive transducer element **101***a*X with respect to each receive signal sub-frame data item rfl that is read out.

(3) Reception Transducer Element Array Determiner **1133**

**[0132]** As illustrated in the upper portion of FIG. **11**, the reception transducer element array determiner **1133** is, for example, capable of selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* including, at an array-direction center position thereof, a high intensity receive transducer element **101***a*X acquired from one receive signal sub-frame data item rfl. When delay-and-sum processing is performed by using a reception apodization, it is preferable that the central axis of the reception apodization in the array direction be set to the high intensity receive transducer element **101***a*X.

**[0133]** With this configuration, a high intensity receive transducer element **101***a*X can be detected and a group of transducer elements including the high intensity receive transducer element **101***a*X at the array-direction center position can be selected as a reception transducer element array Rx, even when the insertion angle (inclination angle) of the puncture needle **101***b* with respect to the examination subject changes as illustrated in FIGS. **12**A and **12**B.

**[0134]** Meanwhile, as already described above, due to transmitted ultrasound being focused ultrasound, the angle θ at which the two straight lines that define the boundary of the ultrasound main irradiation area Ax intersect at the transmission focal point FP is typically approximately greater than or equal to 14° and smaller than or equal to 28°. Due to this, when the transmitted ultrasound is focused ultrasound, an array-direction variance, within the angle θ, is observed in the angle between the puncture needle **101***b* and the transmitted ultrasound, as illustrated in FIGS. **13**A through **13**C. Due to this, a plurality of transducer elements **101***a* with greatest or close-to-greatest signal intensities may be detected from one receive signal sub-frame data item rfl acquired in response to one transmission event. That is, a plurality of high intensity receive transducer elements **101***a*X may be detected from one receive signal sub-frame data item rfl. In such a case, the reception transducer element array determiner **1133** may select, as a reception transducer element array Rx, a group of transducer elements **101***a* including all of these high intensity receive transducer elements **101***a*X, as illustrated in FIG. **13**D. In this case as well, when delay-and-sum processing is performed by using a reception apodization, it is preferable that the central axis of the reception apodization in the array direction be set to the center one of the high intensity receive transducer elements **101***a*X in the array direction. This configuration enables selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* including a plurality of high intensity receive transducer elements **101***a*X.

**[0135]** Alternatively, the reception transducer element array determiner **1133** may select, as a reception transducer element array Rx, a group of transducer elements **101***a* including a plurality of high intensity receive transducer elements **101***a*X acquired from a plurality of receive signal sub-frame data items rfl. When the position of the transmission transducer element array Tx shifts in the array direction between transmission events, high intensity receive transducer elements **101***a*X detected from different receive signal sub-frame data items rfl, each corresponding to a different one of the transmission events, take different positions, as illustrated in FIGS. **14**A through **14**C. In this case, the reception transducer element array determiner **1133** may select, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer elements **101***a*X detected from different receive signal sub-frame data items rfl and including the center one of the high intensity receive transducer elements **101***a*X in the array direction at the center thereof in the array direction, as illustrated in FIG. **14**D. In this case as well, it is preferable that the central axis of the reception apodization in the array direction be set to the center one of the high intensity receive transducer elements **101***a*X in the array direction. This configuration enables selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity across a plurality of transmission events.

**[0136]** The reception transducer element array determiner **1133** outputs information indicating the position of the reception transducer element array Rx it has selected to the reception condition setter **108**. Meanwhile, when not detecting a group of transducer elements **101***a* whose receive signals based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity, the in-puncture reception transducer element array selector **113** does not output any information indicating a reception transducer element array Rx to the reception condition setter **108**.

### 3. Other Components

**[0137]** The B-mode image generator **112** acquires a sequence of combined acoustic line signal frame data items ds from the data storage **114** as input. The B-mode image generator **112** converts combined acoustic line signals in each combined acoustic line signal frame data item ds into luminance signals representing the intensities of the combined acoustic line signals by performing processing such as envelope detection and logarithmic compression, and further converts the luminance signals into coordinates on an orthogonal coordinate system. Thus, the B-mode image generator **112** generates a sequence of B-mode image frame data items. Here, the B-mode image generator **112** may use any conventional method to generate a sequence of B-mode image frame data items from a sequence of combined acoustic line signal frame data items. Further, the B-mode image generator **112** outputs the sequence of B-mode image frame data items to the data storage **114** to be stored therein. The display controller **116** forms display images from the B-mode image frame data items, and causes the display unit **103** to display the display images. The display controller **116** may be further configured to perform processing such as emphasizing or coloring of pixels of the B-mode images corresponding to the puncture needle **101***b*, and to output the processed pixels to the display unit **103**.

**[0138]** The data storage **114** is a recording medium capable of storing sequences of receive signals rf, acoustic line signal sub-frame data items dsl, combined acoustic line signal frame data items ds, B-mode image frame data items, etc., in the order they are received.

**[0139]** The controller **115** controls each of the functional blocks of the ultrasound diagnostic device **100** based on instructions from the operation receiver **102**. The controller **115** may be implemented, for example, by using a processor such as a CPU.

## <Operations>

### 1. Beam Forming for Generating Acoustic Line Signal Sub-Frame Data Items

**[0140]** The following describes beam forming for the generation of acoustic line signal sub-frame data items dsl, performed by the ultrasound diagnostic device **100**, whose structure has been described up to this point.

**[0141]** FIG. **15** is a flowchart illustrating beam forming by the ultrasound diagnostic device **100**.

**[0142]** First, in Step S**101**, the transmission beam former **106** performs transmission processing (a transmission event) of supplying a transmission signal triggering transmission of an ultrasound beam to each transmission transducer element **101***a* of the transmission transducer element array Tx set by the transmission condition setter **105**.

**[0143]** Next, in Step S**102**, the reception beam former **109** generates receive signals rf based on electric signals yielded through the reception of ultrasound reflection by the probe **101**, and outputs the receive signals rf to be stored in the data storage **114**. Then, a determination is made of whether or not a predetermined number of transmission events have been performed (Step S**103**). When the predetermined number of transmission events have not been performed yet, processing returns to S**101**, and another transmission event is performed after shifting the transmission transducer element array Tx by a predetermined pitch in the array direction. Meanwhile, when the predetermined number of transmission events have been performed, processing proceeds to Step S**201**.

**[0144]** Subsequently in Step S**201**, the in-puncture reception transducer element array selector **113** selects a reception transducer element array Rx based on one or more receive signal sub-frame data items rfl, and outputs the information indicating the result of the selection to the reception condition setter **108**. Here, the in-puncture reception transducer element array selector **113** selects, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity, or that is, a group of transducer elements **101***a* suitable for generation of acoustic line signals from the puncture needle **101***b*. The processing in Step S**201** is described in detail later in the present disclosure.

**[0145]** Subsequently, coordinate values i and j indicating a position of a measurement point Pij that is included in the target area Bx set by the reception condition setter **108** are initialized (set to the respective minimum possible values in the target area Bx) (Steps S**301** and S**302**). Then, an acoustic line signal is generated for the current measurement point Pij (Step S**303**), based on the data of sequences of receive signals rf for the reception transducer elements Rpk in the reception transducer element array Rx set by the reception condition setter **108**, which are included in a receive signal sub-frame data item rfl for the processing-target transmission event. The processing in Step S**303** is described in detail later in the present disclosure.

**[0146]** Further, an acoustic line signal is generated for each measurement point Pij (each illustrated in FIGS. **7**A and **7**B as a black dot) that is included in the target area Bx by repeating Step S**303** while incrementing the coordinate values i and j. Subsequently, a determination is made of whether an acoustic line signal has been generated for every measurement point Pij included in the target area Bx (Steps S**305**, S**307**). When an acoustic line signal has not yet been generated for every measurement point Pij within the target area Bx, the coordinate values i and j are incremented (Steps S**306** and S**308**), yielding an acoustic line signal for another measurement point Pij (Step S**303**). Meanwhile, when an acoustic line signal has already been generated for every measurement point Pij within the target area Bx, processing proceeds to Step S**309**. At this point, an acoustic line signal has already been generated for each measurement point Pij that is included in the target area Bx set inside the ultrasound main irradiation area Ax for one transmission event, and the acoustic line signals have been output to and stored to the data storage **114**. In other words, an acoustic line signal sub-frame data item dsl for one transmission event has been generated, and has been output to and stored to the data storage **114**.

**[0147]** Subsequently, a determination is made of whether or not the generation of acoustic line signals has been performed for every transmission event having been performed (Step S**309**). When the generation of acoustic line signals has not yet been performed for every transmission event having been performed, processing returns to Step S**301**, and an acoustic line signal sub-frame data item dsl is generated based on ultrasound transmitted in a subsequent transmission event (Steps S**301** through S**307**). Meanwhile, when the generation of acoustic line signals has been performed for every transmission event having been performed, processing is terminated.

**[0148]** Subsequently, in Step S**401**, the sub-frame combiner **10931** generates a combined acoustic line signal frame data item ds (Step S**401**). Specifically, the sub-frame combiner **10931** reads out acoustic line signal sub-frame data items dsl for all sub-frames from the data storage **114**, and combines the acoustic line signal sub-frame data items dsl according to the positions of the measurement points Pij, such that in the process, a combined acoustic line signal is generated for each measurement point Pij. Thus, a combined acoustic line signal frame data item ds is generated. Subsequently, the amplifier **10932** multiplies each combined acoustic line signal included in the combined acoustic line signal frame data item ds by an amplification factor determined based on the number of acoustic line signals combined to yield the combined acoustic line signal (Step S**402**). Then, the amplifier **10932** outputs the amplified combined acoustic line signal frame data item ds to the data storage **114** (Step S**403**), and processing is terminated.

**[0149]** Thus, the generation of a combined acoustic line signal frame data item ds is completed.

**[0150]** Note that a sequence of combined acoustic line signal frame data items ds is generated by the generation of the combined acoustic line signal frame data item ds illustrated in FIG. **15** being performed repeatedly. The reception beam former **109** outputs the sequence of combined acoustic line signal frame data items ds to be stored in the data storage **114**.

## 2. Details of Processing in Step S**201**

**[0151]** The following describes the processing in Step S**201** of selecting a reception transducer element array Rx suitable for generation of acoustic line signals from the puncture needle **101***b*. FIG. **16** is a flowchart illustrating processing by the in-puncture reception transducer element array selector **113** of selecting such a reception transducer element array Rx.

**[0152]** The in-puncture reception transducer element array selector **113** reads out a plurality of receive signal sub-frame data items rfl from the data storage **114**.

**[0153]** In Step S**2011**, the depth-direction high-intensity signal detector **1131** analyzes the sequences of receive signals rf included in each receive signal sub-frame data item rfl, and extracts, from the sequences of receive signals rf, receive signals rf having relatively high intensities (i.e., intensities higher than or equal to the predetermined threshold). Here, transducer elements **101***a* having received ultrasound reflection from the puncture needle **101***b* can be detected by detecting sequences of receive signals rf including receive signals rf with intensities higher than or equal to the predetermined threshold. This is since the puncture needle **101***b* generates specular ultrasound reflection.

**[0154]** Further, the array-direction maximum intensity transducer element detector **1132** detects, from among receive signals rf having intensities higher than or equal to the predetermined threshold having been detected in each receive signal sub-frame data item rfl, a receive signal rf having the greatest or close-to-greatest intensity. Then, the array-direction maximum intensity transducer element detector **1132** sets the transducer element **101***a* having received a sequence of receive signals rf including such a receive signal rf as a high intensity receive transducer element **101***a*X (i.e., specifies the transducer element **101***a* as a transducer element **101***a* whose receive signal rf based on ultrasound reflection from the puncture needle **101***b* has relatively high signal intensity). The array-direction maximum intensity transducer element detector **1132** performs this detection for each receive signal sub-frame data item rfl that is read out, and specifies a high intensity receive transducer element **101***a*X in each receive signal sub-frame data item rfl that is read out.

**[0155]** In Step S**2012**, the reception transducer element array determiner **1133** specifies the center one of the high intensity receive transducer elements **101***a*X in the array direction, each specified in a different receive signal sub-frame data item rfl.

**[0156]** In Step S**2013**, the reception transducer element array determiner **1133** selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the center one of the high intensity receive transducer elements **101***a*X in the array direction at the center thereof in the array direction. Here, it is preferable that the reception transducer element array Rx be selected to include all the high intensity receive transducer elements **101***a*X, each specified in a different receive signal sub-frame data item rfl. This configuration enables selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity across a plurality of transmission events.

**[0157]** The reception transducer element array determiner **1133** outputs information indicating the position of the reception transducer element array Rx it has selected to the reception condition setter **108**.

## 3. Details of Processing in Step S**303**

**[0158]** The following describes the processing in Step S**303** of generating an acoustic line signal for a measurement point Pij. FIG. **17** is a flowchart illustrating the processing of generating an acoustic line signal for a measurement point Pij, performed by the delay-and-sum calculator **1092**.

**[0159]** The delay-and-sum calculator **1092** receives, from the reception condition setter **108**, information indicating a target area Bx, information indicating a reception transducer element array Rx, and information indicating a reception apodization.

**[0160]** First, in Step S**3031**, the delay processor **10921** calculates, for the current measurement point Pij in the target area Bx, a transmission time required for transmitted ultrasound to arrive at the current measurement point Pij.

**[0161]** As described above, when the measurement point Pij is shallower than the transmission focal point FP, the transmission time is calculated by calculating a transmission path **404** from the transmission transducer element array Tx to the measurement point Pij, and dividing the length of the transmission path **404** by ultrasound velocity cs. Specifically, the transmission path is calculated by calculating the difference (**401**-**402**) between a path **401** from the center position of the transmission transducer element array Tx in the array direction to the transmission focal point FP and a path **402** from the transmission focal point FP to the measurement point Pij.

**[0162]** Meanwhile, as also already described above, when the measurement point Pij is deeper than the transmission focal point FP, the transmission time is also calculated by calculating a transmission path from the transmission transducer element array Tx to the measurement point Pij, and dividing the length of this transmission path by ultrasound velocity cs, but this time, the transmission path is calculated by calculating the sum (**401**+**402**) of the path **401** from the center position of the transmission transducer element array Tx in the array direction to the transmission focal point FP and the path **402** from the transmission focal point FP to the measurement point Pij

**[0163]** Subsequently, value k, which identifies a target reception transducer element Rpk in the reception transducer element array Rx, is initialized (set to the minimum possible value in the reception transducer element array Rx) (Step S**3032**). Then, a reception time for the target reception transducer element Rpk is calculated (Step S**3033**). The reception time is the amount of time required for ultrasound reflection from the measurement point Pij, originating from the transmitted ultrasound, to arrive at the reception transducer element Rpk (Step S**3033**).

**[0164]** The reception time for the target reception transducer element Rpk can be calculated by dividing, by ultrasound velocity cs, the geometrically-calculable length of path **403** from the current measurement point Pij to the target reception transducer element Rk. Further, from a sum of the transmission time and the reception time for the target reception transducer element Rpk, the total propagation time required for ultrasound transmitted from the transmission transducer element array Tx to arrive at the target reception transducer element Rpk after being reflected at the current measurement point Pij is calculated (Step S**3034**). Further, based on the difference in total propagation time among the reception transducer elements Rpk of the reception transducer element array Rx, a delay amount for the target reception transducer element Rpk is calculated (Step S**3035**).

**[0165]** Subsequently, a determination is made of whether or not a delay amount has been calculated for every reception transducer element Rpk in the reception transducer element array Rx (Step S**3036**). When a delay amount has not yet been calculated for one or more of the reception transducer elements Rpk, the value k is incremented (Step S**3037**), and a delay amount for another reception transducer element Rpk is calculated (Step S**3035**). Meanwhile, when a delay amount has been calculated for every reception transducer element Rpk in the reception transducer element array Rx, processing proceeds to Step S**3038**. Note that at this point, a delay amount has already been calculated for each reception transducer element Rpk in the reception transducer element array Rx. The delay amount for a given reception transducer element Rpk indicates the delay with which ultrasound reflection from the current measurement point Pij reaches the reception transducer element Rpk.

**[0166]** In Step S**3038**, the delay processor **10921**, for each reception transducer element Rpk, specifies a receive signal rf based on ultrasound reflection from the current measurement point Pij. Specifically, the delay processor **10921** reads, from the data storage **114**, sequences of receive signals rf corresponding to the reception transducer elements Rpk in the reception transducer element Rx included in a receive signal sub-frame data item rfl. Further, for each reception transducer element Rpk, the delay processor **10921** specifies a receive signal rf corresponding to a time point after subtraction of the delay amount for the reception transducer element Rpk in the corresponding sequence of receive signals rf, as a receive signal based on ultrasound reflection from the current measurement point Pij.

**[0167]** Subsequently, an undepicted weight calculator calculates the reception apodization (numerical sequence of weight coefficients) for the reception transducer element array Rx, so that the maximum weight is set with respect to the reception transducer element Rpk located at the center position of the reception transducer element array Rx in the array direction (Step S**3039**). Subsequently, the sum calculator **10922** generates an acoustic line signal for the current measurement point Pij by first multiplying the specified receive signals rf for the respective reception transducer element Rpk by the corresponding weights in the reception apodization, and summing the weighted receive signals rf (Step S**3040**). The acoustic line signal for the current measurement point Pij so generated is output to the data storage **114** to be stored therein (Step S**3041**).

**[0168]** This completes the processing in Step S**303** in FIG. **15**.

<Effects>

**[0169]** As described up to this point, the ultrasound diagnostic device **100** pertaining to embodiment 1 is an ultrasound diagnostic device to which an ultrasound probe **101** having a plurality of transducer elements **101** arrayed along an array direction is connectable, wherein the ultrasound diagnostic device **100**: (i) repeatedly performs transmission events, each by selecting a first group (transmission transducer element array) Tx of transducer elements **101***a* from among the plurality of transducer elements **101***a* and causing the first group Tx to transmit ultrasound towards an examination subject having a puncture needle **101***b* inserted therein; (ii) for each of the transmission events, generates a sub-frame data item dsl based on ultrasound reflection received in response to the transmission event, the sub-frame data item dsl including acoustic line signals; and (iii) combines sub-frame data items dsl for the transmission events to generate a frame data item ds, the frame data item ds including combined acoustic line signals each being an aggregate of ones of the acoustic line signals, and the ultrasound diagnostic device **100** includes an ultrasound signal processing circuit **150** operating as: a transmitter **107** that performs each of the transmission events by selecting the first group Tx and causing the first group Tx to transmit ultrasound focusing inside the examination subject, the transmitter **107** gradually shifting the first group Tx in the array direction between transmission events; and a receiver **110** that: (i) for each of the transmission events, selects at least some of the plurality of transducer elements **101***a* and generates a sequence of receive signals rf for each of the selected transducer elements **101***a* based on ultrasound reflection that the selected transducer element **101***a* has received from the examination subject in response to the transmission event; (ii) selects a second group (reception transducer element array) Rx of transducer elements **101***a*, the transducer elements **101***a* in the second group Rx being ones among the plurality of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity; (iii) for each of the transmission events, sets a target area Bx for generating the sub-frame data item dsl inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generates the sub-frame data item dsl by performing, for each of a plurality of measurement points Pij in the target area Bx, delay-and-sum processing on receive signals rf, for the transducer elements **101***a* in the second group Rx, based on ultrasound reflection from the measurement point Pij; and (iv) generates the frame data item ds by combining the sub-frame data items dsl for the transmission events.

**[0170]** With this structure, the ultrasound diagnostic device **100** is capable of producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method. Specifically, the ultrasound diagnostic device **100** utilizes the synthetic aperture method and repeatedly performs transmission events while gradually shifting the transmission transducer element array Tx in the array direction. Further, the ultrasound diagnostic device **100** performs delay-and-sum processing for each transmission event by using a reception transducer element array Rx composed of reception transducer elements Rpk whose receive signals rf based on ultrasound reflection from the puncture needle have high intensity.

**[0171]** When performing ultrasound examination by using the ultrasound diagnostic device **100** with the puncture needle **101***b* inserted in the examination subject, signals based on ultrasound reflection from the puncture needle **101***b* have extremely higher intensity than signals based on ultrasound reflection from body tissues. This is since the puncture needle **101***b* produces specular ultrasound reflection and signals based on specular reflection have high directivity, whereas body tissues mainly produce diffuse ultrasound reflection. The ultrasound diagnostic device **100** distinguishes signals based on ultrasound reflection from the puncture needle **101***b* from signals based on ultrasound reflection from body tissues by using a predetermined threshold. Specifically, the ultrasound diagnostic device **100** detects a transducer element **101***a* whose receive signal rf has intensity higher than or equal to the predetermined threshold, specifies such a transducer element **101***a* as a transducer element **101***a* having received ultrasound reflection from the puncture needle **101***b*, and selects a group of transducer elements **101***a* including such a transducer element **101***a* as a reception transducer element array Rx. Thus, the ultrasound diagnostic device **100** is capable of selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have relatively high intensity. The ultrasound diagnostic device **100** is capable of producing ultrasound images imaging the puncture needle **101***b* with high visual perceptibility by performing, for each measurement point Pij in a target area Bx, delay-and-sum processing on receive signals rf corresponding to the reception transducer elements **101***a* of a reception transducer element array Rx selected in such a manner to generate an acoustic line signal sub-frame data item dsl for the target area Bx.

**[0172]** Meanwhile, the generation of acoustic line signals for the target area Bx, performed by using the selected reception transducer element array Rx, also allows generating acoustic line signals based on ultrasound reflection from body tissues. This is since, even when a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity is selected as a reception transducer element array Rx, the transducer elements **101***a* included in the selected reception transducer element array Rx also have received ultrasound reflection from body tissues of the examination subject due to body tissues mainly producing diffuse ultrasound reflection.

**[0173]** Further, the ultrasound diagnostic device **100** is capable of selecting a reception transducer element array Rx through simple processing that does not require prior execution of delay-and-sum processing, which typically has great processing load. Specifically, in the ultrasound diagnostic device **100**, the in-puncture reception transducer element array selector **113** detects, from among sequences of receive signals rf, a sequence of receive signals rf including a receive signal rf with high intensity, and specifies a transducer element **101***a* corresponding to the detected sequence of receive signals rf as a high intensity receive transducer element **101***a*X. Further, the in-puncture reception transducer element array selector **113** selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the specified high intensity receive transducer element **101***a*X. As such, the ultrasound diagnostic device **100** is capable of selecting, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity with a simple circuit structure. Note that the method described in embodiment 1 is a non-limiting example of a method of selecting a reception transducer element array Rx based on receive signals. That is, the selection of a reception transducer element array Rx can be performed by using other methods as long as the selection of a reception transducer element array Rx is performed based on receive signal intensity.

**[0174]** Specifically, the in-puncture reception transducer element array selector **113** is configured to enable selection of a reception transducer element array Rx based on receive signals. In FIG. **10**, the in-puncture reception transducer element array selector **113** is illustrated to include the depth-direction high intensity signal detector **1131** and the array-direction maximum intensity transducer element detector **1132**. However, for example, the in-puncture reception transducer element array selector **113** need not have such a structure. That is, the in-puncture reception transducer element array selector **113** may have any structure as long as it is capable of selecting, based on receive signal intensity, a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity as a reception transducer element array Rx. For example, the in-puncture reception transducer element array selector **113** may be configured to detect a receive signal rf having the greatest or close-to-greatest signal intensity and a high intensity receive transducer element **101***a*X corresponding to the detected receive signal rf from a receive signal sub-frame data item rfl through a single process, and to select a group of transducer elements **101***a* including the detected high intensity receive transducer element **101***a*X at the center thereof in the array direction as a reception transducer element array Rx. Alternatively, the in-puncture reception transducer element array selector **113** may be configured to detect receive signals rf having intensities higher than or equal to the predetermined threshold and transducer elements **101***a* corresponding to such receive signals rf from a receive signal sub-frame data item rfl, and to select a group of transducer elements **101***a* including these transducer elements **101***a* as a reception transducer element array Rx. Alternatively, the in-puncture reception transducer element array selector **113** may be configured to use other processing methods.

### Embodiment 2

**[0175]** The following describes an ultrasound diagnostic device **100**A pertaining to embodiment 2. In the ultrasound diagnostic device **100** pertaining to embodiment 1, the in-puncture reception transducer element array selector **113** selects a group of transducer elements **101***a* whose receive signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity, as illustrated in FIGS. **10** and **11**. Specifically, the in-puncture reception transducer element array selector **113** detects, from among sequences of receive signals rf corresponding to a plurality of transducer elements **101***a,* a sequence of receive signals rf including a high intensity receive signal rf, and specifies a transducer element **101***a* corresponding to the detected receive signal rf as a high intensity receive transducer element **101***a*X. Further, the in-puncture reception transducer element array selector **113** selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X. However, the selection of a reception transducer element array Rx need not be performed according to this specific method, and other methods may be used as long as a group of transducer elements **101***a* suitable for the generation of acoustic line signals from the puncture needle **101***b* is selected as a reception transducer element array Rx.

**[0176]** Specifically, the ultrasound diagnostic device **100**A differs from the ultrasound diagnostic device **100** for including an in-puncture reception transducer element array selector that specifies the position/inclination angle at which the puncture needle has been imaged based on characteristics of acoustic line signals in one or more acoustic line signal sub-frame data items dsl, and performs the selection of a reception transducer element array Rx based on the specified position/inclination angle of the puncture needle.

### <Structure>

**[0177]** The following describes the structure of the ultrasound diagnostic device **100**A.

**[0178]** FIG. **18** illustrates functional blocks of an ultrasound diagnostic system **1000**A including the ultrasound diagnostic device **100**A. Since the ultrasound diagnostic device **100**A differs from the ultrasound diagnostic device **100** for including an in-puncture reception transducer element array selector **113**A, the following description focuses on the structure of the in-puncture reception transducer element array selector **113**A. Since the rest of the components of the ultrasound diagnostic device **100**A other than the in-puncture reception transducer element array selector **113**A are similar to those in the ultrasound diagnostic device **100**, description is not provided of the rest of the components of the ultrasound diagnostic device **100**A.

**[0179]** The in-puncture reception transducer element array selector **113**A is a circuit that selects a reception transducer element array Rx based on the position/inclination angle at which the puncture needle **101***b* has been imaged. Specifically, the in-puncture reception transducer element array selector **113**A extracts, from an acoustic line signal sub-frame data item dsl, a linear area composed of acoustic line signals with high intensity. Further, the in-puncture reception transducer element array selector **113**A, based on the linear area, specifies the position/inclination angle at which the puncture needle **101***b* has been imaged.

**[0180]** FIG. **19** illustrates functional blocks of the in-puncture reception transducer element array selector **113**A. Each of FIGS. **20**A through **20**C is a schematic illustrating processing performed by the in-puncture reception transducer element array selector **113**A, with an acoustic line signal sub-frame data item dsl illustrated over a corresponding position within an examination subject. As illustrated in FIG. **19**, the in-puncture reception transducer element array selector **113**A includes: a high intensity measurement point position detector **1131**A; a puncture needle position/angle calculator **1132**A; and a reception transducer element array determiner **1133**A.

**[0181]** The high intensity measurement point position detector **1131**A reads out one or more acoustic line signal sub-frame data items dsl from the data storage **114**.

**[0182]** In the present embodiment, the high intensity measurement point position detector **1131**A reads out, from the data storage **114**, one or more acoustic line signal sub-frame data items dsl that have been generated in response to one or more transmission events preceding the processing-target transmission event. For example, the high intensity measurement point position detector **1131**A may read out, from the data storage **114**, one acoustic line signal sub-frame data item dsl that has been generated in response to the most recent transmission event having been performed by using the same transmission transducer element array Tx as the processing-target transmission event. Alternatively, the high intensity measurement point position detector **1131**A may read out, from the data storage **114**, a plurality of acoustic line signal sub-frame data items dsl that have been generated in response to transmission events performed before the processing-target transmission event and after the most recent transmission event having been performed by using the same transmission transducer element array Tx as the processing-target transmission event.

**[0183]** The high intensity measurement point position detector **1131**A extracts, from each acoustic line signal sub-frame data item dsl that is read out, positions of measurement points (measurement points Pijh) producing acoustic line signals with intensities higher than or equal to the predetermined threshold. Specifically, from each acoustic line signal sub-frame data item dsl, the high intensity measurement point position detector **1131**A extracts measurement points Pijh as illustrated in FIG. **20**A. The measurement points Pijh are illustrated in the FIGS. **20**A and **20**B as black squares. As described above, the puncture needle **101***b* produces specular ultrasound reflection. Due to this, when an acoustic line signal sub-frame data item dsl having been generated in response to a transmission event includes an acoustic line signal based on ultrasound reflection from the puncture needle **101***b,* the acoustic line signal has extremely higher signal intensity than acoustic line signals based on ultrasound reflection from body tissues. The predetermined threshold is set to distinguish acoustic line signals based on ultrasound reflection from the puncture needle **101***b* from acoustic line signals based on ultrasound reflection from body tissues. As such, an image of the puncture needle **101***b* in an acoustic line signal frame data item dsl can be detected by detecting, in the acoustic line signal frame data item dsl, an array of measurement points

Pijh producing acoustic line signals with intensities higher than or equal to the predetermined threshold.

**[0184]** The puncture needle position/angle calculator **1132**A, by using an acoustic line signal sub-frame data item dsl including acoustic line signals with intensities higher than or equal to the predetermined threshold, analyzes the shape of the area where the measurement points Pijh producing such acoustic line signals exist in the acoustic line signal sub-frame data item dsl, as illustrated in FIG. **20**B. When the area has a linear shape with a predetermined width, the puncture needle position/angle calculator **1132**A determines that the area is a puncture needle imaging area **101***b*X imaging the puncture needle **101***b*, and geometrically calculates the position/angle of the puncture needle imaging area **101***b*X by performing processing such as thinning. Thus, the puncture needle position/angle calculator **1132**A calculates the position/angle at which the puncture needle **101***b* has been imaged. The puncture needle position/angle calculator **1132**A performs the specification of the puncture needle imaging area **101***b*X and the calculation of the position/angle at which the puncture needle **101***b* has been imaged for each acoustic line signal sub-frame data items dsl that is read out.

**[0185]** The reception transducer element array determiner **1133**A, by using an acoustic line signal sub-frame data item dsl, geometrically calculates a position of a high intensity receive transducer element **101***a*X receiving ultrasound reflection from the puncture needle **101***b* located at the puncture needle imaging area **101***b*X. Here, for example, the reception transducer element array determiner **1133**A may specify, as a high intensity receive transducer element **101***a*X, a transducer element **101***a* located at a position where ultrasound transmitted from the center position of the transducer elements **101***a* in the array-direction arrives after undergoing specular reflection at the puncture needle imaging area **101***b*X. Further, the reception transducer element array determiner **1133**A selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction.

**[0186]** When the puncture needle imaging area **101***b*X is specified in a plurality of acoustic line signal sub-frame data items dsl, the reception transducer element array determiner **1133**A calculates the position of a high intensity receive transducer element **101***a*X in each of such acoustic line signal sub-frame data items dsl. In this case, it is preferable that the reception transducer element array determiner **1133**A select, as a reception transducer element array Rx, a group of transducer elements **101***a* that includes all high intensity receive transducer elements **101***a*X having been calculated and that includes the center one of the high intensity receive transducer elements **101***a*X in the array direction at the center thereof in the array direction.

**[0187]** The in-puncture reception transducer element array selector **113**A outputs information indicating the position of the reception transducer element array Rx it has selected to the reception condition setter **108**. Meanwhile, when a puncture needle imaging area **101***b*X is not detected in any acoustic line signal sub-frame data item dsl, the in-puncture reception transducer element array selector **113**A does not output any information indicating a position of a reception transducer element array Rx to the reception condition setter **108**.

<Operations>

**[0188]** The following describes the generation of acoustic line signal sub-frame data items dsl, performed by the ultrasound diagnostic device **100**A. The generation of acoustic line signal sub-frame data items dsl by the ultrasound diagnostic device **100**A differs from the same by the ultrasound diagnostic device **100** in terms of the processing for selecting a reception transducer element array Rx suitable for the generation of acoustic line signals from the puncture needle **101***b*. Thus, the following provides description of only this different processing.

**[0189]** FIG. **21** is a flowchart illustrating the selection of a reception transducer element array Rx, performed by the in-puncture reception transducer element array selector **113**A.

**[0190]** As described above, the in-puncture reception transducer element array selector **113**A selects a reception transducer element array Rx based on puncture needle position/inclination angle calculated based on one or more acoustic line signal sub-frame data items dsl having been generated in response to one or more transmission events preceding the processing-target transmission event. For example, the in-puncture reception transducer element array selector **113**A may perform the selection of a reception transducer element array Rx based on one acoustic line signal sub-frame data item dsl having been generated in response to the most recent transmission event performed by using the same transmission transducer element array Tx as the processing-target transmission event. Alternatively, the in-puncture reception transducer element array selector **113**A may perform the selection of a reception transducer element array Rx based on a plurality of acoustic line signal sub-frame data items dsl having been generated in response to transmission events after the most recent transmission event performed by using the same transmission transducer element array Tx as the processing-target transmission event.

**[0191]** The in-puncture reception transducer element array selector **113**A acquires one or more acoustic signal sub-frame data items rfl from the data storage **114**.

**[0192]** In Step S**2011**A, the high intensity measurement point position detector **1131**A extracts, from each acoustic line signal sub-frame data item dsl having been acquired, positions of measurement points Pijh producing acoustic line signals with intensities higher than or equal to the predetermined threshold.

**[0193]** In Step S**2012**A, the puncture needle position/angle calculator **1132**A, in each acoustic line signal sub-frame data item dsl including a plurality of measurement points Pijh, analyzes the shape of the area where the measurement points Pijh exist in the acoustic line signal sub-frame data item dsl, specifies the area as a puncture needle imaging area **101***b*X when the area has a linear shape, and geometrically calculates the position/angle at which the puncture needle **101***b* has been imaged by calculating the position/angle of the puncture needle imaging area **101***b*X.

**[0194]** In Step S**2013**A, the reception transducer element array determiner **1133**A selects a reception transducer element array Rx based on the detected position/angle at which the puncture needle **101***b* has been imaged. Specifically, the reception transducer element array determiner **1133**A geometrically calculates a position of a high intensity receive transducer element **101***a*X receiving ultrasound reflection from the puncture needle **101***b* at the puncture needle imaging area **101***b*X acquired in Step S**2012**A, and selects a group of transducer element **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction.

**[0195]** Alternatively, when selecting a reception transducer element array Rx based on puncture needle positions/inclination angles calculated based on a plurality of acoustic line signal sub-frame data items dsl having been generated in response to a plurality of transmission events preceding the current transmission event, processing may be performed as follows. When a puncture needle imaging area **101***b*X has been specified in each of a plurality of acoustic line signal sub-frame data items dsl, the reception transducer element array determiner **1133**A may select, as a reception transducer element array Rx, a group of transducer elements that includes that includes all of the high intensity receive transducer elements **101***a*X having been specified based on the acoustic line signal sub-frame data items dsl and that includes the center one of the high intensity receive transducer elements **101***a*X in the array direction at the center thereof in the array direction.

**[0196]** The in-puncture reception transducer element array selector **113**A outputs information indicating the position of the reception transducer element array Rx so selected to the reception condition setter **108**. Following this, a combined acoustic line signal frame data item ds is generated through the relevant processes illustrated in FIG. **15**.

<Effects>

**[0197]** As described up to this point, the ultrasound diagnostic device **100**A is capable of specifying, as a reception transducer element array Rx, a group of transducer elements **101***a* whose receives signals rf based on ultrasound reflection from the puncture needle **101***b* have high intensity. Specifically, the in-puncture reception transducer element array selector **113**A of the ultrasound diagnostic device **100**A extracts a linear area composed of measurement points producing acoustic line signals with high intensity in an acoustic line signal sub-frame data item dsl, specifies the position/inclination angle at which the puncture needle **101***b* has been imaged based on the linear area, and selects a reception transducer element array Rx based on the specified position/inclination angle.

**[0198]** With this structure, the ultrasound diagnostic device **100**A, similar to the ultrasound diagnostic device **100** pertaining to embodiment 1, is capable of producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method. Specifically, the ultrasound diagnostic device **100**A is capable of calculating puncture needle angle/inclination angle with high precision, by performing the calculation of angle/inclination angle at which the puncture needle has been imaged by using an acoustic line signal sub-frame data item dsl, which is generated through delay-and-sum processing and thus has a high signal S/N ratio.

**[0199]** Further, an acoustic line signal sub-frame data item dsl having been generated in response to a transmission event may include a linear area composed of measurement points producing acoustic line signals with high signal intensity. This linear area is indicative of the fact that ultrasound reflection from the puncture needle **101***b* has been received by the reception transducer element array Rx for the transmission event. As such, specifying a high intensity receive transducer element **101***a*X from the detected linear area and selecting a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction as a reception transducer element array Rx for another transmission event increases the possibility of ultrasound reflection from the puncture needle **101***b* being received in the another transmission event.

**[0200]** Note that the method described in embodiment 2 is a non-limiting example of a method of selecting a reception transducer element array Rx based on acoustic line signals. That is, the selection of a reception transducer element array Rx can be performed by using other methods as long as puncture needle position is detected based on acoustic line signal and a reception transducer element array Rx is selected based on the detected position.

## Embodiment 3

**[0201]** The following describes an ultrasound diagnostic device **100**B pertaining to embodiment 3. The ultrasound diagnostic device **100**A pertaining to embodiment 2 includes the in-puncture reception transducer element array selector **113**A, which specifies the position/inclination angle at which the puncture needle has been imaged based on the characteristics of acoustic line signals in one or more acoustic line signal sub-frame data item dsl, and selects a reception transducer element array Rx based on the specified position/inclination angle. However, various other methods can be used as necessary or desired for specifying puncture needle position/inclination angle. Embodiment 3 describes one example of such methods.

**[0202]** The ultrasound diagnostic device **100**B differs from the ultrasound diagnostic device **100**A pertaining to embodiment 2 for including a probe interface acquiring, from the probe **101**, probe identification information identifying the probe **101**, and an in-puncture reception transducer element array selector that specifies the position/inclination angle of the puncture needle **101***b* based on the probe identification information and selects a reception transducer element array Rx based on the specified position/inclination angle.

<Structure>

**[0203]** The following describes the structure of the ultrasound diagnostic device **100**B. FIG. **22** illustrates functional blocks of an ultrasound diagnostic system **1000**B including the ultrasound diagnostic device **100**B. The ultrasound diagnostic device **100**B differs from the ultrasound diagnostic device **100** for including an in-puncture reception transducer element array selector **113**B and a probe interface **117**, as illustrated in FIG. **22**. The following description focuses on the in-puncture reception transducer element array selector **113**B and the probe interface **117**. Since the rest of the components of the ultrasound diagnostic device **100**B other than the in-puncture reception transducer element array selector **113**B and the probe interface **117** are similar to those in the ultrasound diagnostic device **100**, description is not provided of the rest of the components of the ultrasound diagnostic device **100**B.

**[0204]** Upon connection of the probe **101** to the ultrasound diagnostic device **100**B, the probe interface **117** acquires, from the probe **101**, probe identification information identifying the probe **101**. The probe identification information is information unique to the probe **101**, and enables specifying the model and specifications of the probe **101** as well as enabling individually identifying the specific probe **101**. The probe interface **117** outputs the probe identification information so acquired to the in-puncture reception transducer element array selector **113**B.

**[0205]** The in-puncture reception transducer element array selector **113**B is a circuit that specifies the position/inclination angle of the puncture needle **101***b* based on the probe identification information that it acquires from the probe interface **117**, and selects a reception transducer element array Rx based on the specified position/inclination angle.

**[0206]** FIG. **23** illustrates functional blocks of the in-puncture reception transducer element array selector **113**B. Each of FIGS. **24**A and **24**B is a schematic illustrating processing by the in-puncture reception transducer element array selector **113**B. As illustrated in FIG. **23**, the in-puncture reception transducer element array selector **113**B includes a puncture needle position/angle specifier **1132**B and a reception transducer element array determiner **1133**B.

**[0207]** As illustrated in FIG. **24**A, the probe **101** has the puncture guide **101***c* attached thereto, with the puncture guide **101***c* holding the puncture needle **101***b*. As already described above, the puncture guide **101***c* has an undepicted guide member that, when the probe **101** is put in contact with the skin surface of the examination subject, guides the puncture needle **101***b* into the examination subject at a predetermined insertion angle. Usually, every probe has a specific puncture guide compatible therewith, and the puncture guide defines where the puncture needle is attached to the probe and the insertion angle of the puncture needle with respect to examination subject. Thus, acquisition of the probe identification information of the probe **101** allows specifying the position np of the puncture needle **101***b* relative to the transducer elements **101***a* of the probe **101**, and the inclination angle na of the puncture needle **101***b* relative to the surface of the array of transducer elements **101***a* of the probe **101**.

**[0208]** The puncture needle position/angle specifier **1132**B is capable of specifying the position np and the inclination angle na of the puncture needle **101***b* based on the probe identification information that it acquires.

**[0209]** Meanwhile, as illustrated in FIG. **24**A, the reception transducer element array determiner **1133**B geometrically calculates a position of a high intensity receive transducer element **101***a*X receiving ultrasound reflection from the puncture needle **101***b*, based on information indicating the position np and the inclination angle na of the puncture needle **101***b* that it acquires. Here, by using a method similar to that described in embodiment 2, the reception transducer element array determiner **1133**B may specify a puncture needle imaging area **101***b*X in an acoustic line signal sub-frame data item dsl, and geometrically calculate the position of a high intensity receive transducer element **101***a*X based on the position of the puncture needle imaging area **101***b*X, as illustrated in FIG. **24**B. Further, the reception transducer element array determiner **1133**C selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction. The reception transducer element array determiner **1133**C outputs information indicating the position of the reception transducer element array Rx it has selected to the reception condition setter **108**.

<Operations>

**[0210]** The following describes the generation of acoustic line signal sub-frame data items dsl, performed by the ultrasound diagnostic device **100**B. The following describes the processing (illustrated in FIG. **25**) by the ultrasound diagnostic device **100**C of selecting a reception transducer element array Rx suitable for the generation of acoustic line signals from the puncture needle **101***b*, which differs from that of the ultrasound diagnostic device **100**.

**[0211]** The in-puncture reception transducer element array selector **113**B reads out one or more receive signal sub-frame data items rfl from the data storage **114**.

**[0212]** The puncture needle position/angle specifier **1132**B acquires, from the probe interface **117**, probe identification information identifying the probe **101** connected to the ultrasound diagnostic device **100**B, and specifies the position np and the inclination angle na of the puncture needle **101***b* based on the probe identification information (Step S**2012**B). The reception transducer element array determiner **1133**B geometrically calculates the position of a high intensity receive transducer element **101***a*X based on the acquired position np and the acquired angle na of the puncture needle **101***b*, and selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction (Step S**2013**B). The in-puncture reception transducer element array selector **113**B outputs information indicating the position of the reception transducer element array Rx so selected to the reception condition setter **108**. Following this, a combined acoustic line signal frame data item ds is generated through the relevant processes illustrated in FIG. **15**.

<Effects>

**[0213]** As described up to this point, the ultrasound diagnostic device **100**B pertaining to embodiment 3 includes the probe interface **117** and the in-puncture reception transducer element array selector **113**B. The probe interface **117** acquires probe identification information from the probe **101**. The in-puncture reception transducer element array selector **113**B specifies the position np and the inclination angle na of the puncture needle **101***b* based on the probe identification information, and selects a reception transducer element array Rx based on the position np and the inclination angle na.

**[0214]** The ultrasound diagnostic device **100**B is capable of producing ultrasound images imaging a puncture needle with high visual perceptibility. Specifically, the ultrasound diagnostic device **100**B is capable of specifying puncture needle position/inclination angle by using a probe interface, and thus, is capable of specifying puncture needle position/inclination angle with a simple structure, without having to execute detection of puncture needle position/inclination angle based on acoustic line signals, which typically has great processing load.

## Embodiment 4

**[0215]** The following describes an ultrasound diagnostic device **100**C pertaining to embodiment 4. As described above, the ultrasound diagnostic device **100**B pertaining to embodiment 3 includes the probe interface **117** and the in-puncture reception transducer element array selector **113**B. The probe interface **117** acquires probe identification information from the probe **101**, and the in-puncture reception transducer element array selector **113**B specifies the position/inclination angle of the puncture needle **101***b* based on the probe identification information. However, various other methods can be used as necessary or desired for specifying puncture needle position/inclination angle. Embodiment 4 describes one example of such methods.

**[0216]** The ultrasound diagnostic device **100**C is configured to be connectable to the operation receiver **102**, which receives input operations performed by an examiner. This is similar to embodiments 1, 2, and 3. However, embodiment 4 differs from embodiment 3 in that the ultrasound diagnostic device **100**C includes an in-puncture reception transducer element array selector **113**C, and the in-puncture reception transducer element array selector **113**C, when information indicating the position np and the inclination angle na of a puncture needle is input to the operation receiver **102**, selects a reception transducer element array Rx based on the information that is input.

<Structure>

**[0217]** The following describes the structure of the ultrasound diagnostic device **100**C. FIG. **26** illustrates functional blocks of an ultrasound diagnostic system **1000**C including the ultrasound diagnostic device **100**C. The ultrasound diagnostic device **100**C differs from the ultrasound diagnostic device **100** for including an in-puncture reception transducer element array selector **113**C and a puncture needle position/angle information acceptor **104**C, as illustrated in FIG. **26**. The following description focuses on the in-puncture reception transducer element array selector **113**C and the puncture needle position/angle information acceptor **104**C. Since the rest of the components of the ultrasound diagnostic device **100**C other than the in-puncture reception transducer element array selector **113**C and the puncture needle position/angle information acceptor **104**C are similar to those in the ultrasound diagnostic device **100**, description is not provided of the rest of the components of the ultrasound diagnostic device **100**C.

**[0218]** The puncture needle position/angle information acceptor **104**C is similar to the operation acceptor **104** of the ultrasound diagnostic device **100** for having the function of receiving, from the operation receiver **102**, information indicating a manual input operation that the examiner has performed on the operation receiver **102**. The input operation performed by the examiner may be, but is not limited to, an input operation for changing settings of the ultrasound diagnostic device **100**C or an input operation for controlling the ultrasound diagnostic device **100**C. In addition, the puncture needle position/angle information acceptor **104**C has the function of receiving, from the operation receiver **102**, information indicating the insertion angle of the puncture needle **101***b* with respect to the body tissues of the examination subject, the position of the puncture needle **101***b* relative to the transducer elements **101***a*, etc., when the examiner has performed a manual input operation on the operation receiver **102** to input such information. Here, the operation receiver **102** may be configured to enable the examiner to input such information when the examiner provides the operation receiver **102** with input activating an operation mode for puncture needle insertion. The puncture needle position/angle information acceptor **104**C outputs the information that it receives from the operation receiver **102** to the in-puncture reception transducer element array selector **113**C, via the controller **115**.

**[0219]** The in-puncture reception transducer element array selector **113**C is a circuit that selects a reception transducer element array Rx based on puncture needle position/angle information that is acquires.

**[0220]** FIG. **27** illustrates functional blocks of the in-puncture reception transducer element array selector **113**C. Each of FIGS. **28**A and **28**B is a schematic illustrating processing by the in-puncture reception transducer element array selector **113**C. As illustrated in FIG. **27**, the in-puncture reception transducer element array selector **113**C includes a puncture needle position/angle information receiver **1132**C and a reception transducer element array determiner **1133**C.

**[0221]** The puncture needle position/angle information receiver **1132**C receives the position np and the inclination angle na of the puncture needle **101***b* from the puncture needle position/angle information acceptor **104**C.

**[0222]** As illustrated in FIG. **24**A, the reception transducer element array determiner **1133**C geometrically calculates a position of a high intensity receive transducer element **101***a*X receiving ultrasound reflection from the puncture needle **101***b,* based on information indicating the position np and the inclination angle na of the puncture needle **101***b* that it acquires. That is, the reception transducer element array determiner **1133**C geometrically calculates the position of a high intensity receive transducer element **101***a*X according to a method similar to that described in embodiment 3. Further, the reception transducer element array determiner **1133**C selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction. The reception transducer element array determiner **1133**C outputs information indicating the position of the reception transducer element array Rx it has selected to the reception condition setter **108**.

<Operations>

**[0223]** The following describes the generation of acoustic line signal sub-frame data items dsl, performed by the ultrasound diagnostic device **100**C. The following describes the processing (illustrated in FIG. **28**) by the ultrasound diagnostic device **100**C of selecting a reception transducer element array Rx suitable for the generation of acoustic line signals from the puncture needle **101***b,* which differs from that of the ultrasound diagnostic device **100**.

**[0224]** The in-puncture reception transducer element array selector **113**C reads out one or more receive signal sub-frame data items rfl from the data storage **114**. The puncture needle position/angle information receiver **1132**C receives the position np and the inclination angle na of the puncture needle **101***b* from the puncture needle position/angle information acceptor **104**C (Step **S2012**C). The reception transducer element array determiner **1133**C geometrically calculates the position of a high intensity receive transducer element **101***a*X based on the position np and the angle na of the puncture needle **101***b* that it acquires, and selects, as a reception transducer element array Rx, a group of transducer elements **101***a* including the high intensity receive transducer element **101***a*X at the center thereof in the array direction (Step **S2013**C). The in-puncture reception transducer element array selector **113**C outputs information indicating the position of the reception transducer element array

Rx so selected to the reception condition setter **108**. Following this, a combined acoustic line signal frame data item ds is generated through the relevant processes illustrated in FIG. **15**.

<Effects>

**[0225]** As described up to this point, the ultrasound diagnostic device **100**C is configured to be connectable to the operation receiver **102**, which receives input operations performed by an examiner. Further, the ultrasound diagnostic device **100**C includes an in-puncture reception transducer element array selector **113**C. The in-puncture reception transducer element array selector **113**C, when information indicating the position np and the inclination angle na of a puncture needle is input to the operation receiver **102**, selects a reception transducer element array Rx based on the information that is input.

**[0226]** The ultrasound diagnostic device **100**C is capable of producing ultrasound images imaging a puncture needle appear with high visual perceptibility. Specifically, the ultrasound diagnostic device **100**C is capable of specifying puncture needle position/inclination angle without a probe interface, and thus with an even simpler structure. Specifically, the ultrasound diagnostic device **100**C is capable of specifying puncture needle position/inclination angle by including the puncture needle position/angle information acceptor **104**C, which receives information indicating puncture needle position/inclination angle that has been input on the operation receiver **102**.

<Other Modifications>

**[0227]** Up to this point, the technology pertaining to the present disclosure has been described based on specific embodiments thereof. However, the embodiments are non-limiting examples of application of the technology pertaining to the present disclosure, and thus, the technology pertaining to the present disclosure shall be construed to encompass the following exemplar modifications.

**[0228]** For example, the technology pertaining to the present disclosure may be implemented by using a computer system including a memory storing a computer program and a microprocessor operating based on the computer program. For example, the computer system may store a computer program of a diagnosis method of an ultrasound diagnostic device pertaining to the technology of the present disclosure, and the computer system may operate in accordance with the computer program or may provide instructions in accordance with the computer program to various components connected thereto.

**[0229]** Further, the technology pertaining to the present disclosure may be implemented by implementing a part of or the entirety of an ultrasound diagnostic device described above, or a part of or an entirety of an beam former described above by using a computer system including a microprocessor, a recording medium such as a ROM or a RAM, and a hard disk unit. In this implementation, a computer program achieving the same operations as a device described above is stored to the RAM or the hard disk unit. Further, in this implementation, a device achieves its functions by the microprocessor operating in accordance with the computer program.

**[0230]** Further, the technology pertaining to the present disclosure may be implemented by implementing some or all components included in a device described above by using one system LSI (large scale integration). A system LSI is an ultra-multifunctional LSI manufactured by integrating multiple components onto one chip. Specifically, a system LSI is a computer system including a microprocessor, a ROM, a RAM, and the like. Further, each component may be separately implemented by using one chip, or some or all components may be implemented by using one chip. Note that LSIs are referred to by using different names, depending upon the level of integration achieved thereby. Such names include IC, system LSI, super LSI, and ultra LSI. In this implementation, a computer program achieving the same operations as a device described above is stored to the RAM. Further, in this implementation, the system LSI achieves its functions by the microprocessor operating in accordance with the computer program. For example, the technology pertaining to the present disclosure encompasses a form of implementation where an LSI stores a beam forming method pertaining to the present disclosure as a program, the LSI is inserted into a computer, and the computer executes the program (i.e., the beam forming method pertaining to the present disclosure).

**[0231]** Note that integration of circuits may be achieved by a dedicated circuit or a general purpose processor, in addition to being achievable by using an LSI as discussed above. Further, a Field Programmable Gate Array (FPGA), which is programmable after manufacturing, or a reconfigurable processor, which allows reconfiguration of the connection and setting of circuit cells inside the LSI, may be used.

**[0232]** Furthermore, if technology for circuit integration that replaces LSIs emerges, owing to advances in semiconductor technology or to another derivative technology, the integration of functional blocks may naturally be accomplished using such technology.

**[0233]** Further, some or all functions of an ultrasound diagnostic device discussed in the embodiments may be implemented by a processor such as a CPU executing a program. Further, the technology pertaining to the present disclosure may be implemented by using a non-transitory computer-readable recording medium having recorded thereon a program causing execution of a diagnostic method and a beam forming method of an ultrasound diagnostic device described above. Further, execution of the program by another independent computer system may be achieved by transferring the program by recording the program or a signal onto a recording medium. Naturally, the program may be distributed via means of transmission media such as the internet.

**[0234]** Each of the ultrasound diagnostic devices pertaining to the embodiments includes the data storage, which is a recording device. However, the recording device need not be included in the ultrasound diagnostic devices, and may be implemented by using a semiconductor memory, a hard disk drive, an optical disk drive, a magnetic storage device, or the like connected to the ultrasound diagnostic devices from the outside.

**[0235]** Further, the functional blocks illustrated in the block diagrams are mere examples of possible functional blocks. That is, a plurality of functional blocks illustrated in the block diagrams may be combined to form one functional block, a given functional block illustrated in the block diagrams may be divided into a plurality of functional blocks, and a function of a given functional block illustrated in the block diagrams may be transferred to another functional block. Further, with regards to multiple functional blocks having similar functions, such functional blocks may be implemented by one piece of hardware or software executing such functions in parallel or by applying time division.

**[0236]** Further, the above-described order in which steps of processing are executed is a non-limiting example, among multiple possible orders, that is used for the sole sake of providing specific description of the technology pertaining to the present disclosure. Further, some of the steps of processing described above may be executed simultaneously (in parallel).

**[0237]** Further, in the embodiments, description is provided that the ultrasound diagnostic devices may have a probe and a display attached thereto. However, the ultrasound diagnostic devices may include a probe and a display therein.

**[0238]** Further, in the embodiments, the probe includes a plurality of piezoelectric transducer elements arrayed along one direction. However, the probe may have a different structure. For example, the probe may include a plurality of piezoelectric transducer elements arrayed two-dimensionally. Alternatively, the probe may be a swingable probe including a plurality of swingable transducer elements (i.e., transducer elements that can be caused to swing by mechanical means) arrayed along one direction, which enables acquisition of three-dimensional tomographic images. Further, probes of different types may be selected and used depending upon the examination to be performed. For example, when using a probe including piezoelectric transducer elements arrayed two-dimensionally, supplying different piezoelectric transducer elements with voltages at different timings or with voltages with different values achieves controlling the irradiation position, direction, etc., of the ultrasound beam to be transmitted.

**[0239]** Further, the probe may be provided with some of the functions of the transmitter/receiver. For example, the probe may be capable of generating a transmission electric signal based on a control signal that the transmitter/receiver outputs to cause generation of a transmission electric signal, and of converting the transmission electronic signal into ultrasound. In addition, the probe may be capable of converting ultrasound reflection into receive signals, and of generating acoustic line signals based on the receive signals.

**[0240]** The transmitter **107** and the receiver **110** in the ultrasound diagnostic devices pertaining to the embodiments need not have the respective structures described in the embodiments, and may be provided with different structures as required. For example, in the embodiments, the transmitter **107** sets, for each transmission event, a group of some of the transducer elements **101***a* of the probe **101** as a transmission transducer element array, and performs transmission events repeatedly while gradually shifting the transmission transducer element array in the array direction each time, to cause all of the transducer elements **101***a* of the probe **101** to perform ultrasound transmission. However, the transmitter **107** may cause all the transducer elements **101***a* of the probe **101** to perform ultrasound transmission all at once. This modification achieves receiving ultrasound reflection from the entire ultrasound main irradiation area through one transmission event, and thus, makes unnecessary performing transmission events repeatedly.

**[0241]** Further, in the embodiments, the receiver **110** causes, for each transmission event, all of the transducer elements **101***a* of the probe **101** to each receive ultrasound reflection. However, the receiver **110** may set, for each transmission event, a group of some of the transducer elements **101***a* of the probe **101** as a receive transducer element array, and perform reception of ultrasound reflection repeatedly, while gradually shifting the receive transducer element array in the array direction each time, such that all of the transducer elements **101***a* of the probe **101** each receive ultrasound reflection. This achieves, for each transmission event, generating sequences of receive signals by using only ultrasound reflection received from the vicinity of the transmitted ultrasound, and generating acoustic line signals based on such sequences of receive signals in the target area. Thus, this reduces the processing load of the generation of acoustic line signals for each transmission event, and further improves signal resolution in the time domain.

**[0242]** Further, the area within which measurement points are distributed (i.e., the target area) need not have the shape described in the embodiments, as long as target areas are set inside ultrasound main irradiation areas. For example, a target area may be an hourglass-shaped area whose base has a length corresponding to the length of the reception transducer element array and whose central axis passes through the center position of the reception transducer element array in the array direction. Alternatively, a target area may be a rectangular, belt-shaped area having a width corresponding to the widths of at least two transducer elements and whose central axis passes through the center position of the reception transducer element array in the array direction and is perpendicular to the reception transducer element array. When making such modifications, the central axis of the target area need not pass through the center position of the reception transducer element array in the array direction.

**[0243]** Further, in embodiment 2, the receiver **110** selects a reception transducer element array Rx based on the position np and the inclination angle na of the puncture needle **101***b*, which are calculated based on an acoustic line signal sub-frame data item dsl having been generated in response to a transmission event preceding the processing-target transmission event. Alternatively, the receiver **110** may first generate a provisional acoustic line signal sub-frame data item dsl for the processing-target transmission event, then select a reception transducer element array Rx based on the position and the inclination angle of the puncture needle **101***b* calculated based on the provisional acoustic line signal sub-frame data item dsl, and generate an acoustic line signal sub-frame data item dsl for the processing-target transmission event by performing delay-and-sum processing by using the sequences of receive signals corresponding to the transducer elements **101***a* in the selected reception transducer element array Rx. Here, the receiver **110** may generate the provisional acoustic line signal sub-frame data item dsl by selecting a provisional reception transducer element array Rx based on a certain rule (e.g., the transmission transducer element array for the processing-target transmission event may be selected as the provisional reception transducer element array Rx) and performing delay-and-sum processing by using sequences of receive signals corresponding to the transducer elements **101***a* in the provisional reception transducer element array Rx. This modification enables detection of the position np and the inclination angle na of the puncture needle **101***b* even when no transmission event has been performed preceding the processing-target transmission event (e.g., the processing-target transmission event is the first transmission event being performed), as well as producing ultrasound images imaging a puncture needle appear with high visual perceptibility.

**[0244]** Further, at least some of the functions of the ultrasound diagnostic devices pertaining to the embodiments and the modifications may be combined with functions of other ones of the ultrasound diagnostic devices pertaining to the embodiments and the modifications. Further, the values used above are non-limiting examples used for the sole sake of providing specific description of the technology pertaining to the present disclosure, and may be replaced with other values. Further, the technology pertaining to the present disclosure should be construed as encompassing various modifications that a skilled artisan would arrive at based on the embodiments describe above.

<<Summary>>

**[0245]** One aspect of the present disclosure is an ultrasound diagnostic device to which an ultrasound probe having a plurality of transducer elements arrayed along an array direction is connectable, wherein the ultrasound diagnostic device: (i) repeatedly performs transmission events, each by selecting a first group of transducer elements from among the plurality of transducer elements and causing the first group to transmit ultrasound towards an examination subject having a puncture needle inserted therein; (ii) for each of the transmission events, generates a sub-frame data item based on ultrasound reflection received in response to the transmission event, the sub-frame data item including acoustic line signals; and (iii) combines sub-frame data items for the transmission events to generate a frame data item, the frame data item including combined acoustic line signals each being an aggregate of ones of the acoustic line signals, and the ultrasound diagnostic device includes an ultrasound signal processing circuit operating as: a transmitter that performs each of the transmission events by selecting the first group and causing the first group to transmit ultrasound focusing inside the examination subject, the transmitter gradually shifting the first group in the array direction between transmission events; and a receiver that: (i) for each of the transmission events, selects at least some of the plurality of transducer elements and generates a sequence of receive signals for each of the selected transducer elements based on ultrasound reflection that the selected transducer element has received from the examination subject in response to the transmission event; (ii) selects a second group of transducer elements, the transducer elements in the second group being ones among the plurality of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity; (iii) for each of the transmission events, sets a target area for generating the sub-frame data item inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generates the sub-frame data item by performing, for each of a plurality of measurement points in the target area, delay-and-sum processing on receive signals, for the transducer elements in the second group, based on ultrasound reflection from the measurement point; and (iv) generates the frame data item by combining the sub-frame data items for the transmission events.

**[0246]** With this structure, the ultrasound diagnostic device is capable of producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method. Specifically, the ultrasound diagnostic device utilizes the synthetic aperture method and repeatedly performs transmission events while gradually shifting the transmission transducer element array in the array direction. Further, the ultrasound diagnostic device performs delay-and-sum processing for each transmission event by using a reception transducer element array composed of reception transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity.

**[0247]** When performing ultrasound examination by using the ultrasound diagnostic device with the puncture needle inserted in the examination subject, signals based on ultrasound reflection from the puncture needle have extremely higher intensity than signals based on ultrasound reflection from body tissues since the puncture needle produces specular ultrasound reflection whereas body tissues mainly produce diffuse ultrasound reflection. The ultrasound diagnostic device distinguishes signals based on ultrasound reflection from the puncture needle from signals based on ultrasound reflection from body tissues by using a predetermined threshold. Specifically, the ultrasound diagnostic device detects a transducer element whose receive signal has intensity higher than or equal to the predetermined threshold, specifies such a transducer element as a transducer element having received ultrasound reflection from the puncture needle, and selects a group of transducer elements including such a transducer element as a reception transducer element array. Thus, the ultrasound diagnostic device is capable of selecting, as a reception transducer element array, a group of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have relatively high intensity. The ultrasound diagnostic device is capable of producing ultrasound images imaging the puncture needle with high visual perceptibility by performing, for each measurement point in a target area, delay-and-sum processing on receive signals corresponding to the reception transducer elements of a reception transducer element array selected in such a manner to generate an acoustic line signal sub-frame data item for the target area.

**[0248]** Meanwhile, the generation of acoustic line signals for the target area, performed by using the selected reception transducer element array, also allows generating acoustic line signals based on ultrasound reflection from body tissues. This is since, even when a group of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity is selected as a reception transducer element array, the transducer elements included in the selected reception transducer element array also have received ultrasound reflection from body tissues of the examination subject due to body tissues mainly producing diffuse ultrasound reflection.

**[0249]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the receiver may detect, from among the generated sequences of receive signals, a sequence of receive signals including a high intensity receive signal, specify a high intensity transducer element, among the selected transducer elements, corresponding to the high intensity receive signal, and select a group of transducer elements including the high intensity transducer element as the second group.

**[0250]** With this structure, the ultrasound diagnostic device is capable of selecting, as a reception transducer element array, a group of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensities with a simple circuit structure, by performing simple processing that does not require prior execution of delay-and-sum processing, which typically has great processing load.

**[0251]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the receiver may specify two or more high intensity transducer elements based on different ones of the transmission events, and select a group of transducer elements including the two or more high intensity transducer elements as the second group.

**[0252]** With this structure, the ultrasound diagnostic device is capable of performing reception beam forming utilizing the synthetic aperture method, where the transmission transducer element array is gradually shifted in the array direction between different transmission events, by using a reception transducer element array that enables efficiently generating acoustic line signals based on ultrasound reflection from the puncture needle across multiple transmission events, selected independent from the positions of the transmission transducer element arrays for the transmission events.

**[0253]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein from at least one of the sub-frame data items, the receiver may extract a linear area composed of acoustic line signals with high intensity, calculate a position and an inclination angle at which the puncture needle is imaged based on the linear area, and select the second group based on the position and the inclination angle.

**[0254]** With this structure, the ultrasound diagnostic device is capable of calculating puncture needle angle/inclination angle with high precision, for performing the calculation of angle/inclination angle at which the puncture needle has been imaged in an ultrasound image by using an acoustic line signal sub-frame data item dsl, which is generated through delay-and-sum processing and thus has a high signal S/N ratio.

**[0255]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the at least one of the sub-frame data items may be a sub-frame data item having been generated for a transmission event preceding a processing-target transmission event.

**[0256]** With this structure, the ultrasound diagnostic device, when an acoustic line signal sub-frame data item having been generated in response to a transmission event includes a linear area composed of acoustic line signals with high signal intensity, selects a group of transducer elements including a high intensity receive transducer element specified based on the detected linear area at the center thereof as a reception transducer element array and thus increases the possibility of ultrasound reflection from the puncture needle being received in a subsequent transmission event. Thus, the ultrasound diagnostic device is capable of performing the generation of acoustic line signals based on the subsequent transmission event so that the ultrasound image yielded as a result images the puncture needle with high visual perceptibility.

**[0257]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the transmission event preceding the processing-target transmission event may be a most recent transmission event having been performed by using the same first group as the processing-target transmission event.

**[0258]** With this structure, the ultrasound diagnostic device is capable of producing ultrasounds images imaging the puncture needle with high visual perceptibility, by selecting a reception transducer element array for a processing-target transmission event based on accurate puncture needle position/inclination angle calculated based on acoustic line signals generated for a transmission event performed by using the same transmission transducer element array as the processing-target transmission event.

**[0259]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the transmission event preceding the processing-target transmission event may include two or more transmission events having been performed after a most recent transmission event having been performed by using the same first group as the processing-target transmission event, and the receiver may extract the linear area from each of two or more sub-frame data items corresponding to the two or more transmission events.

**[0260]** With this structure, the ultrasound diagnostic device is capable of producing ultrasounds images imaging the puncture needle with high visual perceptibility, by being capable of selecting a reception transducer element array for a processing-target transmission event based on accurate puncture needle position/inclination angle calculated based on acoustic line signals generated for a plurality of transmission events.

**[0261]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, further including a probe interface that, upon connection of the ultrasound probe to the ultrasound diagnostic device, acquires probe identification information identifying the ultrasound probe, wherein the receiver may specify a position and an inclination angle of the puncture needle based on the probe identification information, and selects the second group based on the position and the inclination angle.

**[0262]** With this structure, the ultrasound diagnostic device is capable of producing ultrasound images in which puncture needles appear with high visual perceptibility, by being capable of specifying puncture needle position/inclination angle with a simple structure incorporating a probe interface, and without having to execute processing with heavy load of detecting puncture needle position/inclination angle based on acoustic line signals.

**[0263]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the ultrasound diagnostic device may be connectable to an operation receiver receiving input from an external source, and when the operation receiver receives input of information indicating a position and an inclination angle of the puncture needle, the receiver may select the second group based on the information.

**[0264]** With this structure, the ultrasound diagnostic device is capable of producing ultrasound images imaging a puncture needle appear with high visual perceptibility by being capable of specifying puncture needle position/inclination angle without a probe interface, and thus with an even simpler structure. Specifically, the ultrasound diagnostic device is capable of specifying puncture needle position/inclination angle by receiving information indicating puncture needle position/inclination angle that has been input on the operation receiver.

**[0265]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the receiver may perform the selection of the second group for each of the transmission events based on the first group for the transmission event, the second groups for the transmission events differing from one another.

**[0266]** With this structure, the ultrasound diagnostic device is capable of performing reception beam forming utilizing the synthetic aperture method, where the transmission transducer element array is gradually shifted in the array direction between different transmission events, by selecting, for each transmission event, a group of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have relatively high signal intensity as a reception transducer element array based on the transmission transducer element array for the transmission event.

**[0267]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein the receiver may include a delay-and-sum calculator that generates an acoustic line signal for each of the measurement points in the target area by performing delay-and-sum processing on receive signals corresponding to ultrasound reflection from the measurement point, and the delay-and-sum calculator may generate an acoustic line signal for each of the measurement points by: (i) calculating, for each of the transducer elements in the second group, a total propagation time required for transmitted ultrasound to reach the transducer element after being reflected at the measurement point, by calculating a sum of a transmission time required for the transmitted ultrasound to reach the measurement point and a reception time required for ultrasound reflection from the measurement point to reach the transducer element; (ii) calculating delay amounts for the transducer elements in the second group based on the total propagation time for each of the transducer elements in the second group; (iii) for each of the transducer elements in the second group, specifying a receive signal corresponding to the delay amount for the transducer element in the sequence of receive signals for the transducer element; and (iv) summing the specified receive signals for the transducer elements in the second group.

**[0268]** With this structure, the ultrasound diagnostic device is capable of generating, for each ultrasound transmission event, not only acoustic line signals based on ultrasound reflection from an area of the ultrasound main irradiation area along the central axis of the transmitted ultrasound beam, but also acoustic line signals based on ultrasound reflection from areas of the ultrasound main irradiation area other than the rather narrow area along the central axis of the transmitted ultrasound beam, and thus, improves spatial resolution and signal S/N ratio as well as enhancing the efficiency of use of transmitted ultrasound.

**[0269]** Further, the ultrasound diagnostic device, by utilizing the synthetic aperture method, combines acoustic line signals generated in response to different transmission events for the same measurement point. Thus, the ultrasound diagnostic device achieves the effect of performing, for multiple transmission events, virtual transmission focusing even for measurement points that are located in depths other than that of the transmission focal point, and thus further improves spatial resolution and S/N ratio.

**[0270]** Another aspect of the present disclosure is an ultrasound diagnostic device with any structure described above, wherein when the measurement point is deeper in the examination subject than a predetermined depth at which transmitted ultrasound focuses in the examination subject, the delay-and-sum calculator may calculate the transmission time by dividing a sum of a first distance and a second distance by velocity, and when the measurement point is shallower in the examination subject than the predetermined depth, the delay-and-sum calculator may calculate the transmission time by subtracting the second distance from the first distance and dividing the difference by velocity, where the first distance is a distance between a center position of the first group in the array direction and a beam center of transmitted ultrasound at the predetermined depth, and the second distance is a distance between the beam center and the measurement point.

**[0271]** With this structure, the ultrasound diagnostic device adaptively performs delay processing using the total propagation path depending upon whether the processing-target measurement point is deeper or shallower than the transmission focal point of the transmitted ultrasound. Thus, the ultrasound diagnostic device is capable of performing delay-and-sum processing focusing on every measurement point in the target area, and thus is capable of generating an acoustic line signal for every measurement point. Accordingly, the ultrasound diagnostic device is capable of generating ultrasound images with higher resolution, less noise, and higher image quality for the entirety of the ultrasound main irradiation area than conventional ultrasound images.

**[0272]** Another aspect of the present disclosure is an ultrasound signal processing method of: (i) repeatedly performing transmission events, each by selecting a first group of transducer elements from among a plurality of transducer elements arrayed along an array direction of an ultrasound probe and causing the first group to transmit ultrasound towards an examination subject having a puncture needle inserted therein; (ii) for each of the transmission events, generating a sub-frame data item based on ultrasound reflection received in response to the transmission event, the sub-frame data item including acoustic line signals; and (iii) combining sub-frame data items for the transmission events to generate a frame data item, the frame data item including combined acoustic line signals each being an aggregate of ones of the acoustic line signals, the ultrasound signal processing method including: performing each of the transmission events by selecting the first group and causing the first group to transmit ultrasound focusing inside the examination subject, the first group being gradually shifted in the array direction between transmission events; for each of the transmission events, selecting at least some of the plurality of transducer elements and generating a sequence of receive signals for each of the selected transducer elements based on ultrasound reflection that the selected transducer element has received from the examination subject in response to the transmission event; selecting a second group of transducer elements, the transducer elements in the second group being ones among the plurality of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity; for each of the transmission events, setting a target area for generating the sub-frame data item inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generating the sub-frame data item by performing, for each of a plurality of measurement points in the target area, delay-and-sum processing on receive signals, for the transducer elements in the second group, based on ultrasound reflection from the measurement point; and generating the frame data item by combining the sub-frame data items for the transmission events.

**[0273]** Further, another aspect of the present disclosure is a non-transitory computer-readable recording medium with the ultrasound signal processing method recorded thereon.

**[0274]** The ultrasound signal processing method achieves producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method.

**[0275]** As described up to this point, the ultrasound diagnostic device and the ultrasound signal processing method pertaining to the present disclosure achieve producing ultrasound images imaging a puncture needle with high visible perceptibility, with reception beam forming utilizing the synthetic aperture method.

<<Supplement>>

**[0276]** Each of the embodiments described above should be construed as being a preferable and specific example of implementation of the technology pertaining to the present disclosure. As such, any value, any shape, any material, any constituent element, any position of any constituent element, any connection of any constituent element, any step, and any order in which any step is performed, in the embodiments, shall be construed as being a non-limiting example. Further, among the constituent elements described in the embodiments, any constituent element not recited in the independent claims, which represent the broadest concept of the present disclosure, shall be construed as a constituent element not necessarily essential but included in a preferable form of implementation of the technology pertaining to the present disclosure.

**[0277]** Further, in order to facilitate understanding, constituent elements described in the embodiments may be illustrated in drawings at a scale differing from their actual sizes. Further, the technology pertaining to the present disclosure shall not be construed as being limited to the embodiments, and instead, shall be construed as encompassing any modification that does not depart from the spirit and the scope of the present disclosure.

**[0278]** Further, the embodiments and modifications do not provide description of circuit parts and lead wires disposed on substrates in ultrasound diagnostic devices. This is since various forms of electric wiring and electric circuitry are implementable based on knowledge possessed by a skilled artisan in the present field of technology, and are not directly essential in describing the technology pertaining to the present disclosure. Further, all drawings referred to in the above are schematic drawings and may not be accurate in a strict sense.

**[0279]** Although the technology pertaining to the present disclosure has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Therefore, unless such changes and modifications depart from the scope of the technology pertaining to the present disclosure, they should be construed as being included therein.

What is claimed is:

**1**. An ultrasound diagnostic device to which an ultrasound probe having a plurality of transducer elements arrayed along an array direction is connectable, wherein

the ultrasound diagnostic device:

(i) repeatedly performs transmission events, each by selecting a first group of transducer elements from among the plurality of transducer elements and causing the first group to transmit ultrasound towards an examination subject having a puncture needle inserted therein;

(ii) for each of the transmission events, generates a sub-frame data item based on ultrasound reflection received in response to the transmission event, the sub-frame data item including acoustic line signals; and

(iii) combines sub-frame data items for the transmission events to generate a frame data item, the frame data item including combined acoustic line signals each being an aggregate of ones of the acoustic line signals, and

the ultrasound diagnostic device comprises an ultrasound signal processing circuit operating as:

a transmitter that performs each of the transmission events by selecting the first group and causing the first group to transmit ultrasound focusing inside the examination subject, the transmitter gradually shifting the first group in the array direction between transmission events; and

a receiver that:

(i) for each of the transmission events, selects at least some of the plurality of transducer elements and generates a sequence of receive signals for each of the selected transducer elements based on ultrasound reflection that the selected transducer element has received from the examination subject in response to the transmission event;

(ii) selects a second group of transducer elements, the transducer elements in the second group being ones among the plurality of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity;

(iii) for each of the transmission events, sets a target area for generating the sub-frame data item inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generates the sub-frame data item by performing, for each of a plurality of measurement points in the target area, delay-and-sum processing on receive signals, for the transducer elements in the second group, based on ultrasound reflection from the measurement point; and

(iv) generates the frame data item by combining the sub-frame data items for the transmission events.

**2**. The ultrasound diagnostic device of claim **1**, wherein

the receiver detects, from among the generated sequences of receive signals, a sequence of receive signals including a high intensity receive signal, specifies a high intensity transducer element, among the selected transducer elements, corresponding to the high intensity receive signal, and selects a group of transducer elements including the high intensity transducer element as the second group.

**3**. The ultrasound diagnostic device of claim **2**, wherein the receiver specifies two or more high intensity transducer elements based on different ones of the transmission events, and selects a group of transducer elements including the two or more high intensity transducer elements as the second group.

**4**. The ultrasound diagnostic device of claim **1**, wherein from at least one of the sub-frame data items, the receiver extracts a linear area composed of acoustic line signals with high intensity, calculates a position and an inclination angle at which the puncture needle is imaged based on the linear area, and selects the second group based on the position and the inclination angle.

**5**. The ultrasound diagnostic device of claim **4**, wherein the at least one of the sub-frame data items is a sub-frame data item having been generated for a transmission event preceding a processing-target transmission event.

**6**. The ultrasound diagnostic device of claim **5**, wherein the transmission event preceding the processing-target transmission event is a most recent transmission event having been performed by using the same first group as the processing-target transmission event.

**7**. The ultrasound diagnostic device of claim **5**, wherein the transmission event preceding the processing-target transmission event includes two or more transmission events having been performed after a most recent transmission event having been performed by using the same first group as the processing-target transmission event, and

the receiver extracts the linear area from each of two or more sub-frame data items corresponding to the two or more transmission events.

**8**. The ultrasound diagnostic device of claim **1**, further comprising:

a probe interface that, upon connection of the ultrasound probe to the ultrasound diagnostic device, acquires probe identification information identifying the ultrasound probe, wherein

the receiver specifies a position and an inclination angle of the puncture needle based on the probe identification information, and selects the second group based on the position and the inclination angle.

**9**. The ultrasound diagnostic device of claim **1**, wherein the ultrasound diagnostic device is connectable to an operation receiver receiving input from an external source, and

when the operation receiver receives input of information indicating a position and an inclination angle of the puncture needle, the receiver selects the second group based on the information.

**10**. The ultrasound diagnostic device of claim **1**, wherein the receiver performs the selection of the second group for each of the transmission events based on the first group for the transmission event, the second groups for the transmission events differing from one another.

**11**. The ultrasound diagnostic device of claim **1**, wherein the receiver includes a delay-and-sum calculator that generates an acoustic line signal for each of the measurement points in the target area by performing delay-and-sum processing on receive signals corresponding to ultrasound reflection from the measurement point, and

the delay-and-sum calculator generates an acoustic line signal for each of the measurement points by:

(i) calculating, for each of the transducer elements in the second group, a total propagation time required for transmitted ultrasound to reach the transducer element after being reflected at the measurement point, by calculating a sum of a transmission time required for the transmitted ultrasound to reach the measurement point and a reception time required for ultrasound reflection from the measurement point to reach the transducer element;

(ii) calculating delay amounts for the transducer elements in the second group based on the total propagation time for each of the transducer elements in the second group;

(iii) for each of the transducer elements in the second group, specifying a receive signal corresponding to the delay amount for the transducer element in the sequence of receive signals for the transducer element; and

(iv) summing the specified receive signals for the transducer elements in the second group.

**12**. The ultrasound diagnostic device of claim **11**, wherein when the measurement point is deeper in the examination subject than a predetermined depth at which transmitted ultrasound focuses in the examination subject, the delay-and-sum calculator calculates the transmission time by dividing a sum of a first distance and a second distance by velocity, and

when the measurement point is shallower in the examination subject than the predetermined depth, the delay-and-sum calculator calculates the transmission time by subtracting the second distance from the first distance and dividing the difference by velocity, where

the first distance is a distance between a center position of the first group in the array direction and a beam center of transmitted ultrasound at the predetermined depth, and

the second distance is a distance between the beam center and the measurement point.

**13**. An ultrasound signal processing method of:

(i) repeatedly performing transmission events, each by selecting a first group of transducer elements from among a plurality of transducer elements arrayed along an array direction of an ultrasound probe and causing the first group to transmit ultrasound towards an examination subject having a puncture needle inserted therein;

(ii) for each of the transmission events, generating a sub-frame data item based on ultrasound reflection received in response to the transmission event, the sub-frame data item including acoustic line signals; and

(iii) combining sub-frame data items for the transmission events to generate a frame data item, the frame data item including combined acoustic line signals each being an aggregate of ones of the acoustic line signals,

the ultrasound signal processing method comprising:

performing each of the transmission events by selecting the first group and causing the first group to transmit ultrasound focusing inside the examination subject, the first group being gradually shifted in the array direction between transmission events;

for each of the transmission events, selecting at least some of the plurality of transducer elements and generating a sequence of receive signals for each of the selected transducer elements based on ultrasound reflection that the selected transducer element has received from the examination subject in response to the transmission event;

selecting a second group of transducer elements, the transducer elements in the second group being ones among the plurality of transducer elements whose receive signals based on ultrasound reflection from the puncture needle have high intensity;

for each of the transmission events, setting a target area for generating the sub-frame data item inside a virtual area of the examination subject that receives ultrasound transmitted in the transmission event, and generating the sub-frame data item by performing, for each of a plurality of measurement points in the target area, delay-and-sum processing on receive signals, for the transducer elements in the second group, based on ultrasound reflection from the measurement point; and

generating the frame data item by combining the sub-frame data items for the transmission events.

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| 外部链接 | Espacenet USPTO |  |  |

## 摘要(译)

超声诊断装置包括：发射器，其通过使用在事件之间沿阵列方向逐渐移位的第一换能器组在对象内发射超声聚焦来执行事件;接收器，对于每个事件，基于换能器响应于事件而接收的超声反射产生用于换能器的接收信号序列，其选择第二换能器组，其基于来自穿刺针的超声反射具有高强度，即，对于每个事件，设置用于在接收在事件中发送的超声波的对象的虚拟区域内生成子帧数据项的目标区域，并且通过对于每个测量点执行子帧数据项来生成子帧数据项。目标区域，对第二换能器组的接收信号序列的延迟和求和处理，并且通过组合事件的子帧数据项来产生帧数据项。