US009622718B2

(12) United States Patent
Watanabe

(10) Patent No.: US 9,622,718 B2
(45) Date of Patent: Apr. 18, 2017

(54) **WIRELESS ULTRASONIC DIAGNOSTIC APPARATUS, WIRELESS ULTRASONIC PROBE, AND PROBE AUTHENTICATION METHOD**

(75) Inventor: **Yasuhito Watanabe**, Osaka (JP)

(73) Assignee: **KONICA MINOLTA, INC.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 524 days.

(21) Appl. No.: **13/001,821**

(22) PCT Filed: **Apr. 22, 2010**

(86) PCT No.: **PCT/JP2010/002892**
§ 371 (c)(1),
(2), (4) Date: **Dec. 29, 2010**

(87) PCT Pub. No.: **WO2010/122791**
PCT Pub. Date: **Oct. 28, 2010**

(65) **Prior Publication Data**

US 2011/0105904 A1 May 5, 2011

(30) **Foreign Application Priority Data**

Apr. 24, 2009 (JP) 2009-105983

(51) **Int. Cl.**
A61B 8/00 (2006.01)
G01S 7/52 (2006.01)
G01S 7/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 8/00*** (2013.01); ***A61B 8/4438*** (2013.01); ***A61B 8/4472*** (2013.01); ***A61B 8/56*** (2013.01); ***G01S 7/5205*** (2013.01); *G01S 7/003* (2013.01)

(58) **Field of Classification Search**
CPC C03B 2201/12; C03B 2203/23; C03B 37/01413; C03B 37/01807; A61B 8/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,693,120 A * 9/1987 Robinson 73/618
5,278,757 A * 1/1994 Hoctor et al. 600/459
(Continued)

FOREIGN PATENT DOCUMENTS

AU WO 2009067740 A1 * 6/2009 .... A61B 8/08
CN 1672639 9/2005
(Continued)

OTHER PUBLICATIONS

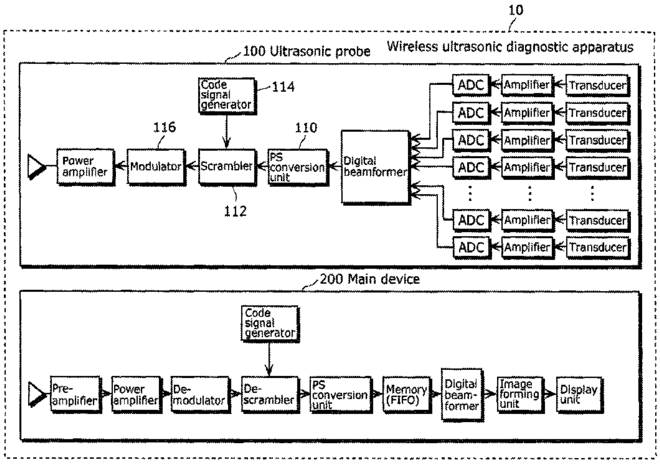
International Search Report issued Jul. 6, 2010 in International (PCT) Application No. PCT/JP2010/002892.
(Continued)

Primary Examiner — Joseph M Santos Rodriguez
(74) *Attorney, Agent, or Firm* — Holtz, Holtz & Volek PC

(57) **ABSTRACT**

A wireless ultrasonic diagnostic apparatus (**30**) including a wireless ultrasonic probe (**300**) and a diagnostic device (**400**). The wireless ultrasonic probe (**300**) includes: a wireless transmission unit (**306**) which wirelessly transmits echo data (**352**); and an ultrasound transmission unit (**303**) which transmits pairing ultrasound (**351**) including probe information for identifying the wireless ultrasonic probe (**300**). The diagnostic device (**400**) includes: an ultrasound reception unit (**401**) which receives the pairing ultrasound (**351**); a probe information detection unit (**402**) which detects the probe information (**452**) from the pairing ultrasound (**351**); and a wireless reception unit (**406**) which determines, using the probe information (**452**), whether or not received data is the echo data (**352**) wirelessly transmitted by the wireless ultrasonic probe (**300**).

24 Claims, 19 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

5,505,205	A *	4/1996	Solomon et al.	600/459
6,289,238	B1 *	9/2001	Besson et al.	600/509
6,995,682	B1 *	2/2006	Chen	B66D 1/46 340/12.22
7,988,633	B2 *	8/2011	Hossack et al.	600/467
2004/0015079	A1	1/2004	Berger et al.	
2004/0122315	A1 *	6/2004	Krill	600/437
2004/0171935	A1	9/2004	Van Creveld et al.	
2006/0268795	A1 *	11/2006	Tamaki	370/338
2007/0083111	A1 *	4/2007	Hossack et al.	600/437
2007/0088213	A1 *	4/2007	Poland	600/437
2008/0114249	A1	5/2008	Randall et al.	
2008/0114255	A1 *	5/2008	Schwartz et al.	600/474
2008/0194961	A1 *	8/2008	Randall	600/459
2008/0287835	A1 *	11/2008	Zhao et al.	601/2
2009/0036780	A1	2/2009	Abraham	
2009/0054769	A1 *	2/2009	Satoh	600/437
2009/0112099	A1 *	4/2009	Kurokawa	600/459
2010/0298711	A1 *	11/2010	Pedersen	A61B 8/00 600/459
2014/0051984	A1	2/2014	Berger et al.	

FOREIGN PATENT DOCUMENTS

EP	2 101 191	A2 *	9/2009	G01S 7/52
GB	WO 2008/152411	*	12/2008	A61B 5/055
JP	2006-095071		4/2006	
JP	2007-244579		9/2007	
JP	2008-000406		1/2008	
JP	2008-253500		10/2008	
JP	2008-271383	A	11/2008	
JP	2009-053967	A	3/2009	
WO	WO 2008115312	A2 *	9/2008	A61B 8/00

OTHER PUBLICATIONS

Japanese Office Action dated Jan. 14, 2014 (and English translation thereof) in counterpart Japanese Application No. 2010-542865.

Extended European Search Report (EESR) dated Mar. 19, 2014 (in English) issued in counterpart European Application No. 10766852.7.

* cited by examiner

FIG. 1

10

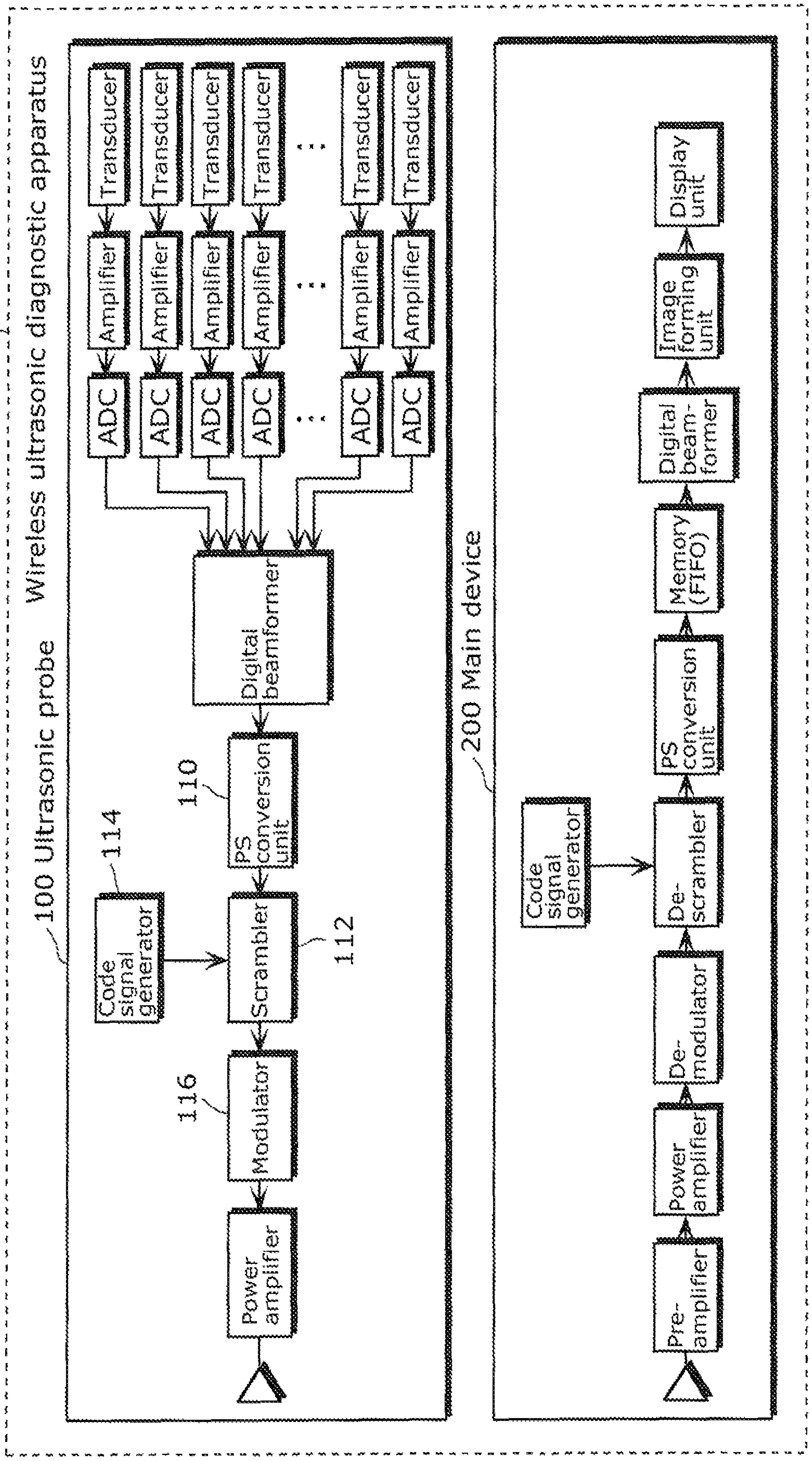

Wireless ultrasonic diagnostic apparatus
100 Ultrasonic probe
Transducer
Amplifier
ADC
Digital beamformer
110
PS conversion unit
112
Scrambler
114
Code signal generator
116
Modulator
Power amplifier
200 Main device
Pre-amplifier
Power amplifier
De-modulator
De-scrambler
Code signal generator
PS conversion unit
Memory (FIFO)
Digital beam-former
Image forming unit
Display unit

FIG. 2

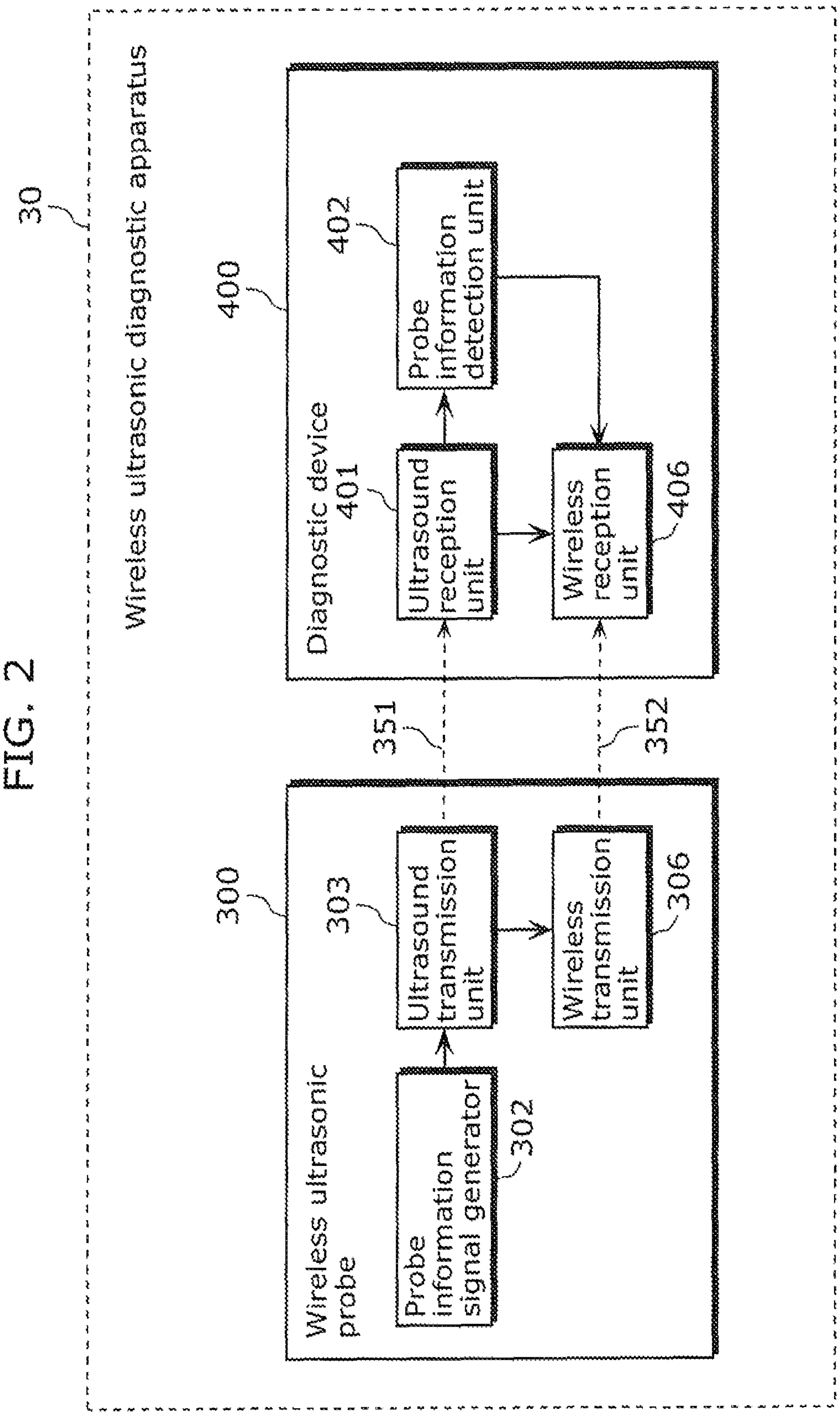
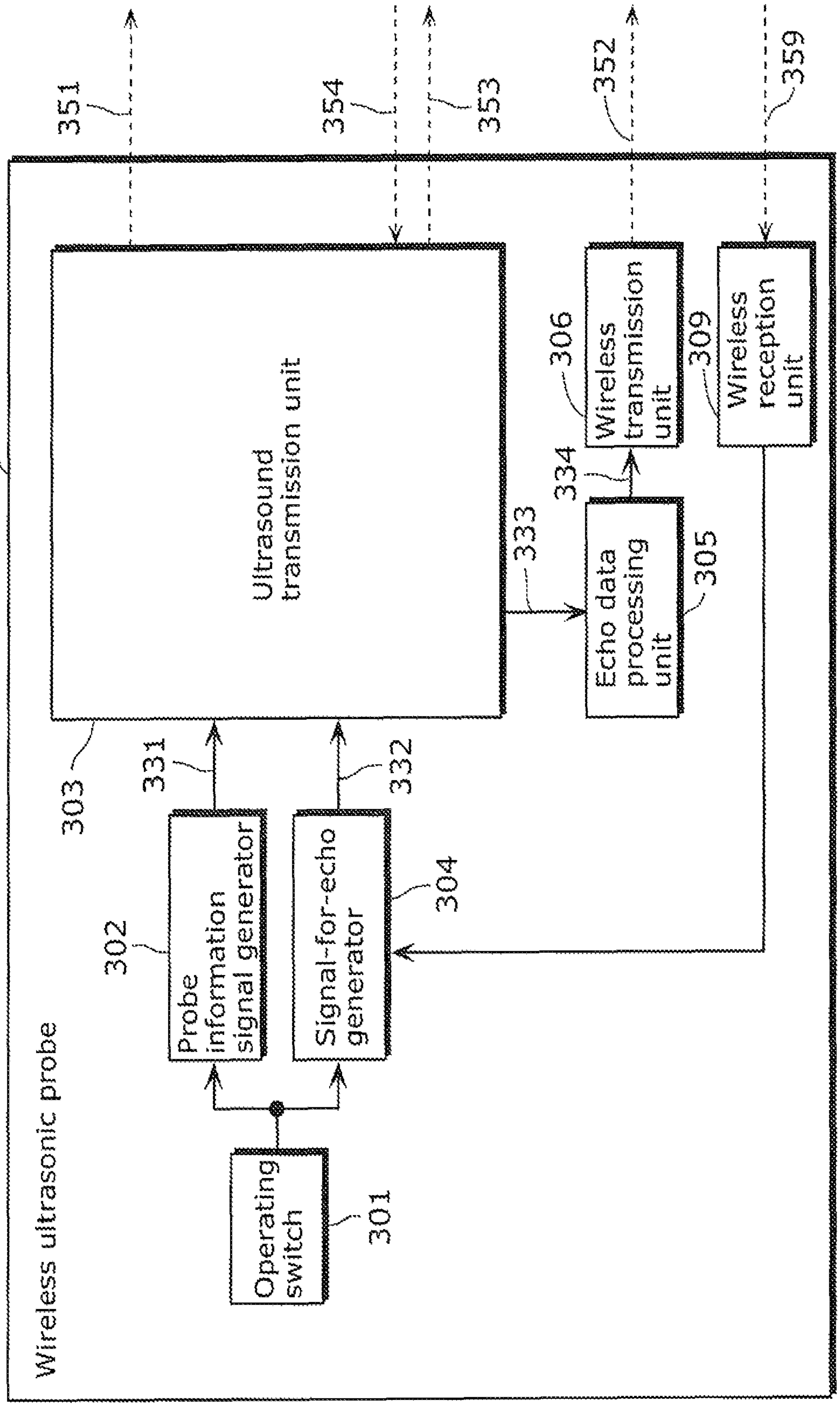

30
Wireless ultrasonic diagnostic apparatus
400
Diagnostic device
401
Ultrasound reception unit
402
Probe information detection unit
Wireless reception unit
406
351
352
300
Wireless ultrasonic probe
302
Probe information signal generator
303
Ultrasound transmission unit
Wireless transmission unit
306

FIG. 3



Wireless ultrasonic probe
300
Operating switch
301
Probe information signal generator
302
Signal-for-echo generator
304
331
332
303
Ultrasound transmission unit
333
Echo data processing unit
305
334
Wireless transmission unit
306
Wireless reception unit
309
351
354
353
352
359

FIG. 4

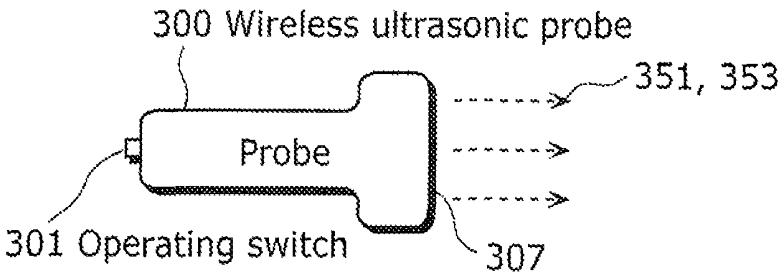

300 Wireless ultrasonic probe
351, 353
Probe
301 Operating switch
307

FIG. 5

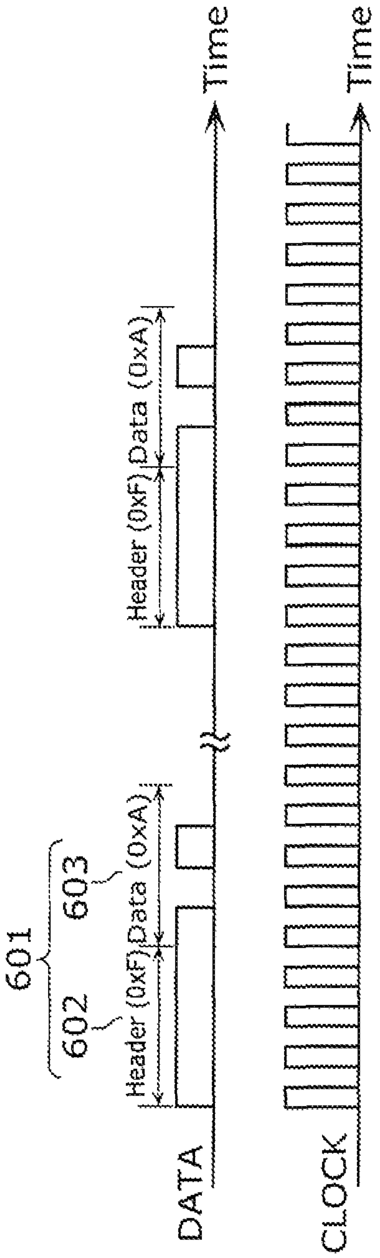

601
602
603
Header (0xF)
Data (0xA)
Header (0xF)
Data (0xA)
DATA
Time
CLOCK
Time

FIG. 6

data	Shape of probe
0x1	Convex
0x2	Linear
⋮	
0xA	Sector

FIG. 7

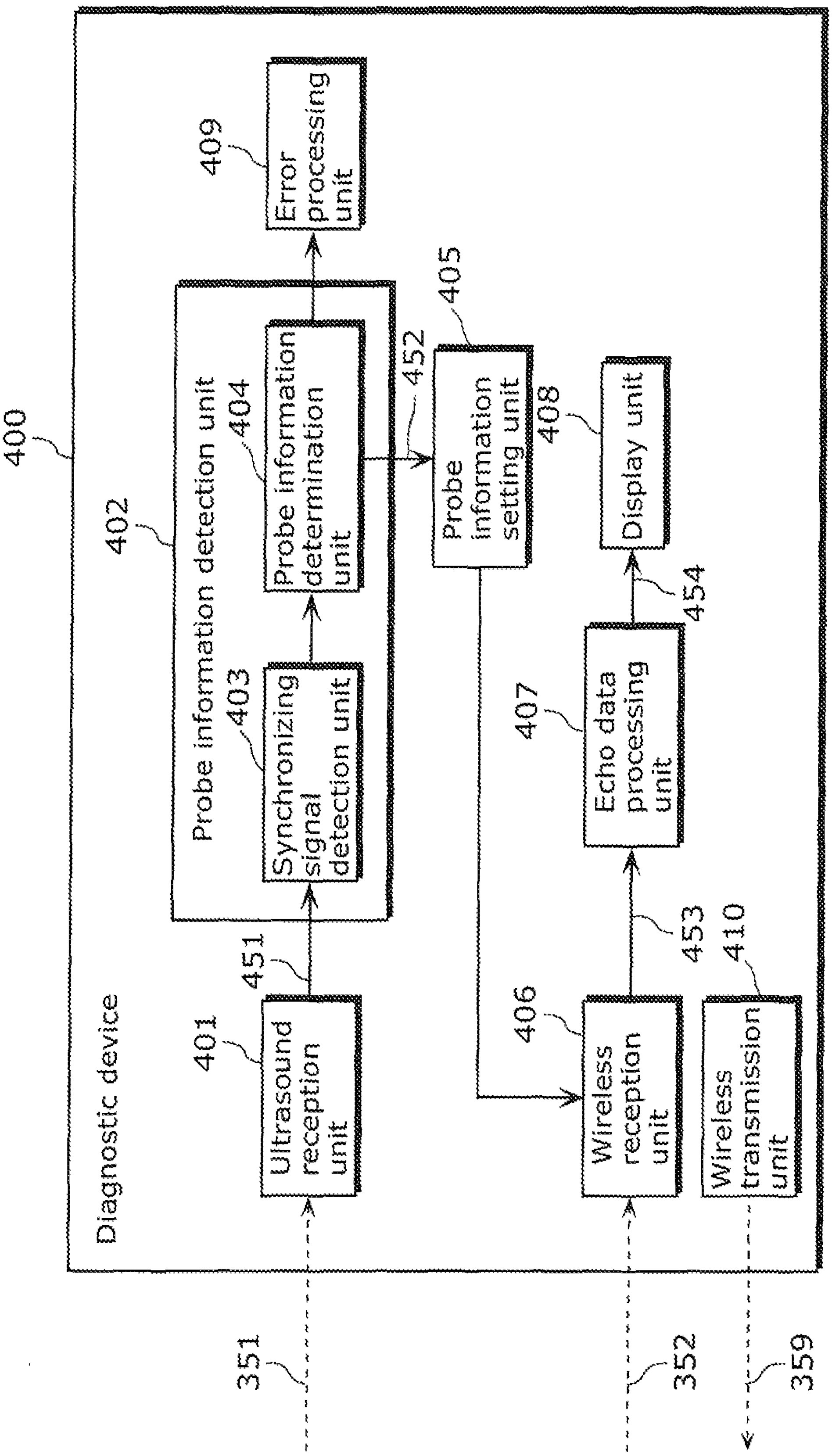

400
Diagnostic device
401
Ultrasound reception unit
451
402
Probe information detection unit
403
Synchronizing signal detection unit
404
Probe information determination unit
409
Error processing unit
452
405
Probe information setting unit
408
Display unit
454
407
Echo data processing unit
453
406
Wireless reception unit
410
Wireless transmission unit
351
352
359

FIG. 8

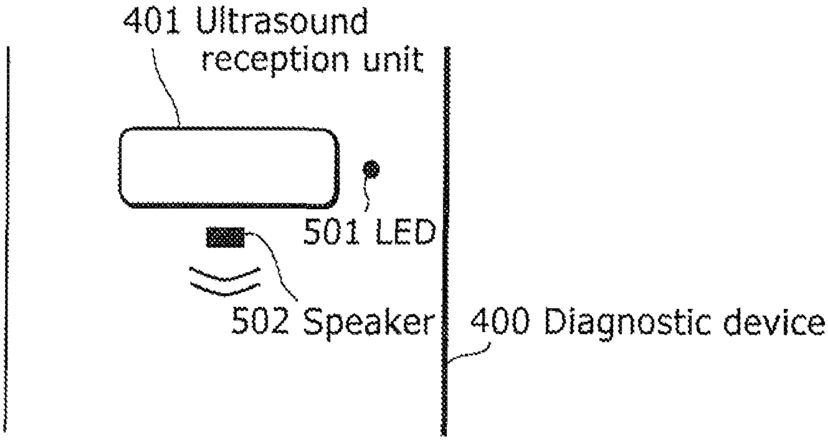

401 Ultrasound reception unit
501 LED
502 Speaker
400 Diagnostic device

FIG. 9

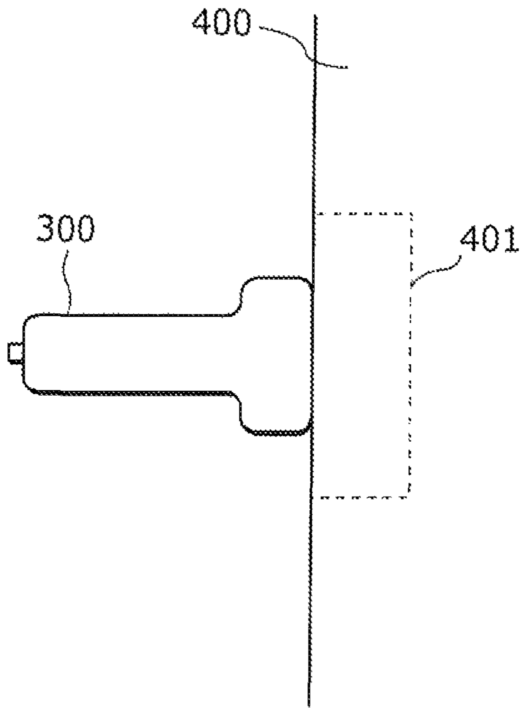

400
300
401

FIG. 10

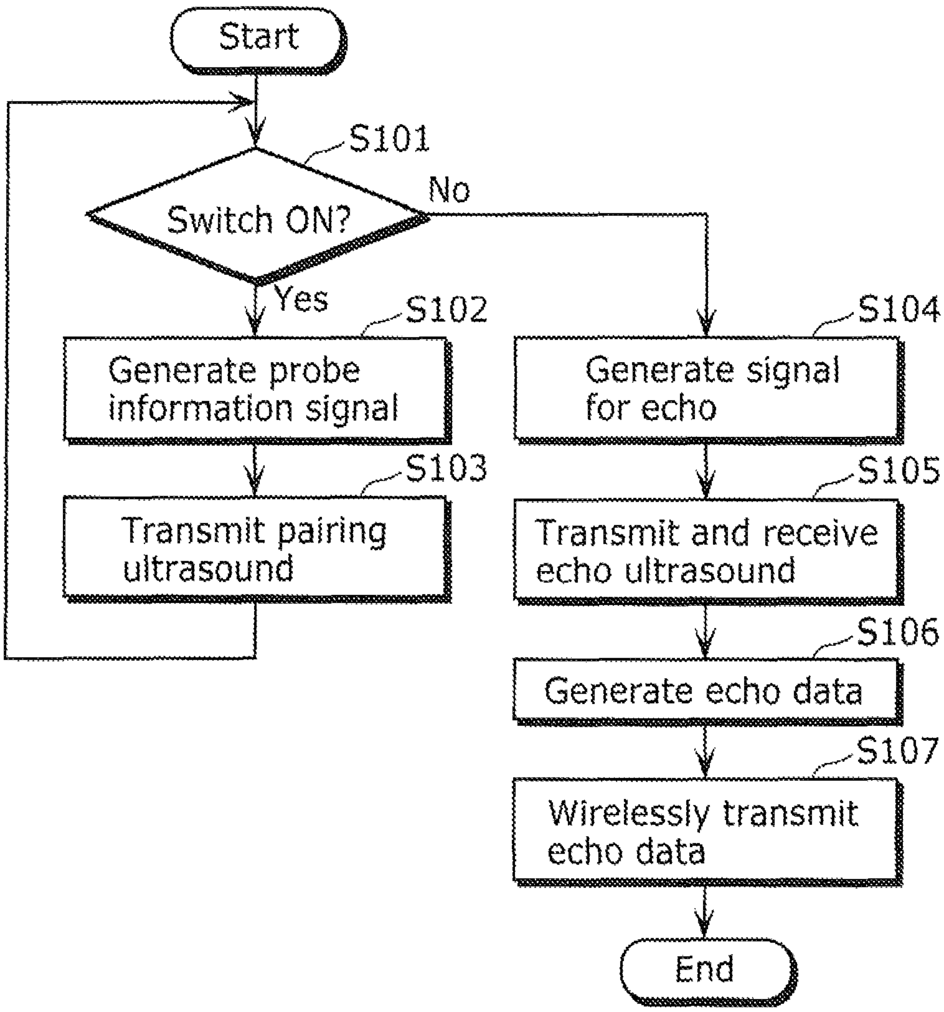

Start
S101
Switch ON?
No
Yes
S102
Generate probe information signal
S103
Transmit pairing ultrasound
S104
Generate signal for echo
S105
Transmit and receive echo ultrasound
S106
Generate echo data
S107
Wirelessly transmit echo data
End

FIG. 11

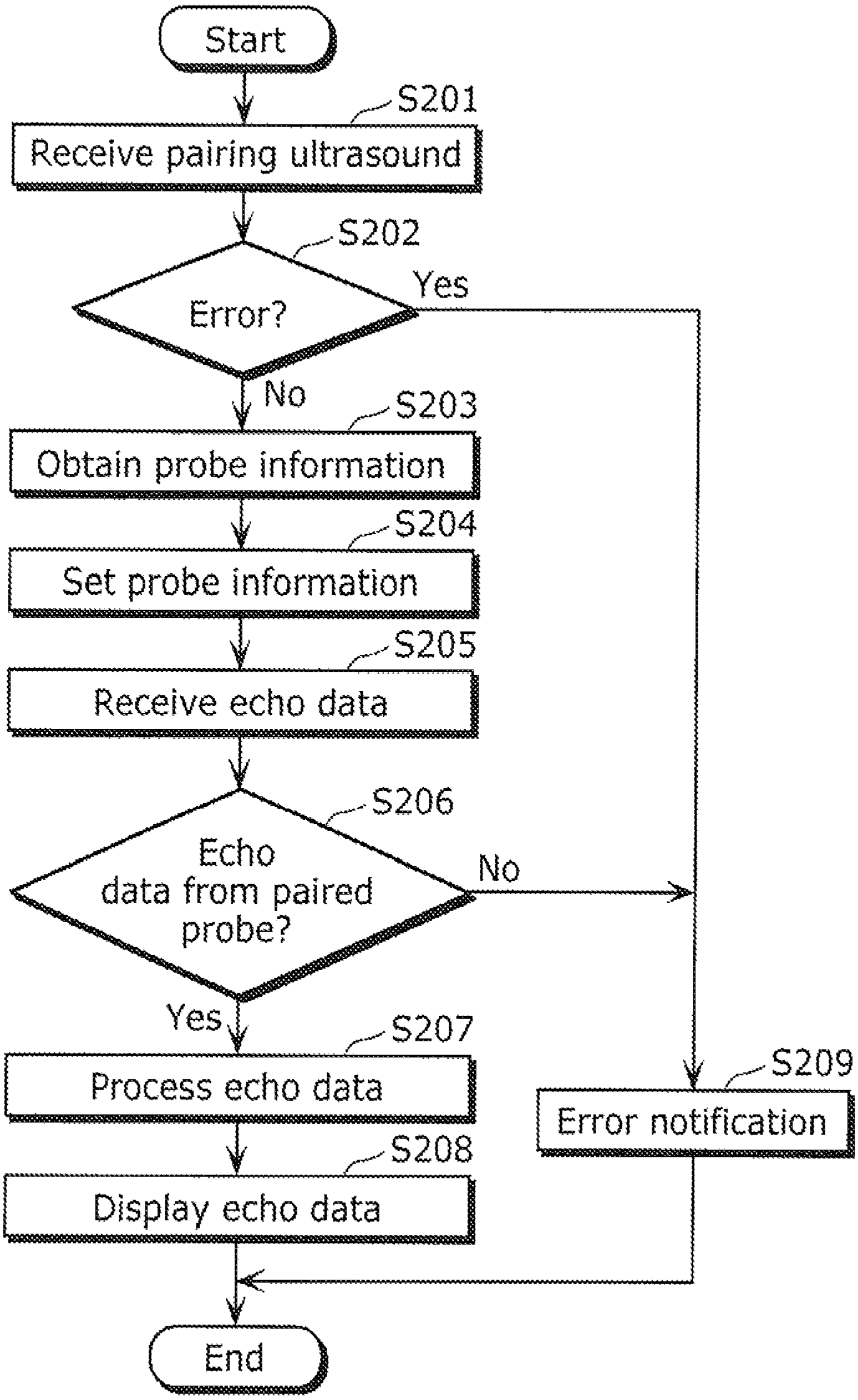

Start
S201
Receive pairing ultrasound
S202
Error?
Yes
No
S203
Obtain probe information
S204
Set probe information
S205
Receive echo data
S206
Echo data from paired probe?
No
Yes
S207
Process echo data
S208
Display echo data
S209
Error notification
End

FIG. 12

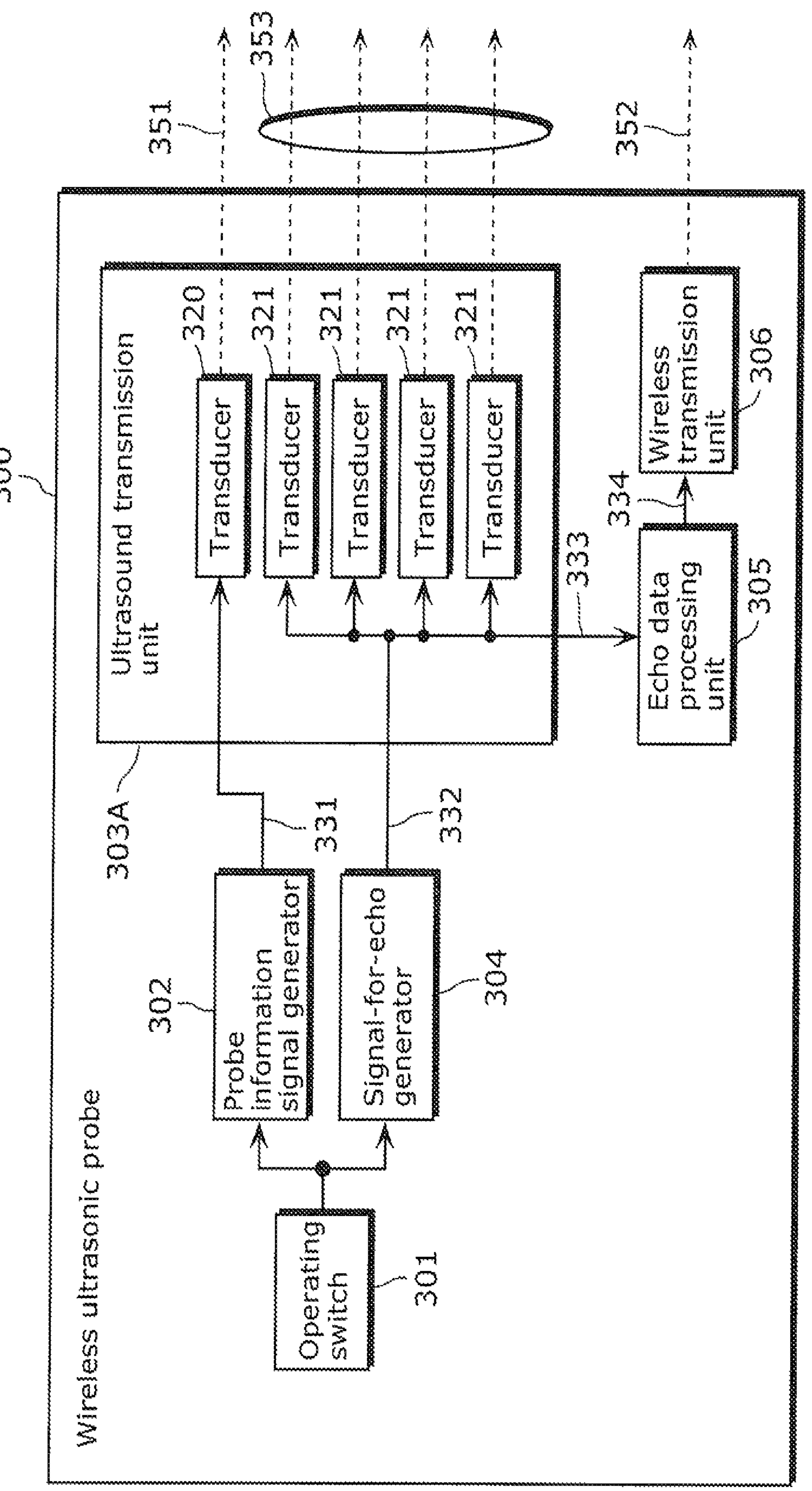
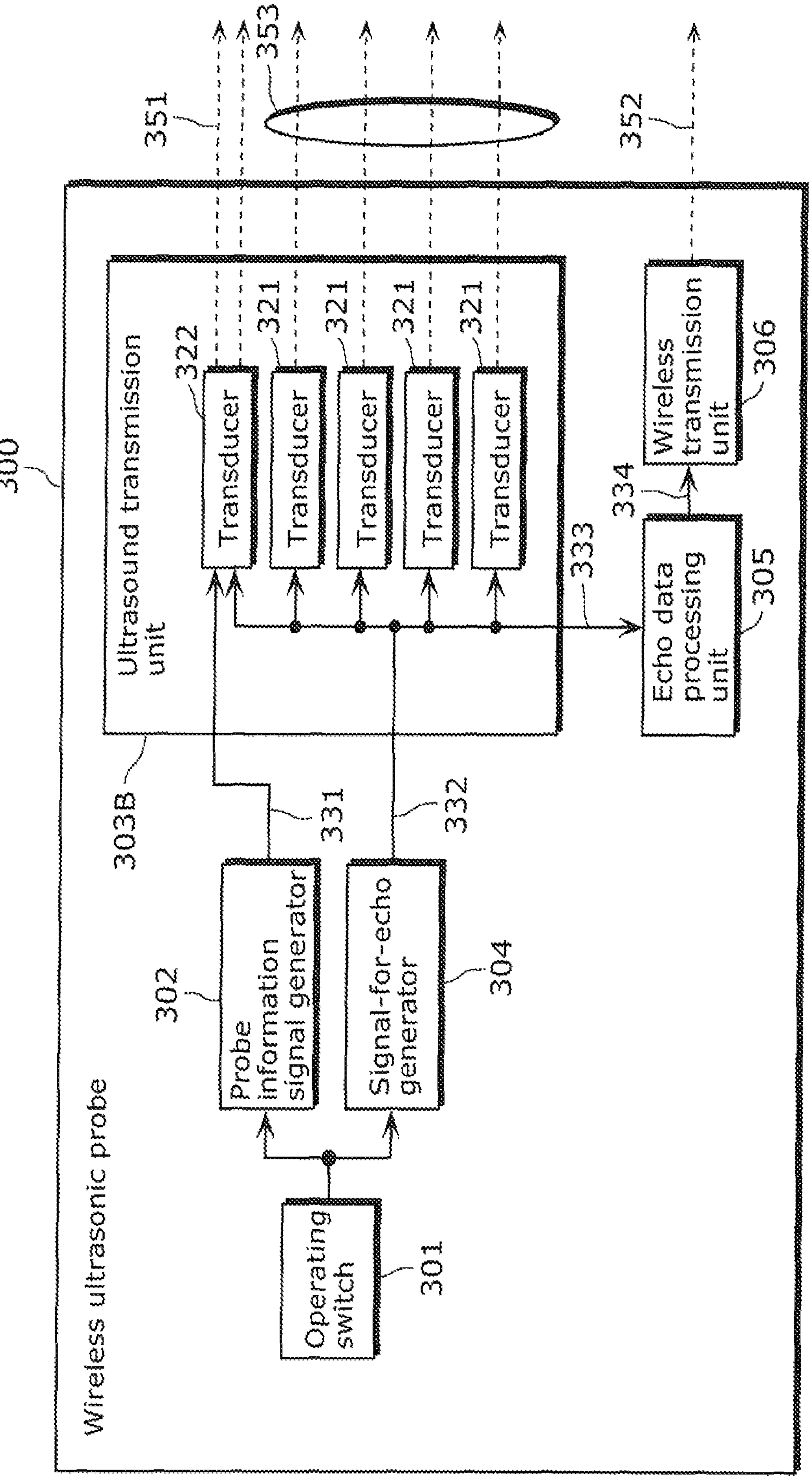

Wireless ultrasonic probe
300
Operating switch
301
Probe information signal generator
302
Signal-for-echo generator
304
331
332
Ultrasound transmission unit
303A
Transducer
320
Transducer
321
Transducer
321
Transducer
321
Transducer
321
333
Echo data processing unit
305
334
Wireless transmission unit
306
351
352
353

FIG. 13



300
Wireless ultrasonic probe
Operating switch
301
Probe information signal generator
302
Signal-for-echo generator
304
331
332
303B
Ultrasound transmission unit
Transducer
322
321
333
Echo data processing unit
305
334
Wireless transmission unit
306
351
352
353

FIG. 14

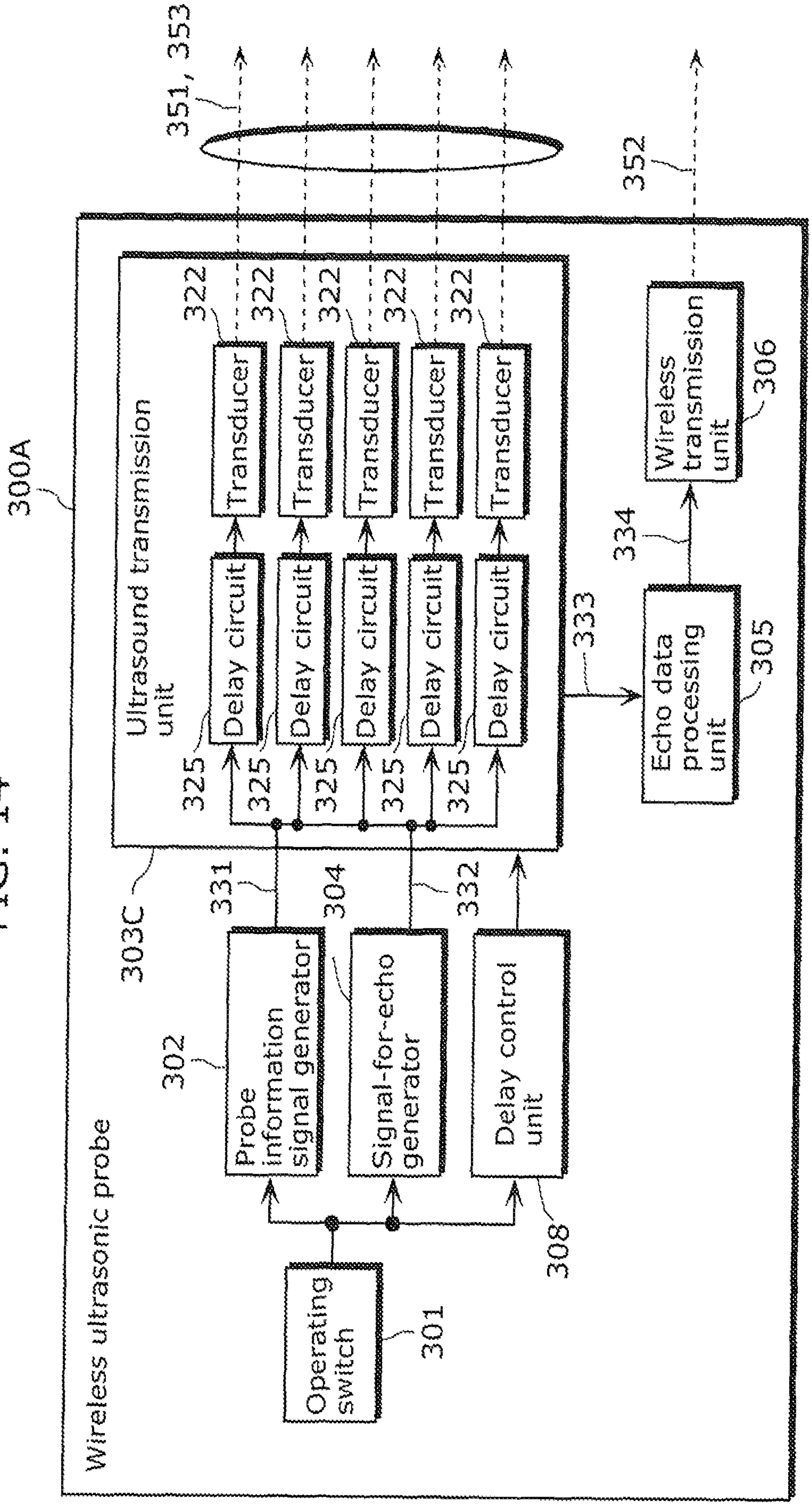

351, 353
352
300A
Wireless ultrasonic probe
Ultrasound transmission unit
Transducer
Transducer
Transducer
Transducer
Transducer
322
322
322
322
322
Delay circuit
Delay circuit
Delay circuit
Delay circuit
Delay circuit
325
325
325
325
325
333
334
Wireless transmission unit
306
Echo data processing unit
305
303C
331
304
332
Probe information signal generator
302
Signal-for-echo generator
Delay control unit
308
Operating switch
301

FIG. 15

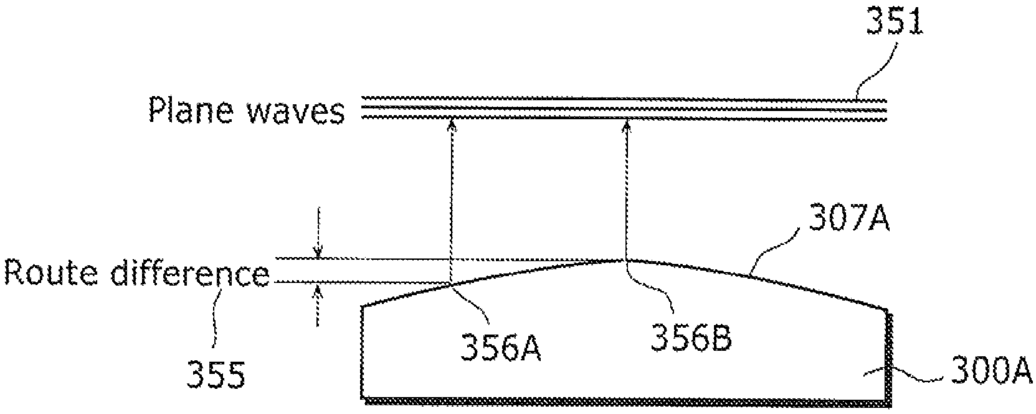

351
Plane waves
307A
Route difference
356A
356B
300A
355

FIG. 16

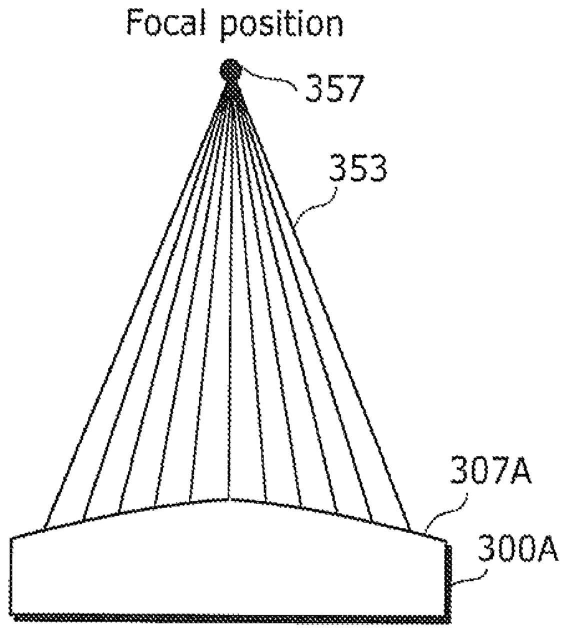

Focal position
357
353
307A
300A

FIG. 17

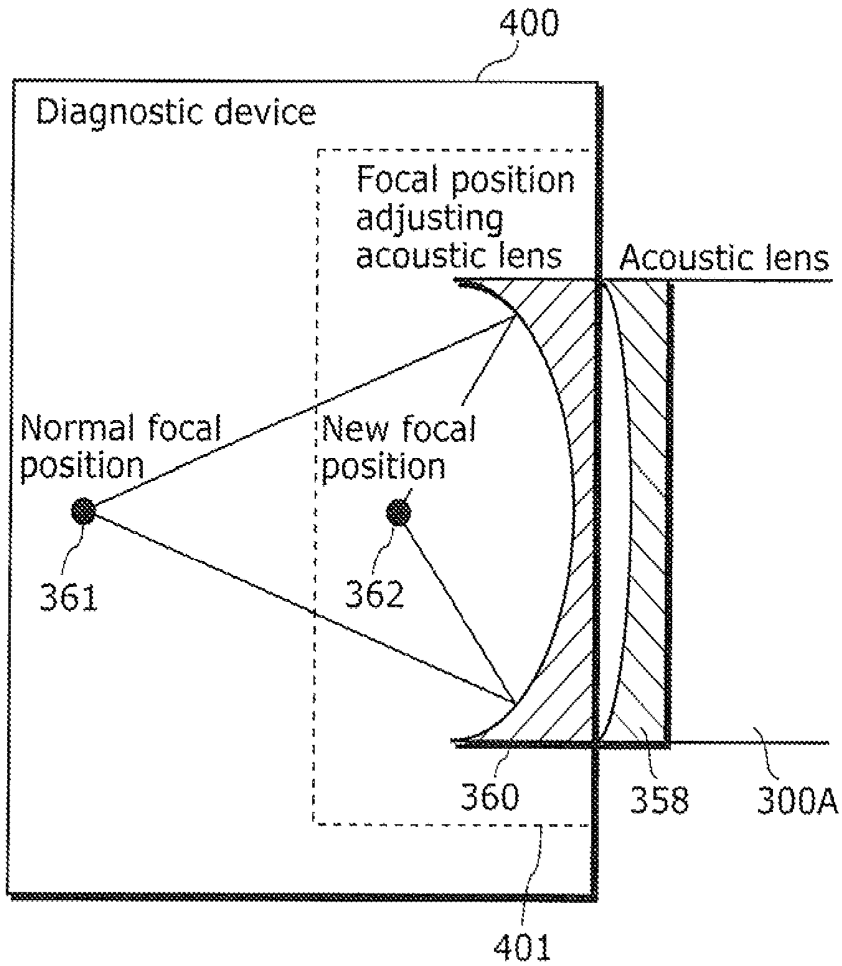

400
Diagnostic device
Focal position adjusting acoustic lens
Acoustic lens
Normal focal position
New focal position
361
362
360
358
300A
401

FIG. 18

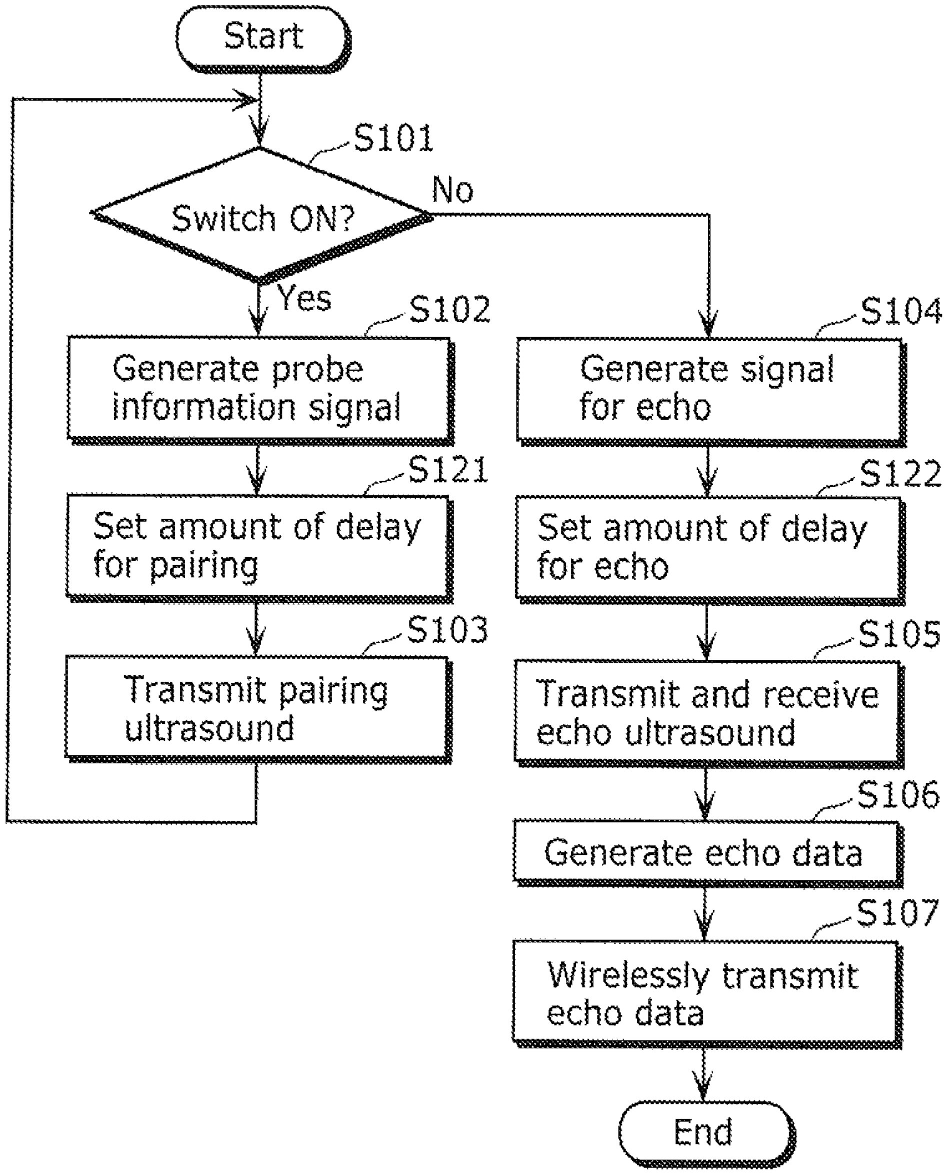
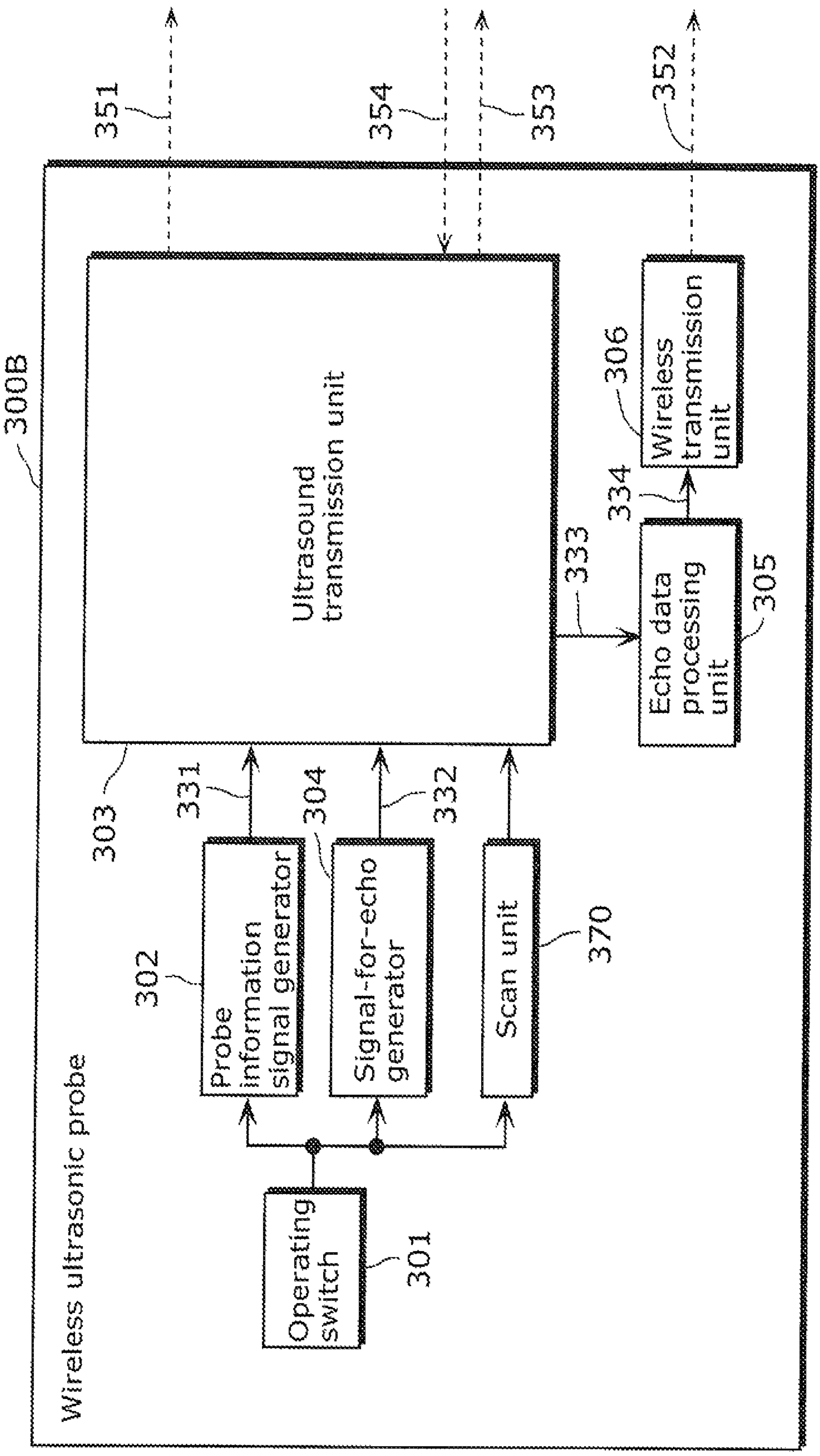

Start
S101
Switch ON?
No
Yes
S102
Generate probe information signal
S121
Set amount of delay for pairing
S103
Transmit pairing ultrasound
S104
Generate signal for echo
S122
Set amount of delay for echo
S105
Transmit and receive echo ultrasound
S106
Generate echo data
S107
Wirelessly transmit echo data
End

FIG. 19



Wireless ultrasonic probe
300B
Ultrasound transmission unit
303
Probe information signal generator
302
Signal-for-echo generator
304
Scan unit
370
Operating switch
301
Echo data processing unit
305
Wireless transmission unit
306
331
332
333
334
351
352
353
354

FIG. 20

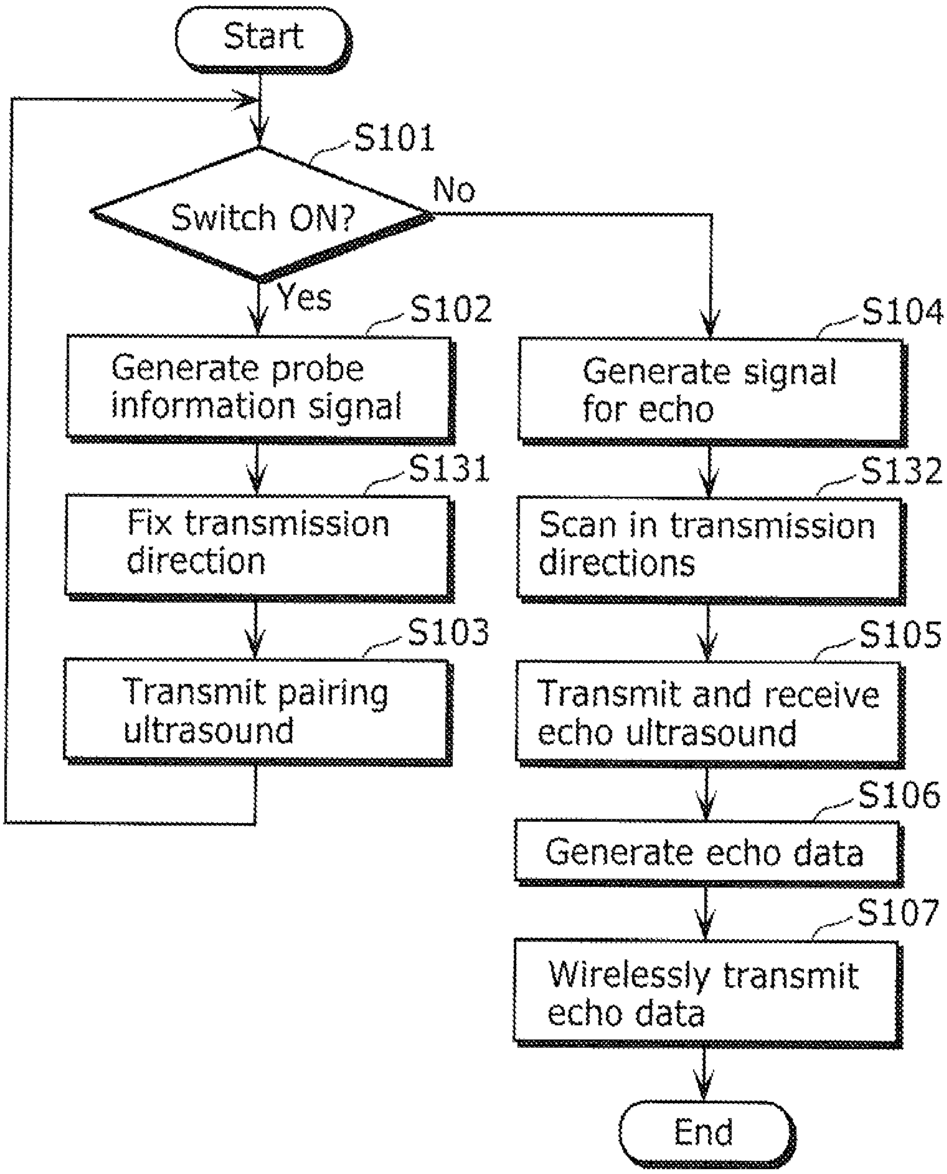
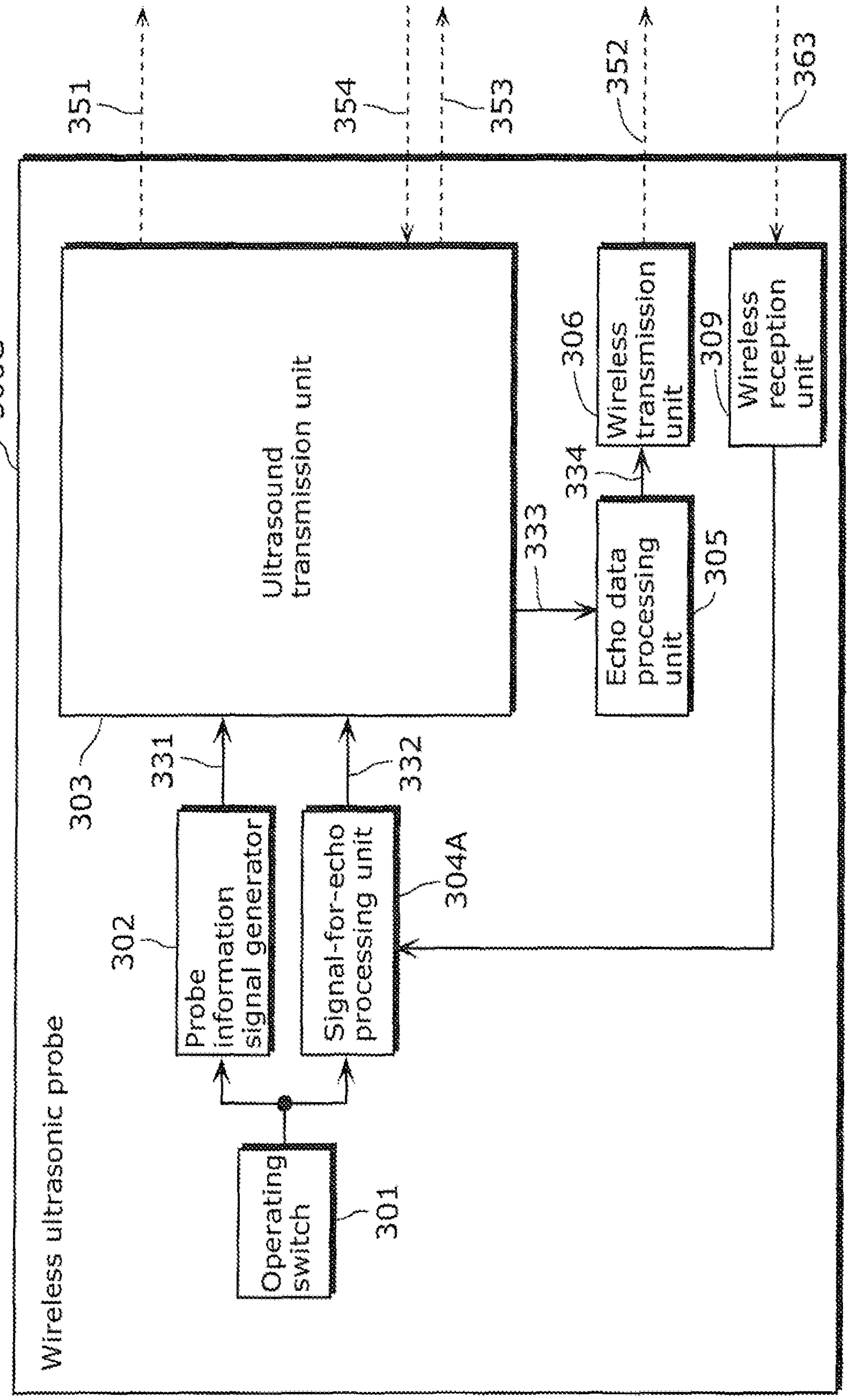

Start
S101
Switch ON?
No
Yes
S102
Generate probe information signal
S131
Fix transmission direction
S103
Transmit pairing ultrasound
S104
Generate signal for echo
S132
Scan in transmission directions
S105
Transmit and receive echo ultrasound
S106
Generate echo data
S107
Wirelessly transmit echo data
End

FIG. 21


300C
Wireless ultrasonic probe
Operating switch
301
Probe information signal generator
302
Signal-for-echo processing unit
304A
331
332
Ultrasound transmission unit
303
333
Echo data processing unit
305
334
Wireless transmission unit
306
Wireless reception unit
309
351
354
353
352
363

WIRELESS ULTRASONIC DIAGNOSTIC APPARATUS, WIRELESS ULTRASONIC PROBE, AND PROBE AUTHENTICATION METHOD

TECHNICAL FIELD

The present invention relates to wireless ultrasonic diagnostic apparatuses, wireless ultrasonic probes, and probe authentication methods, and relates particularly to a wireless ultrasonic diagnostic apparatus that includes a wireless ultrasonic probe which wirelessly transmits echo data and a diagnostic device which receives the echo data wirelessly transmitted by the wireless ultrasonic probe.

BACKGROUND ART

Some of conventional wireless ultrasonic diagnostic apparatuses wirelessly transmit echo data obtained by an ultrasonic probe to the main device (see Patent Literature 1, for example).

FIG. **1** shows a structure of a conventional wireless ultrasonic diagnostic apparatus **10** disclosed in Patent Literature 1. A scrambler **112** shown in FIG. **1** scrambles echo data using either unique data identifying a main device **200** or unique data identifying an ultrasonic probe **100**. More specifically, the scrambler **112** scrambles serial data provided by a PS conversion unit **110**, using either a code signal provided by a code signal generator **114** for identifying the main device **200** or a code signal provided by the code signal generator **114** for identifying the ultrasonic probe **100**. Then, the scrambler **112** provides the scrambled data to a modulator **116**.

CITATION LIST

Patent Literature

[PTL 1] Japanese Unexamined Patent Application Publication No. 2007-244579

SUMMARY OF INVENTION

Technical Problem

The conventional structure disclosed in Patent Literature 1 enables identification of a specific diagnostic device and a specific wireless ultrasonic probe in one-to-one correspondence using a code signal. However, in some cases, the probe is used with more than one diagnostic device. Thus, if the code signal of the wireless ultrasonic probe corresponds to more than one diagnostic device, plural diagnostic devices respond to one wireless ultrasonic probe. This results in interference.

That is to say, the conventional structure disclosed in Patent Literature 1 does not mention how a plurality of wireless ultrasonic probes are to be concurrently used.

The present invention, conceived to solve the above conventional problem, aims to provide a wireless ultrasonic diagnostic apparatus capable of easily and reliably establishing wireless communication between a diagnostic device and a wireless ultrasonic probe in the case of concurrently using a plurality of wireless ultrasonic probes.

Solution to Problem

In order to solve the conventional problem, the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention is a wireless ultrasonic diagnostic apparatus including: a wireless ultrasonic probe which generates echo data and wirelessly transmits the echo data; and a diagnostic device which receives the echo data wirelessly transmitted by the wireless ultrasonic probe, the wireless ultrasonic probe including: a first signal generator which generates a first signal including probe information for identifying the wireless ultrasonic probe; an ultrasound transmission unit configured to transmit the first signal as first ultrasound; and a wireless transmission unit configured to wirelessly transmit the echo data associated with the probe information, and the diagnostic device including: an ultrasound reception unit configured to receive the first ultrasound transmitted by the wireless ultrasonic probe; a probe information detection unit configured to detect the probe information from the first ultrasound received; and a wireless reception unit configured to receive data that is wirelessly transmitted, and determine, using the probe information detected by the probe information detection unit, whether or not the received data is the echo data wirelessly transmitted by the wireless ultrasonic probe.

With this structure, the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention performs processing (hereinafter referred to as "pairing") to establish wireless communication between the diagnostic device and the wireless ultrasonic probe. Here, the ultrasound does not reach a long distance. Therefore, the wireless ultrasonic probe can transmit the first ultrasound to only the desired diagnostic device even when there is a plurality of diagnostic devices. This enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to easily and reliably establish wireless communication between the diagnostic device and the wireless ultrasonic probe.

In addition, the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention uses, for the purpose of pairing, the ultrasound used for diagnosis, thereby suppressing an increase in cost necessary for adding the above functions.

Furthermore, the wireless ultrasonic probe may further include an operating switch operable by an operator, and when the operating switch is pressed, the first signal generator may generate the first signal, and the ultrasound transmission unit may transmit the first signal as the first ultrasound.

With this structure of the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention, the operator can perform the pairing through a simple operation of pressing the operating switch provided on the wireless ultrasonic probe.

In addition, the first signal generator may generate the first signal including a synchronizing signal, and the probe information detection unit may be configured to detect the probe information from the first ultrasound by detecting the synchronizing signal included in the first ultrasound received.

This structure enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to easily detect the probe information included in the first ultrasound.

Moreover, the ultrasound transmission unit may be further configured to emit second ultrasound for generating the echo data.

Furthermore, the ultrasound transmission unit may include: a first transducer which transmits the first ultrasound according to the first signal; and a second transducer which emits the second ultrasound, the second transducer being different from the first transducer.

With this structure, the frequency of the first transducer can differ from that of the second transducer. Thus, the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention can set an optimal frequency for the first ultrasound.

Furthermore, the first transducer may have a transmission frequency lower than a transmission frequency of the second transducer.

This structure enables the diagnostic device to receive the first ultrasound transmitted from the wireless ultrasonic probe, even when the diagnostic device and the wireless ultrasonic probe are distant from each other.

In addition, the ultrasound transmission unit may include a transducer which transmits the first ultrasound according to the first signal and emits the second ultrasound.

This structure enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to suppress an increase in cost by using the same transducer for both the transmission of the first ultrasound and the transmission and reception of the second ultrasound.

Moreover, the ultrasound transmission unit may include a plurality of transducers which synchronously transmit the first ultrasound according to the first signal.

This structure increases the signal level of the first ultrasound transmitted from the wireless ultrasonic probe, thereby increasing the possibility of successful communication between the wireless ultrasonic probe and the diagnostic device even when the wireless ultrasonic probe and the diagnostic device are distant from each other.

Furthermore, the ultrasound transmission unit may include a delay circuit which delays, according to a shape of a surface of the wireless ultrasonic probe from which the first ultrasound is emitted, the first signal provided to the transducers so that the first ultrasound synchronously transmitted by the transducers becomes plane waves.

This structure enables the wireless ultrasonic probe according to an aspect of the present invention to transmit data without data turbulence even in the case of using a probe having a curved emitting surface, such as a convex wireless ultrasonic probe.

Moreover, the wireless ultrasonic probe may further include a second signal generator which generates a second signal, the transducers may generate the second ultrasound according to the second signal, and the delay circuit may further delay the second signal to adjust a focal position of the second ultrasound, and provide the delayed second signal to the transducers.

This structure enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to enhance the communication quality while suppressing an increase in cost.

In addition, the wireless ultrasonic probe may include a scan unit configured to perform, when the ultrasound transmission unit emits the second ultrasound, sector scanning in directions in which the second ultrasound is emitted, and when the ultrasound transmission unit emits the first ultrasound, the scan unit may fix a direction in which the first ultrasound is emitted.

This structure enables a sector-scanning wireless ultrasonic probe to reliably perform the pairing.

The ultrasound reception unit may have an acoustic impedance in a range of 1.5 to 2.0 inclusive.

This structure enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to receive the first ultrasound with high sensitivity.

Furthermore, the ultrasound reception unit may include an acoustic lens which adjusts a focal position of the first ultrasound.

This structure enables the wireless ultrasonic diagnostic apparatus according to an aspect of the present invention to receive the first ultrasound with high sensitivity.

Moreover, the diagnostic device may include an error processing unit configured to notify an operator of error occurrence when an error occurs with the probe information transmitted by the wireless ultrasonic probe.

This structure allows the operator to easily recognize a failure in connection between the wireless ultrasonic probe and the diagnostic device.

The error processing unit may be configured to notify the operator of the error occurrence by causing an LED to flash or by changing a color of the LED.

This structure allows the operator to recognize a connection error more quickly.

Furthermore, the error processing unit may be configured to notify the operator of the error occurrence by beeping.

This structure allows the operator to recognize a connection error by a sound, enabling a more quick recognition of the connection error.

Note that the present invention can be realized not only as the above wireless ultrasonic diagnostic apparatus, but also as: a probe authentication method which includes, as steps, the characteristic elements included in the wireless ultrasonic diagnostic apparatus; and a program which causes a computer to execute such characteristic steps. It is apparent that such a program can be distributed via a recording medium such as a CD-ROM and a transmission medium such as the Internet.

In addition, the present invention may also be realized as a wireless ultrasonic probe or a diagnostic device included in the wireless ultrasonic diagnostic apparatus.

Furthermore, the present invention can also be realized as a semiconductor integrated circuit (LSI) which achieves some or all of the functions of the wireless ultrasonic diagnostic apparatus.

Advantageous Effects of Invention

The present invention provides a wireless ultrasonic diagnostic apparatus capable of easily and reliably establishing wireless communication between a diagnostic device and a wireless ultrasonic probe in the case of concurrently using a plurality of wireless ultrasonic probes.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram of a conventional wireless ultrasonic diagnostic apparatus.

FIG. **2** is a block diagram of a wireless ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention.

FIG. **3** is a block diagram of a wireless ultrasonic probe according to Embodiment 1 of the present invention.

FIG. **4** is an external view of a wireless ultrasonic probe according to Embodiment 1 of the present invention.

FIG. **5** shows a structural example of pairing ultrasound according to Embodiment 1 of the present invention.

FIG. **6** shows a data example of pairing ultrasound according to Embodiment 1 of the present invention.

FIG. **7** is a block diagram of a diagnostic device according to Embodiment 1 of the present invention.

FIG. **8** is an external view of a diagnostic device according to Embodiment 1 of the present invention.

FIG. **9** shows pairing performed in a wireless ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention.

FIG. **10** is a flowchart showing a processing flow of a wireless ultrasonic probe according to Embodiment 1 of the present invention.

FIG. **11** is a flowchart showing a processing flow of a diagnostic device according to Embodiment 1 of the present invention.

FIG. **12** shows a structure of an ultrasound transmission unit according to Embodiment 1 of the present invention.

FIG. **13** shows a structure of an ultrasound transmission unit according to Embodiment 1 of the present invention.

FIG. **14** is a block diagram of a wireless ultrasonic probe according to Embodiment 2 of the present invention.

FIG. **15** shows pairing ultrasound according to Embodiment 2 of the present invention.

FIG. **16** shows echo ultrasound according to Embodiment 2 of the present invention.

FIG. **17** shows a structure of an ultrasound reception unit according to Embodiment 2 of the present invention.

FIG. **18** is a flowchart showing a processing flow of a wireless ultrasonic probe according to Embodiment 2 of the present invention.

FIG. **19** is a block diagram of a wireless ultrasonic probe according to Embodiment 3 of the present invention.

FIG. **20** is a flowchart showing a processing flow of a wireless ultrasonic probe according to Embodiment 3 of the present invention.

FIG. **21** is a block diagram of a wireless ultrasonic probe according to a variation of the present invention.

DESCRIPTION OF EMBODIMENTS

Hereinafter, Embodiment 1 of the present invention is described with reference to the drawings.

Embodiment 1

The wireless ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention pairs a wireless ultrasonic probe with a diagnostic device using ultrasound. By doing so, the wireless ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention can easily and reliably establish wireless communication between the wireless ultrasonic probe and the diagnostic device.

First, an overall structure of the wireless ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention is described.

FIG. **2** is a block diagram of a wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention. The wireless ultrasonic diagnostic apparatus **30** shown in FIG. **2** includes a wireless ultrasonic probe **300** and a diagnostic device **400**.

The wireless ultrasonic probe **300** shown in FIG. **2** wirelessly transmits echo data **352** to the diagnostic device **400**. The wireless ultrasonic probe **300** includes: a wireless transmission unit **306** which wirelessly transmits the echo data **352**; a probe information signal generator **302** (a first signal generator) which generates a probe information signal including probe information for identifying the wireless ultrasonic probe **300**; and an ultrasound transmission unit **303** which transmits the probe information signal as pairing ultrasound **351** (first ultrasound).

The diagnostic device **400** shown in FIG. **2** receives the echo data **352** wirelessly transmitted by the wireless ultrasonic probe **300**. The diagnostic device **400** includes: an ultrasound reception unit **401** which receives the pairing ultrasound **351** transmitted by the wireless ultrasonic probe **300**; a probe information detection unit **402** which detects the probe information from the pairing ultrasound **351**; and a wireless reception unit **406** which identifies, using the probe information detected by the probe information detection unit **402**, the echo data **352** wirelessly transmitted from the wireless ultrasonic probe **300**.

Hereinafter, a structure of the wireless ultrasonic probe **300** is described in detail.

FIG. **3** is a block diagram showing a detailed structure of the wireless ultrasonic probe **300**.

The wireless ultrasonic probe **300** transmits echo ultrasound **353** (second ultrasound) to a subject (a patient, for example), and receives reflected waves **354** (echo) which are the echo ultrasound **353** reflected from the subject. Furthermore, the wireless ultrasonic probe **300** wirelessly transmits, to the diagnostic device **400**, the echo data **352** which is based on the reflected waves **354** received.

The wireless ultrasonic probe **300** shown in FIG. **3** includes an operating switch **301** operable by an operator, the probe information signal generator **302**, the ultrasound transmission unit **303**, a signal-for-echo generator **304** (a second signal generator), an echo data processing unit **305**, the wireless transmission unit **306**, and a wireless reception unit **309**.

FIG. **4** is an external view of the wireless ultrasonic probe **300**.

The operating switch **301** is a button, for example. When the operator presses the button, the pairing ultrasound **351** which is low in power is output from the wireless ultrasonic probe **300**, and the pairing of the wireless ultrasonic probe **300** with the diagnostic device **400** starts.

The button of the operating switch **301** is desirably provided at a position out of the way of diagnosis. For example, as shown in FIG. **4**, the button may be provided on a side opposite to an emitting surface **307** from which the pairing ultrasound **351** and the echo ultrasound **353** are emitted.

When the operating switch **301** is pressed, the probe information signal generator **302** generates a probe information signal **331** including the probe information for identifying the wireless ultrasonic probe **300**.

The ultrasound transmission unit **303** transmits the probe information signal **331** as the pairing ultrasound **351**.

FIG. **5** shows a structural example of the probe information signal **331** (the pairing ultrasound **351**).

As shown in FIG. **5**, the probe information signal **331** includes a header portion **602** which is a synchronizing signal and a data portion **603** which is the probe information.

The header portion **602** is added so that the starting point of the data portion **603** can be searched. A data sequence not used in the data portion **603** (0xF in FIG. **5**) is used in the header portion **602**, so that the header can be distinguished.

The data portion **603** indicates, for example, at least one of information on the shape of the wireless ultrasonic probe **300**, information on the compatible frequency band of the wireless ultrasonic probe **300**, and information on the individual number of the wireless ultrasonic probe **300**.

FIG. **6** shows an example of the data portion **603**. FIG. **6** shows a case where the data portion **603** indicates the shape of the wireless ultrasonic probe **300**.

More specifically, in FIG. **5**, the data portion **603** following the header portion **602** indicates 0xA. The shape of the wireless ultrasonic probe corresponding to 0xA is sector, and thus the diagnostic device **400** recognizes that the wireless ultrasonic probe **300** to be connected with is of a sector type. Furthermore, by transmitting the individual number of the wireless ultrasonic probe **300**, it is possible to make settings on a probe-by-probe basis even if there is more than one wireless ultrasonic probe of the same type (the sector type, for example).

While the operating switch **301** is pressed, the probe information signal generator **302** continuously outputs data signals **601** each of which includes one header portion **602** and one data portion **603** as shown in FIG. **5**.

When the pairing is established, the operator releases the operating switch **301** to stop the output of the pairing ultrasound **351**. With such a structure by which the output of the pairing ultrasound **351** is automatically stopped when the operator releases the operating switch **301**, it is possible to prevent the operating switch **301** from remaining on.

The pairing ultrasound **351** may be output when the operating switch **301** is pressed once, and stopped when the operating switch **301** is pressed once more. In that case, it is desirable to stop the pairing ultrasound **351** after a certain period of time (after the data signal **601** is output a certain number of times).

The signal-for-echo generator **304** generates a signal for echo **332** while the operating switch **301** is not pressed.

The ultrasound transmission unit **303** transmits the probe information signal **331** as the pairing ultrasound **351**, and transmits the signal for echo **332** as the echo ultrasound **353**. For example, the frequencies of the pairing ultrasound **351** and the echo ultrasound **353** are in a range of 1 M to 20 MHz inclusive.

The ultrasound transmission unit **303** receives the reflected waves **354** that are the echo ultrasound **353** reflected from the subject, and outputs the reflected waves **354** as an echo signal **333**.

The echo data processing unit **305** first performs processing such as signal amplification and A/D conversion on the echo signal **333**, and then associates the resultant signal with the probe information so as to generate echo data **334**. For example, the echo data processing unit **305** generates the echo data **334** by adding to the echo signal **333** identification information corresponding to the probe information. Note that the echo data processing unit **305** may generate the echo data **334** by scrambling and compressing the echo signal **333** using a predetermined code corresponding to the probe information.

The wireless transmission unit **306** performs such processing as modulation and power amplification on the echo data **334**, and wirelessly transmits the resultant data as the echo data **352**. The frequency used for the wireless transmission of the echo data **352** is several GHz, for example.

The wireless reception unit **309** receives a control signal **359** wirelessly transmitted by the diagnostic device **400**. According to the control signal **359** received by the wireless reception unit **309**, the signal-for-echo generator **304** changes the signal for echo **332** to be generated.

Next, a detailed structure of the diagnostic device **400** is described.

FIG. **7** is a block diagram showing the detailed structure of the diagnostic device **400**.

The diagnostic device **400** includes the ultrasound reception unit **401**, the probe information detection unit **402**, a probe information setting unit **405**, the wireless reception unit **406**, an echo data processing unit **407**, a display unit **408**, an error processing unit **409**, and a wireless transmission unit **410**. The probe information detection unit **402** includes a synchronizing signal detection unit **403** and a probe information determination unit **404**.

The ultrasound reception unit **401** receives the pairing ultrasound **351** transmitted by the wireless ultrasonic probe **300**, and outputs the pairing ultrasound **351** as a probe information signal **451**.

FIG. **8** is an external view of the diagnostic device **400**. As shown in FIG. **8**, the diagnostic device **400** includes an LED **501** and a speaker **502**.

Here, to perform the pairing, the operator presses the operating switch **301** while allowing the wireless ultrasonic probe **300** to contact the ultrasound reception unit **401** provided in the diagnostic device **400** as shown in FIG. **9**. With this, the ultrasound reception unit **401** receives the pairing ultrasound **351** transmitted by the wireless ultrasonic probe **300**.

The acoustic impedance of the ultrasound reception unit **401** is desirably similar to that of the body, water, or a gel applied to the tested area at the time of echo diagnosis. For example, the acoustic impedance of the ultrasound reception unit **401** is preferably in a range of 1 to 10 inclusive, more preferably in a range of 1.5 to 2.0 inclusive.

This reduces the difference between the acoustic impedance of the wireless ultrasonic probe **300** and that of the ultrasound reception unit **401**, allowing the ultrasound reception unit **401** to reliably receive the pairing ultrasound **351** transmitted from the wireless ultrasonic probe **300**.

The synchronizing signal detection unit **403** detects the synchronizing signal (the header portion **602**) included in the probe information signal **451**.

The probe information determination unit **404** obtains, based on the synchronizing signal detected by the synchronizing signal detection unit **403**, probe information **452** (the data portion **603**) included in the probe information signal **451**. Furthermore, the probe information determination unit **404** determines whether or not an error has occurred with the probe information signal **451**.

Based on the probe information **452** obtained by the probe information determination unit **404**, the probe information setting unit **405** makes settings of the pairing of the wireless ultrasonic probe **300** with the diagnostic device **400**, so as to enable identification of the echo data **352** transmitted from the wireless ultrasonic probe **300**.

Based on the probe information **452** obtained by the probe information determination unit **404**, the probe information setting unit **405** also makes settings of the operations of the wireless ultrasonic probe **300** and the diagnostic device **400**. With this, connection is established between the wireless ultrasonic probe **300** and the diagnostic device **400**, and the settings of the wireless ultrasonic probe **300** and the diagnostic device **400** are completed.

Note that when the connection is established, the diagnostic device **400** may notify the operator of the establishment of the connection by changing the color of the LED **501** (from red to blue, for instance). When the connection is established, the diagnostic device **400** may also notify the operator of the establishment of the connection by lighting up the LED **501**, for example. Furthermore, the diagnostic device **400** may also notify the operator of the establishment of the connection by emitting, from the speaker **502**, a sound indicating the connection establishment.

When an error has occurred with the probe information signal **451**, the error processing unit **409** notifies the operator of the error occurrence. More specifically, the error processing unit **409** performs the error notification in such cases as where the synchronizing signal (the header portion **602**) is not detected even though the ultrasound signal is detected or where the value of the data portion **603** is outside a specified value range even though the ultrasound signal is detected. In addition, the error processing unit **409** performs the error notification using either the LED **501** or the speaker **502**. For example, the error processing unit **409** either causes the LED **501** to flash or changes the color of the LED **501**. Specifically, the error processing unit **409** may cause the LED **501** to flash in red. Alternatively, the error processing unit **409** may beep through the speaker **502**.

In such a manner, the wireless ultrasonic diagnostic apparatus **30** notifies the operator of the connection establishment and the error occurrence using either the LED **501** or the speaker **502**. This allows the operator to recognize that the pairing has been reliably completed.

Note that the diagnostic device **400** may include both the LED **501** and the speaker **502**, or only one of them.

The wireless reception unit **406** receives the echo data **352** wirelessly transmitted by the wireless ultrasonic probe **300**. Furthermore, the wireless reception unit **406** determines, according to the probe information **452** set by the probe information setting unit **405**, whether or not the received data is the echo data **352** transmitted by the wireless ultrasonic probe **300** corresponding to the probe information **452** set by the probe information setting unit **405**. When the received data is the echo data **352** transmitted by the wireless ultrasonic probe **300** corresponding to the probe information **452** set by the probe information setting unit **405**, the wireless reception unit **406** outputs the echo data **352** as echo data **453**.

For example, when the wireless ultrasonic probe **300** transmits the echo data **352** including identification information corresponding to the probe information of the wireless ultrasonic probe **300**, the wireless reception unit **406** generates the echo data **453** by performing power amplification and demodulation on the echo data **352**. Furthermore, the wireless reception unit **406** extracts identification information included in the echo data **453**. In addition, when the probe information corresponding to the extracted identification information matches the set probe information **452**, the wireless reception unit **406** determines that the echo data **453** is the data transmitted by the paired wireless ultrasonic probe **300**, and outputs the echo data **453** to the subsequently-provided echo data processing unit **407**.

Furthermore, when the wireless ultrasonic probe **300** transmits the echo data **334** generated through the scrambling and the compression using a predetermined code corresponding to the probe information of the wireless ultrasonic probe **300**, the wireless reception unit **406** generates the echo data **453** by performing power amplification and demodulation on the echo data **352** and then performing descrambling and decompression using a predetermined code corresponding to the probe information **452**. In this case, the wireless reception unit **406** can correctly reconstruct only the echo to data **352** transmitted by the paired wireless ultrasonic probe **300**.

The echo data processing unit **407** generates image data **454** from the echo data **453**.

The display unit **408** displays the image data **454**.

The wireless transmission unit **410** wirelessly transmits the control signal **359** for changing the echo ultrasound **353** emitted by the wireless ultrasonic probe **300**.

Next, a flow of the operation of the wireless ultrasonic probe **300** is described.

FIG. **10** is a flowchart showing the flow of the operation of the wireless ultrasonic probe **300**.

As shown in FIG. **10**, when the operating switch **301** is on (Yes in S**101**), the probe information signal generator **302** generates the probe information signal **331** (S**102**).

Next, the ultrasound transmission unit **303** transmits, as the pairing ultrasound **351**, the probe information signal **331** generated by the probe information signal generator **302** (S**103**).

On the other hand, when the operating switch **301** is off (No in S**101**), the signal-for-echo generator **304** generates the signal for echo **332** (S**104**).

Subsequently, the ultrasound transmission unit **303** transmits the signal for echo **332** as the echo ultrasound **353** (S**105**).

Then, the ultrasound transmission unit **303** receives the reflected waves **354** that are the echo ultrasound **353** reflected from the subject, and outputs the reflected waves **354** as the echo signal **333**. Next, the echo data processing unit **305** generates the echo data **334** from the echo signal **333** (S**106**).

Subsequently, the wireless transmission unit **306** wirelessly transmits the echo data **334** as the echo data **352** (S**107**).

Next, a flow of the operation of the diagnostic device **400** is described.

FIG. **11** is a flowchart showing the flow of the operation of the diagnostic device **400**.

As shown in FIG. **11**, first, the ultrasound reception unit **401** receives the pairing ultrasound **351** and outputs the pairing ultrasound **351** as the probe information signal **451** (S**201**).

Then, the probe information detection unit **402** determines whether or not an error has occurred with the probe information signal **451** (S**202**).

When an error has occurred with the probe information signal **451** (Yes in S**202**), the error processing unit **409** notifies the operator of the error occurrence (S**209**).

On the other hand, when no error has occurred with the probe information signal **451** (No in S**202**), the probe information detection unit **402** obtains the probe information **452** included in the probe information signal **451** (S**203**).

Subsequently, according to the probe information **452**, the probe information setting unit **405** makes settings of the pairing of the wireless ultrasonic probe **300** with the diagnostic device **400** (S**204**).

Next, the wireless reception unit **406** receives the echo data **352** wirelessly transmitted from the wireless ultrasonic probe **300**, and generates the echo data **453** from the received echo data **352** (S**205**).

Then, the wireless reception unit **406** determines whether or not the received echo data **352** is the echo data **352** transmitted from the paired wireless ultrasonic probe **300** (S**206**).

When the received echo data **352** is not the echo data **352** transmitted from the paired wireless ultrasonic probe **300** (No in S**206**), the diagnostic device **400** notifies the operator that an error has occurred (S**209**), and terminates the processing.

On the other hand, when the received echo data **352** is the echo data **352** transmitted from the paired wireless ultrasonic probe **300** (Yes in S**206**), the echo data processing unit **407** generates the image data **454** from the echo data **453** (S**207**). Subsequently, the display unit **408** displays the image data **454** (S**208**).

With the above operations, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention pairs the wireless ultrasonic probe **300** with the diagnostic device **400** using ultrasound.

Here, in the case where the pairing is performed through the wireless transmission used for transmitting the echo data **352**, another diagnostic device might receive the pairing signal transmitted from the wireless ultrasonic probe, resulting in recognition by the other diagnostic device in error.

In contrast, the pairing ultrasound **351** output from the wireless ultrasonic probe **300** according to Embodiment 1 of the present invention is low in signal level and thus does not reach the diagnostic device located at distance. This prevents recognition by the other diagnostic device in error.

In such a manner, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention can reliably pair the wireless ultrasonic probe **300** with the diagnostic device **400**.

Another possible approach is to register, in the diagnostic device, information on a plurality of wireless ultrasonic probes in advance, so that the wireless ultrasonic probes can be switched from one to the other through operation on the diagnostic device. When using such a method, it is necessary to make initial settings by, for example, naming each wireless ultrasonic probe, in order to identify a wireless ultrasonic probe for actual use and a wireless ultrasonic probe which is to be selected through the diagnostic device. It is also necessary to put the individual names or the like on the wireless ultrasonic probes, for example, to allow distinction therebetween.

In contrast, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention can enable the diagnostic device **400** to recognize only a pairing-target wireless ultrasonic probe **300** through a simple operation of pressing the operating switch **301** while allowing the pairing-target wireless ultrasonic probe **300** to contact the diagnostic device **400**. In such a manner, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention can easily pair the wireless ultrasonic probe **300** with the diagnostic device **400**. Furthermore, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention is advantageous in that there is no need to perform, in the diagnostic device, the registration and the initial settings that enable the probe identification.

In addition, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 1 of the present invention uses, for the purpose of pairing, the ultrasound used for generating the echo data. This enables the wireless ultrasonic diagnostic apparatus **30** to perform the above-described functions while suppressing an increase in cost.

Hereinafter, structural examples of the ultrasound transmission unit **303** are described.

FIG. **12** shows a structural example of an ultrasound transmission unit **303**A that is an example of the ultrasound transmission unit **303**.

The ultrasound transmission unit **303**A shown in FIG. **12** includes a transducer **320** and a plurality of transducers **321**.

The transducer **320** is used only for the transmission of the pairing ultrasound **351**. The transducers **321** are used only for the transmission and reception (emission) of the echo ultrasound **353**.

Using the transducer **320** dedicated for the generation of the pairing ultrasound **351** incurs an additional cost for the transducer **320**; however, it increases the flexibility of the pairing ultrasound **351**. For example, the frequency of the pairing ultrasound **351** can be set lower than that of the echo ultrasound **353**. That is to say, the transmission frequency of the transducer **320** may be lower than that of the transducers **321**. Here, a lower frequency reduces the amount of attenuation that occurs during propagation through the air. This leads to an increase in the possibility of successful communication between the wireless ultrasonic probe **300** and the diagnostic device **400** using the pairing ultrasound **351** even when they are slightly distant from each other. This means that in the case of using the dedicated transducer **320**, the communication between the wireless ultrasonic probe **300** and the diagnostic device **400** is possible by simply bringing them close each other, that is, without making the wireless ultrasonic probe **300** contact the ultrasound reception unit **401**.

Note that ultrasound signals are high in frequency and thus have the property of traveling straight without spreading in the lateral direction. For this reason, a wireless ultrasonic probe **300** not in use is placed distantly from the diagnostic device **400**, and is usually not positioned along a straight line extending from the reception point of the diagnostic device **400**. Therefore, erroneous pressing of the operating switch **301** does not result in recognition of the unused wireless ultrasonic probe **300** by the diagnostic device **400**.

FIG. **13** shows a structural example of an ultrasound transmission unit **303**B that is another example of the ultrasound transmission unit **303**.

The ultrasound transmission unit **303**B shown in FIG. **13** includes a transducer **322** and a plurality of transducers **321**.

The transducers **321** are used only for the transmission and reception of the echo ultrasound **353**. The transducer **322** is used for both the transmission of the pairing ultrasound **351** and the transmission and reception of the echo ultrasound **353**.

In the case of using the transducer **322** for the generation of both the pairing ultrasound **351** and the echo ultrasound **353** as described above, no additional cost is necessary for the transducer because the shape thereof remains the same as the conventional one. However, the flexibility in the sound pressure and the frequency of the pairing ultrasound **351** decreases because they are determined based on the echo ultrasound **353**.

Note that although the number of the transducers **320** dedicated for the pairing ultrasound **351** is one in FIG. **12**, there may be more than one transducer **320**.

In addition, although the number of the transducers **322** used for both the pairing ultrasound **351** and the echo ultrasound **353** is one in FIG. **13**, there may be more than one transducer **322**. Furthermore, all the transducers included in the ultrasound transmission unit **303**B may be used for both the pairing ultrasound **351** and the echo ultrasound **353**.

The number of transducers **321** that are shown in FIGS. **12** and **13** and used for generating the echo ultrasound **353** is a mere example, and there may be more or less transducers **321**. The number of transducers **321** may be one.

Furthermore, the diagnostic device **400** may reset the pairing when the wireless ultrasonic probe **300** is switched off and the echo data **352** is no longer transmitted to the diagnostic device **400**.

Embodiment 2

Embodiment 2 of the present invention describes a variation of the wireless ultrasonic probe **300** according to Embodiment 1.

FIG. **14** is a block diagram showing a structure of a wireless ultrasonic probe **300**A according to Embodiment 2 of the present invention. Note that the same elements as those in FIG. **3** are given the same numerical references, and common descriptions are not repeated. Also note that the wireless reception unit **309** is omitted in FIG. **14**.

The wireless ultrasonic probe **300**A shown in FIG. **14** is different from the wireless ultrasonic probe **300** shown in FIG. **3** in including an ultrasound transmission unit **303**C instead of the ultrasound transmission unit **303**. In addition, the wireless ultrasonic probe **300**A further includes a delay control unit **308**.

The ultrasound transmission unit **303**C includes a plurality of transducers **322** and a plurality of delay circuits **325** corresponding to the transducers **322** on a one-by-one basis.

The transducers **322** are used for both the transmission of the pairing ultrasound **351** and the transmission and reception of the echo ultrasound **353**. The transducers **322** synchronously transmit the pairing ultrasound **351** according to the probe information signal **331**. The transducers **322** also synchronously transmit the echo ultrasound **353** according to the signal for echo **332**.

The delay circuits **325** delay the probe information signal **331** and the signal for echo **332** that are provided to the transducers **322**.

The delay control unit **308** controls the amount of delay caused by the delay circuits **325**.

FIG. **15** shows the pairing ultrasound **351** transmitted by the wireless ultrasonic probe **300**A. Here, it is assumed that the wireless ultrasonic probe **300**A has a convex shape as shown in FIG. **15**.

As shown in FIG. **15**, with the wireless ultrasonic probe **300**A having an emitting surface **307**A that is curved like a convex shape, for example, there is a route difference **355** between the transducers **322**. Therefore, when a large number of transducers **322** are simultaneously driven, the route difference **355** causes a delay in the output signals transmitted from the transducers **322**, which could lead to a situation where data included in the output signals do not match each other at the reception position of the diagnostic device **400**. To prevent such a situation, the delay circuits **325** delay the probe information signal **331** provided to the transducers **322** so that the route difference **355** is corrected.

Furthermore, the delay control unit **308** adjusts the amount of delay caused by the delay circuits **325** so that the pairing ultrasound **351** becomes plane waves as shown in FIG. **15**. More specifically, the transducer **322** at a position **356**A in FIG. **15** is the first transducer to transmit ultrasound. At a time when the transmitted ultrasound has traveled the distance of the route difference **355**, the transducer **322** at a position **356**B in FIG. **15** transmits ultrasound. This allows the ultrasound output from the transducers **322** to be transmitted as plane waves. Such a structure increases the signal level of the pairing ultrasound **351** transmitted from the wireless ultrasonic probe **300**A, thereby increasing the possibility of successful communication between the wireless ultrasonic probe **300**A and the diagnostic device **400** using the pairing ultrasound **351** even when the wireless ultrasonic probe **300**A and the diagnostic device **400** are distant from each other.

With the wireless ultrasonic probe **300**A according to Embodiment 2 of the present invention, it is acceptable to use, as the delay circuits **325**, a delay circuit which is normally included in the ultrasonic diagnostic apparatus for use in the beamforming performed for generating transmission data.

Here, in the process of beamforming, the transducers **322** are driven and the amount of delay is adjusted in such a manner that the signal level of the output signals is maximized at a focal position **357** as shown in FIG. **16**. In other words, the delay control unit **308** adjusts the amount of delay caused by the delay circuits **325** so that the focal position **357** of the echo ultrasound **353** matches a predetermined position as shown in FIG. **16**.

In such a manner, the wireless ultrasonic diagnostic apparatus **30** according to Embodiment 2 of the present invention uses, for adjusting the delay of the pairing ultrasound **351**, the delay circuits normally included in the ultrasonic diagnostic apparatus, thereby increasing the possibility of successful communication between the wireless ultrasonic probe **300**A and the diagnostic device **400** using the pairing ultrasound **351** while suppressing an increase in cost.

FIG. **17** shows a structure of the ultrasound reception unit **401** included in the diagnostic device **400** according to Embodiment 2 of the present invention.

Here, the pairing ultrasound **351** preferably comes into a focus in a shorter distance. To bring the focal position closer, the ultrasound reception unit **401** may include a focal position adjusting acoustic lens **360** which adjusts the focal length as shown in FIG. **17**.

General wireless ultrasonic probes include an acoustic lens **358** so that the focal position is at several centimeters ahead within the body. Thus, when the ultrasound reception unit **401** does not include the focal position adjusting acoustic lens **360**, the focal position of the pairing ultrasound **351** is at a focal position **361** shown in FIG. **17**. On the other hand, when the ultrasound reception unit **401** includes the focal position adjusting acoustic lens **360**, the focal position of the pairing ultrasound **351** is at a focal position **362** shown in FIG. **17**.

By bringing the focal position closer in such a manner, it is possible to reduce attenuation of the pairing ultrasound **351**, thereby increasing the possibility of successful communication between the wireless ultrasonic probe **300**A and the diagnostic device **400** using the pairing ultrasound **351**.

Next, a flow of the operation of the wireless ultrasonic probe **300**A is described.

FIG. **18** is a flowchart showing the flow of the operation of the wireless ultrasonic probe **300**A. Note that the same processing as that in FIG. **10** are given the same numerical references. FIG. **18** shows Steps S**121** and S**122** in addition to the processing shown in FIG. **10**.

As shown in FIG. **18**, when the operating switch **301** is on (Yes in S**101**), the probe information signal generator **302** generates the probe information signal **331** (S**102**).

Next, the delay control unit **308** sets the amount of delay to be caused by the delay circuits **325** to an amount of delay for pairing so that the pairing ultrasound **351** becomes plane waves (S**121**).

Next, the ultrasound transmission unit **303** transmits, as the pairing ultrasound **351**, the probe information signal **331** delayed by the delay circuits **325** (S**103**).

On the other hand, when the operating switch **301** is off (No in S**101**), the signal-for-echo generator **304** generates the signal for echo **332** (S**104**).

Next, the delay control unit **308** sets the amount of delay to be caused by the delay circuits **325** to an amount of delay for echo so that the focal position of the echo ultrasound **353** matches a predetermined position (S**122**).

Subsequently, the ultrasound transmission unit **303** transmits, as the echo ultrasound **353**, the signal for echo **332** delayed by the delay circuits **325** (S**105**).

Then, the ultrasound transmission unit **303** receives the reflected waves **354** that are the echo ultrasound **353** reflected from the subject, and outputs the reflected waves **354** as the echo signal **333**. Next, the echo data processing unit **305** generates the echo data **334** from the echo signal **333** (S**106**).

Subsequently, the wireless transmission unit **306** wirelessly transmits the echo data **334** as the echo data **352** (S**107**).

Although it has been described above that the wireless ultrasonic probe **300**A has a convex shape, the wireless ultrasonic probe **300**A may have a different shape. In that case, it is sufficient as long as the delay circuits **325** delay, according to the shape of the emitting surface **307**A of the wireless ultrasonic probe **300**A, the probe information signal **331** provided to the transducers **322** so that the pairing ultrasound **351** synchronously transmitted by the transducers **322** becomes plane waves.

Although it has also been described above that all the transducers **322** included in the ultrasound transmission unit **303**C are used for the generation of both the pairing ultrasound **351** and the echo ultrasound **353**, the ultrasound transmission unit **303**C may include a transducer dedicated for the pairing ultrasound **351** or a transducer dedicated for the echo ultrasound **353**.

Embodiment 3

Embodiment 3 of the present invention describes application of the present invention to a mechanical sector-scanning wireless ultrasonic probe.

FIG. **19** is a block diagram showing a structure of a wireless ultrasonic probe **300**B according to Embodiment 3 of the present invention. Note that the same elements as those in FIG. **3** are given the same numerical references, and common descriptions are not repeated. Also note that the wireless reception unit **309** is omitted in FIG. **19**.

The wireless ultrasonic probe **300**B shown in FIG. **19** includes a scan unit **370** in addition to the constituent elements of the wireless ultrasonic probe **300** shown in FIG. **3**.

When the ultrasound transmission unit **303** transmits the echo ultrasound **353**, the scan unit **370** performs sector scanning in directions in which the echo ultrasound **353** is transmitted. In addition, when the ultrasound transmission unit **303** transmits the pairing ultrasound **351**, the scan unit **370** fixes the direction in which the pairing ultrasound **351** is transmitted.

More specifically, when the operating switch **301** is pressed, the scan unit **370** causes the transducer at the tip of the wireless ultrasonic probe **300**B to pause at the position directly in front of the diagnostic device **400**. This enables the mechanical sector-scanning wireless ultrasonic probe **300**B to reliably perform the pairing.

Next, a flow of the operation of the wireless ultrasonic probe **300**B is described.

FIG. **20** is a flowchart showing the flow of the operation of the wireless ultrasonic probe **300**B. Note that the same processing as that in FIG. **10** are given the same numerical references. FIG. **20** shows Steps S**131** and S**132** in addition to the processing shown in FIG. **10**.

As shown in FIG. **20**, when the operating switch **301** is on (Yes in S**101**), the probe information signal generator **302** generates the probe information signal **331** (S**102**).

Next, the scan unit **370** fixes the direction in which the pairing ultrasound **351** is transmitted (S**131**).

Then, the ultrasound transmission unit **303** transmits the probe information signal **331** as the pairing ultrasound **351** (S**103**).

On the other hand, when the operating switch **301** is off (No in S**101**), the signal-for-echo generator **304** generates the signal for echo **332** (S**104**).

Next, the scan unit **370** performs scanning in directions in which the echo ultrasound **353** is transmitted (S**132**).

Subsequently, the ultrasound transmission unit **303** transmits the signal for echo **332** as the echo ultrasound **353** (S**105**).

Then, the ultrasound transmission unit **303** receives the reflected waves **354** that are the echo ultrasound **353** reflected from the subject, and outputs the reflected waves **354** as the echo signal **333**. Next, the echo data processing unit **305** generates the echo data **334** from the echo signal **333** (S**106**).

Subsequently, the wireless transmission unit **306** wirelessly transmits the echo data **334** as the echo data **352** (S**107**).

Although the above embodiments describe that the signal-for-echo generator **304** included in the wireless ultrasonic probe generates the signal for echo **332** from which the echo ultrasound **353** is generated, the wireless ultrasonic probe may output, as the signal for echo **332**, a transmission signal transmitted from the diagnostic device.

FIG. **21** shows a structure of a wireless ultrasonic probe **300**C that outputs, as the signal for echo **332**, a transmission signal **363** transmitted from the diagnostic device **400**.

The wireless ultrasonic probe **300**C shown in FIG. **21** is different from the wireless ultrasonic probe **300** shown in FIG. **3** in including a signal-for-echo processing unit **304**A instead of the signal-for-echo generator **304**. Furthermore, the wireless reception unit **309** receives the transmission signal **363** wirelessly transmitted from the diagnostic device **400**.

The signal-for-echo processing unit **304**A outputs, as the signal for echo **332**, the transmission signal **363** wirelessly transmitted from the diagnostic device **400**.

At least some of the processing units included in the wireless ultrasonic diagnostic apparatus **30** according to the above embodiments may be implemented in the form of a Large Scale Integrated (LSI) circuit that is an integrated circuit. These may be implemented in a single chip individually, or in a single chip that includes some or all of them.

Furthermore, the means for circuit integration is not limited to to an LSI, and implementation with a dedicated circuit or a general-purpose processor is also available. It is also acceptable to use a field programmable gate array (FPGA) that is programmable after the LSI has been manufactured, and a reconfigurable processor in which connections and settings of circuit cells within the LSI are reconfigurable.

Some or all of the functions of the wireless ultrasonic diagnostic apparatus **30** according to the embodiments of the present invention may be achieved through execution of a program by a processor such as a CPU.

In addition, the present invention may be realized as the program or a recording medium on which the program is recorded. It is apparent that the program may be distributed via a transmission medium such as the Internet.

Furthermore, it is possible to combine at least some of the functions of the wireless ultrasonic diagnostic apparatus according to Embodiments 1 to 3 and the wireless ultrasonic diagnostic apparatus according to the variation of Embodiments 1 to 3.

The present invention includes various variations achieved through modifications of the embodiments of the present invention that a person skilled in the art could conceive without departing from the scope of the present invention.

INDUSTRIAL APPLICABILITY

The wireless ultrasonic diagnostic apparatus according to the present invention is capable of easily and reliably establishing connection between a wireless ultrasonic probe and a diagnostic device using an ultrasound signal. It is particularly useful as a wireless ultrasonic diagnostic apparatus that uses a plurality of wireless ultrasonic probes.

REFERENCE SIGNS LIST

10, **30** Wireless ultrasonic diagnostic apparatus
100 Ultrasonic probe
110 PS conversion unit
112 Scrambler
114 Code signal generator
116 Modulator
200 Main device
300, **300**A, **300**B, **300**C Wireless ultrasonic probe
301 Operating switch
302 Probe information signal generator
303, **303**A, **303**B, **303**C Ultrasound transmission unit
304 Signal-for-echo generator
304A Signal-for-echo processing unit
305 Echo data processing unit
306 Wireless transmission unit
307, **307**A Emitting surface
308 Delay control unit
309 Wireless reception unit
320, **321**, **322** Transducer
325 Delay circuit
331, **451** Probe information signal
332 Signal for echo
333 Echo signal
334, **352**, **453** Echo data
351 Pairing ultrasound
353 Echo ultrasound
354 Reflected waves
355 Route difference
356A, **356**B Position
357, **361**, **362** Focal position
358 Acoustic lens
359 Control signal
360 Focal position adjusting acoustic lens
363 Transmission signal
370 Scan unit
400 Diagnostic device
401 Ultrasound reception unit
402 Probe information detection unit
403 Synchronizing signal detection unit
404 Probe information determination unit
405 Probe information setting unit
406 Wireless reception unit
407 Echo data processing unit
408 Display unit
409 Error processing unit
410 Wireless transmission unit
452 Probe information
454 Image data
501 LED
502 Speaker
601 Data signal
602 Header portion
603 Data portion

The invention claimed is:

1. A wireless ultrasonic diagnostic apparatus comprising:

a diagnostic device which comprises a processor or integrated circuit and is configured to receive ultrasound signals and to wirelessly receive data in a frequency band different from ultrasound, under control by the processor or integrated circuit; and

a wireless ultrasonic probe which (i) generates a first signal including probe information for identifying said wireless ultrasonic probe, (ii) transmits the first signal as a pairing ultrasound to said diagnostic device for pairing said wireless ultrasonic probe and said diagnostic device, (iii) transmits an echo ultrasound to a subject, (iv) generates echo data using reflected waves that are the echo ultrasound reflected from the subject, the echo data being generated so as to be associated with the probe information included in the first signal for identifying said wireless ultrasonic probe, and (v) wirelessly transmits, in the frequency band different from ultrasound, the echo data associated with the probe information to said diagnostic device;

wherein said diagnostic device, under control of the processor or integrated circuit, (i) receives the pairing ultrasound transmitted by said wireless ultrasonic probe, detects the probe information from the received pairing ultrasound, and sets the detected probe information, to thereby pair said wireless ultrasonic probe and said diagnostic device, (ii) receives data that is wirelessly transmitted in the frequency band different from ultrasound, (iii) determines whether or not the received data is associated with the set probe information, and determines that the received data is the echo data wirelessly transmitted by said paired wireless ultrasonic probe when it is determined that the received data is associated with the set probe information, and (v) when it is determined that the received data is the echo data wirelessly transmitted by said paired wireless ultrasonic probe, processes the received echo data,

wherein said wireless ultrasonic probe includes a transducer which both (i) transmits the pairing ultrasound according to the first signal and (ii) emits the echo ultrasound,

wherein output of both the pairing ultrasound and the echo ultrasound are controlled in accordance with a single input from an operating switch that is operated by an operator, and

wherein said wireless ultrasonic probe transmits the first signal as the pairing ultrasound to said diagnostic device when the operator provides the operating switch with the single input, in a state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device, and the pairing ultrasound reaches said diagnostic device only in the state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device.

2. The wireless ultrasonic diagnostic apparatus according to claim **1**, wherein said wireless ultrasonic probe further includes the operating switch, which is operable by the operator, and

wherein when said operating switch is pressed, said wireless ultrasonic probe generates the first signal, and transmits the first signal as the pairing ultrasound.

3. The wireless ultrasonic diagnostic apparatus according to claim **1**,

wherein the first signal generated by said wireless ultrasonic probe includes a synchronizing signal, and

wherein said diagnostic device is configured to detect the probe information from the pairing ultrasound by detecting the synchronizing signal included in the received pairing ultrasound.

4. The wireless ultrasonic diagnostic apparatus according to claim **1**, wherein said transducer comprises a plurality of transducers which synchronously transmit the pairing ultrasound according to the first signal.

5. The wireless ultrasonic diagnostic apparatus according to claim 4, wherein said wireless ultrasonic probe delays, according to a shape of a surface of said wireless ultrasonic probe from which the pairing ultrasound is emitted, the first signal so that the pairing ultrasound being synchronously transmitted becomes plane waves.

6. The wireless ultrasonic diagnostic apparatus according to claim 5, wherein said wireless ultrasonic probe (i) generates a second signal, (ii) delays the second signal to adjust a focal position of the echo ultrasound, and (iii) generates the echo ultrasound according to the delayed second signal.

7. The wireless ultrasonic diagnostic apparatus according to claim 1, wherein said wireless ultrasonic probe (i) scans, when the echo ultrasound is emitted, in directions in which the echo ultrasound is emitted using a sector scanning method, and (ii) emits the pairing ultrasound in a fixed direction.

8. The wireless ultrasonic diagnostic apparatus according to claim 1, wherein said diagnostic device has an acoustic impedance in a range of 1.5 to 2.0×10^6 kg/m^2s inclusive.

9. The wireless ultrasonic diagnostic apparatus according to claim 1, wherein said diagnostic device includes an acoustic lens which adjusts a focal position of the pairing ultrasound.

10. The wireless ultrasonic diagnostic apparatus according to claim 1, wherein said diagnostic device notifies an operator of error occurrence when an error occurs with the probe information transmitted by said wireless ultrasonic probe.

11. The wireless ultrasonic diagnostic apparatus according to claim 10, wherein said diagnostic device notifies the operator of the error occurrence by causing an LED to flash or by changing a color of the LED.

12. The wireless ultrasonic diagnostic apparatus according to claim 10, wherein said diagnostic device notifies the operator of the error occurrence by beeping.

13. The wireless ultrasonic diagnostic apparatus according to claim 1, wherein said wireless ultrasonic probe transmits the echo ultrasound to the subject and receives the reflected waves, in a state in which the wireless ultrasonic probe is pressed against a body surface of the subject.

14. The wireless ultrasound diagnostic apparatus according to claim 1, wherein said wireless ultrasonic probe comprises a processor or integrated circuit which is configured to receive the input from the operating switch and control the output of the pairing ultrasound and the output of the echo ultrasound according to the input.

15. The wireless ultrasound diagnostic apparatus according to claim 1, wherein the transducer continues to output the pairing ultrasound when instructed by the operating switch to output the pairing ultrasound, and outputs the echo ultrasound without outputting the pairing ultrasound when instructed by the operating switch not to output the pairing ultrasound.

16. The wireless ultrasound diagnostic apparatus according to claim 1, wherein the transducer outputs the pairing ultrasound when the operating switch is pressed, and stops outputting the pairing ultrasound and outputs the echo ultrasound when the operating switch is released.

17. The wireless ultrasound diagnostic apparatus according to claim 1, wherein the transducer outputs the pairing ultrasound when the operating switch is pressed once, and stops outputting the pairing ultrasound and outputs the echo ultrasound when the operating switch is pressed once more.

18. A wireless ultrasonic probe which is capable of wirelessly communicating with a diagnostic device that comprises a processor or integrated circuit and that is configured to receive ultrasound signals and to wirelessly receive data in a frequency band different from ultrasound under control by the processor or integrated circuit, wherein said wireless ultrasonic probe transmits an echo ultrasound to a subject and receives reflected waves that are the echo ultrasound reflected from the subject, said wireless ultrasonic probe comprising:

a transducer which both (i) transmits the pairing ultrasound according to the first signal and (ii) emits the echo ultrasound;

a processor or integrated circuit; and

a non-transitory memory having stored thereon executable instructions, which when executed by the processor or integrated circuit, cause said wireless ultrasonic probe to:

(i) generate a first signal including probe information for identifying said wireless ultrasonic probe;

(ii) transmit the first signal as a pairing ultrasound to the diagnostic device for pairing said wireless ultrasonic probe and said diagnostic device;

(iii) generate echo data using the reflected waves that are the echo ultrasound reflected from the subject, the echo data being generated so as to be associated with the probe information included in the first signal for identifying said wireless ultrasonic probe; and

(iv) wirelessly transmit, in the frequency band different from ultrasound, the echo data associated with the probe information to the diagnostic device, and wherein output of both the pairing ultrasound and the echo ultrasound are controlled in accordance with a single input from an operating switch that is operated by an operator, and

wherein said wireless ultrasonic probe transmits the first signal as the pairing ultrasound to said diagnostic device when the operator provides the operating switch with the single input, in a state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device, and the pairing ultrasound reaches said diagnostic device only in the state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device.

19. A probe pairing and authentication method performed by a wireless ultrasonic diagnostic apparatus, the wireless ultrasonic diagnostic apparatus including: (i) a diagnostic device which comprises a processor or integrated circuit and is configured to receive ultrasound signals and to wirelessly receive data in a frequency band different from ultrasound, under control by the processor or integrated circuit, and (ii) a wireless ultrasonic probe which is configured to transmit ultrasound and to wirelessly transmit data in the frequency band different from ultrasound, wherein the wireless ultrasonic probe transmits an echo ultrasound to a subject and receives reflected waves that are the echo ultrasound reflected from the subject, and wherein the wireless ultrasonic probe comprises a transducer which both (i) transmits the pairing ultrasound according to the first signal and (ii) emits the echo ultrasound, said probe pairing and authentication method comprising:

generating, by the wireless ultrasonic probe, a first signal including probe information for identifying the wireless ultrasonic probe;

transmitting, by the wireless ultrasonic probe, the first signal as a pairing ultrasound to the diagnostic device for pairing the wireless ultrasonic probe and the diagnostic device;

receiving, by the diagnostic device, the pairing ultrasound transmitted by the wireless ultrasonic probe, detecting, by the diagnostic device, the probe information from the received pairing ultrasound, and setting the detected probe information, to thereby pair the wireless ultrasonic probe and the diagnostic device;

generating, by the wireless ultrasonic probe, echo data using the reflected waves that are the echo ultrasound reflected from the subject, the echo data being generated so as to be associated with the probe information included in the first signal for identifying the wireless ultrasonic probe;

wirelessly transmitting, by the wireless ultrasonic probe, the echo data associated with the probe information, to the diagnostic device, in the frequency band different from ultrasound;

receiving, by the diagnostic device, data that is wirelessly transmitted;

determining, by the diagnostic device, whether or not the received data is associated with the set probe information, and determining that the received data is the echo data wirelessly transmitted by the paired wireless ultrasonic probe when it is determined that the received data is associated with the set probe information; and

when it is determined that the received data is the echo data wirelessly transmitted by said paired wireless ultrasonic probe, processing the received echo data, wherein output of both the pairing ultrasound and the echo ultrasound are controlled in accordance with a single input from an operating switch that is operated by an operator, and

wherein said wireless ultrasonic probe transmits the first signal as the pairing ultrasound to said diagnostic device when the operator provides the operating switch with the single input, in a state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device, and the pairing ultrasound reaches said diagnostic device only in the state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device.

20. The wireless diagnostic apparatus according to claim **1**, wherein the pairing ultrasound is transmitted in a first frequency band, and the echo ultrasound is transmitted in a second frequency band different from the first frequency band.

21. The wireless ultrasonic diagnostic apparatus according to claim **20**, wherein the second frequency band is higher than the first frequency band.

22. The wireless ultrasonic diagnostic apparatus according to claim **20**,

wherein the first frequency band and the second frequency band are between 1 MHz and 20 MHz inclusive.

23. The wireless ultrasonic diagnostic apparatus according to claim **22**, wherein the frequency band used for wireless transmission and reception of the echo data is on the order of GHz.

24. A wireless ultrasonic diagnostic apparatus comprising:

a diagnostic device which comprises a processor or integrated circuit and is configured to receive ultrasound signals and to wirelessly receive data in a frequency band different from ultrasound, under control by the processor or integrated circuit; and

a wireless ultrasonic probe which (i) generates a first signal including probe information for identifying said wireless ultrasonic probe, (ii) transmits the first signal as a pairing ultrasound to said diagnostic device for pairing said wireless ultrasonic probe and said diagnostic device, (iii) transmits an echo ultrasound to a subject, (iv) generates echo data using reflected waves that are the echo ultrasound reflected from the subject, the echo data being generated so as to be associated with the probe information included in the first signal for identifying said wireless ultrasonic probe, and (v) wirelessly transmits, in the frequency band different from ultrasound, the echo data associated with the probe information to said diagnostic device;

wherein said diagnostic device, under control of the processor or integrated circuit, (i) receives the pairing ultrasound transmitted by said wireless ultrasonic probe, detects the probe information from the received pairing ultrasound, and sets the detected probe information, to thereby pair said wireless ultrasonic probe and said diagnostic device, (ii) receives data that is wirelessly transmitted in the frequency band different from ultrasound, (iii) determines whether or not the received data is associated with the set probe information, and determines that the received data is the echo data wirelessly transmitted by said paired wireless ultrasonic probe when it is determined that the received data is associated with the set probe information, and (v) when it is determined that the received data is the echo data wirelessly transmitted by said paired wireless ultrasonic probe, processes the received echo data,

wherein output of the pairing ultrasound is controlled in accordance with a single input from an operating switch that is operated by an operator, and

wherein said wireless ultrasonic probe transmits the first signal as the pairing ultrasound to said diagnostic device when the operator provides the operating switch with the single input, in a state in which said wireless ultrasonic probe is in direct physical contact with said diagnostic device, and the pairing ultrasound reaches said diagnostic device only in the state in which said wireless ultrasonic probe is in physical contact with said diagnostic device.

* * * * *

专利名称(译)	无线超声诊断设备，无线超声探头和探头认证方法		
公开(公告)号	[US9622718](US9622718)	公开(公告)日	2017-04-18
申请号	US13/001821	申请日	2010-04-22
[标]申请(专利权)人(译)	渡边保仁		
申请(专利权)人(译)	渡边保仁		
当前申请(专利权)人(译)	柯尼卡美能达，INC.		
[标]发明人	WATANABE YASUHITO		
发明人	WATANABE, YASUHITO		
IPC分类号	A61B8/00 G01S7/52 G01S7/00		
CPC分类号	A61B8/00 A61B8/4438 A61B8/4472 A61B8/56 G01S7/5205 G01S7/003		
优先权	2009105983 2009-04-24 JP		
其他公开文献	US20110105904A1		
外部链接	Espacenet USPTO		

摘要(译)

一种无线超声诊断设备（ 30 ），包括无线超声探头（ 300 ）和诊断设备（ 400 ）。无线超声波探头（ 300 ）包括：无线传输单元（ 306 ），其无线传输回波数据（ 352 ）;发送包括用于识别无线超声波探头的探测信息（ 300 ）的配对超声波（ 351 ）的超声波发送单元（ 303 ）。诊断设备（ 400 ）包括：超声接收单元（ 401 ），其接收配对超声（ 351 ）;探测信息检测单元（ 402 ），用于从配对超声波（ 351 ）中检测探测信息（ 452 ）;和无线接收单元（ 406 ），使用探测信息（ 452 ）确定接收数据是否为回波数据（ 352 ）通过无线超声探头无线传输（ 300 ）。