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**OGASAWARA et al.**

(54) **ULTRASOUND DIAGNOSIS APPARATUS**

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(57) **ABSTRACT**

An ultrasound diagnosis apparatus according to an aspect includes an ultrasound probe and a processing apparatus. The ultrasound probe is configured so that a contact face thereof to be in contact with a subject for the purpose of adhering thereto is formed so as to have a shape that can be fitted to a projection part of the subject. The processing apparatus processes a reflected-wave signal of an ultrasound wave that is transmitted from the ultrasound probe attached to the subject toward the subject.

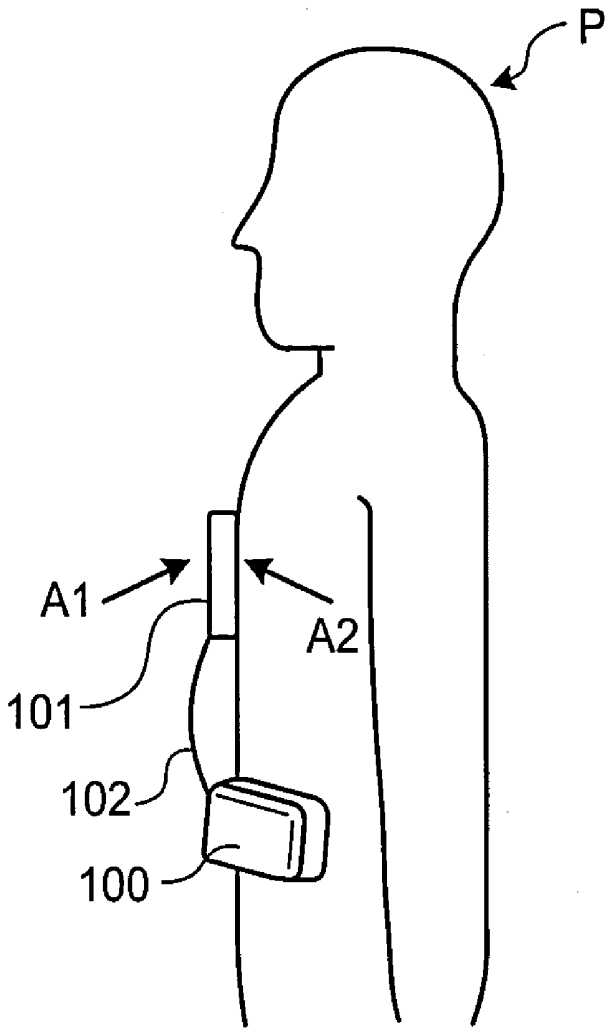


FIG.1

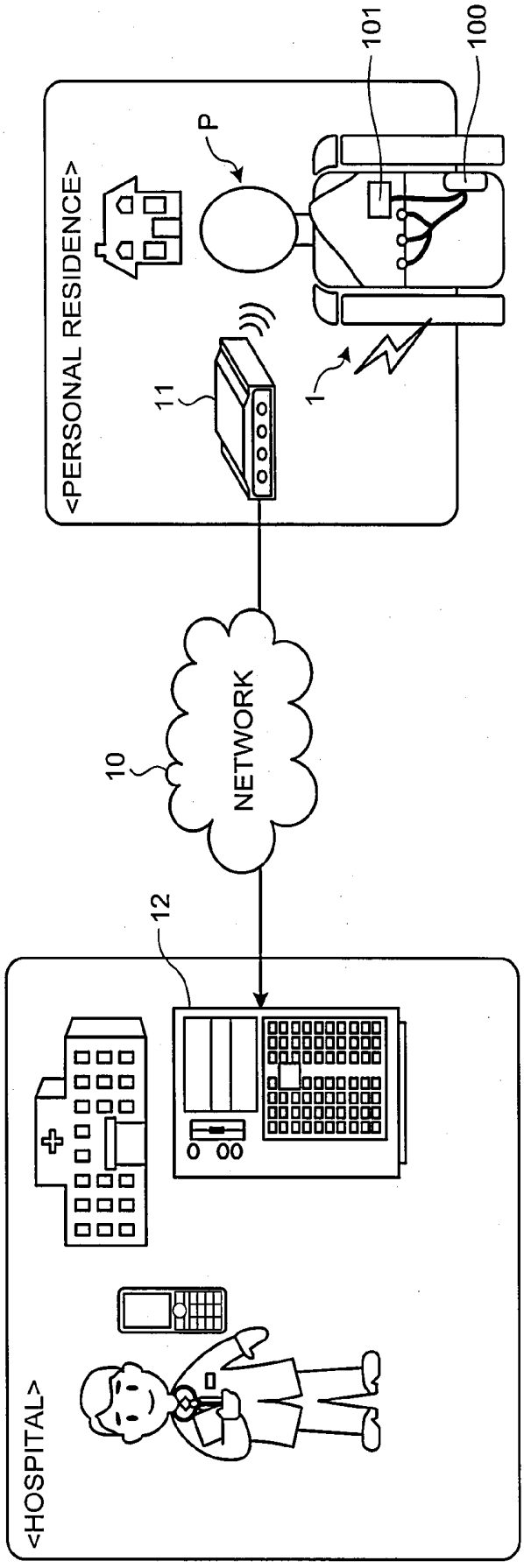


FIG.2

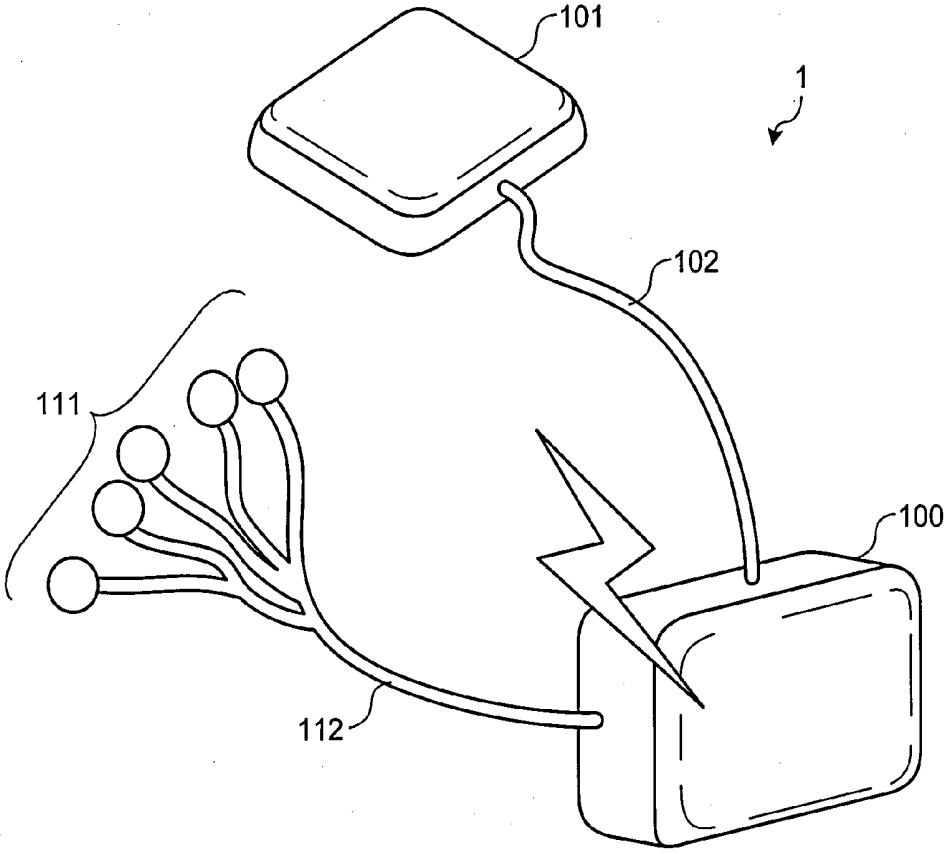



FIG.3

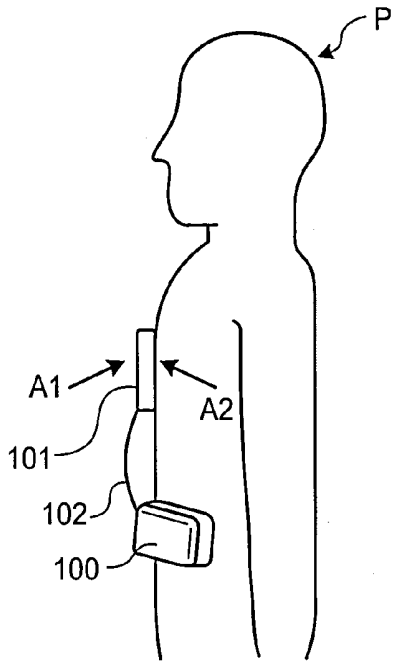


FIG.4

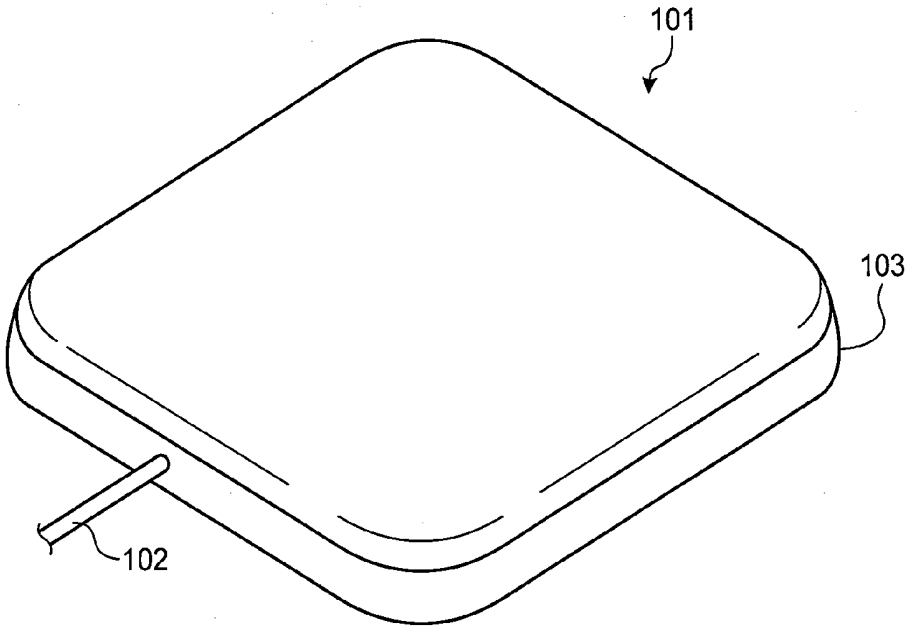



FIG.5

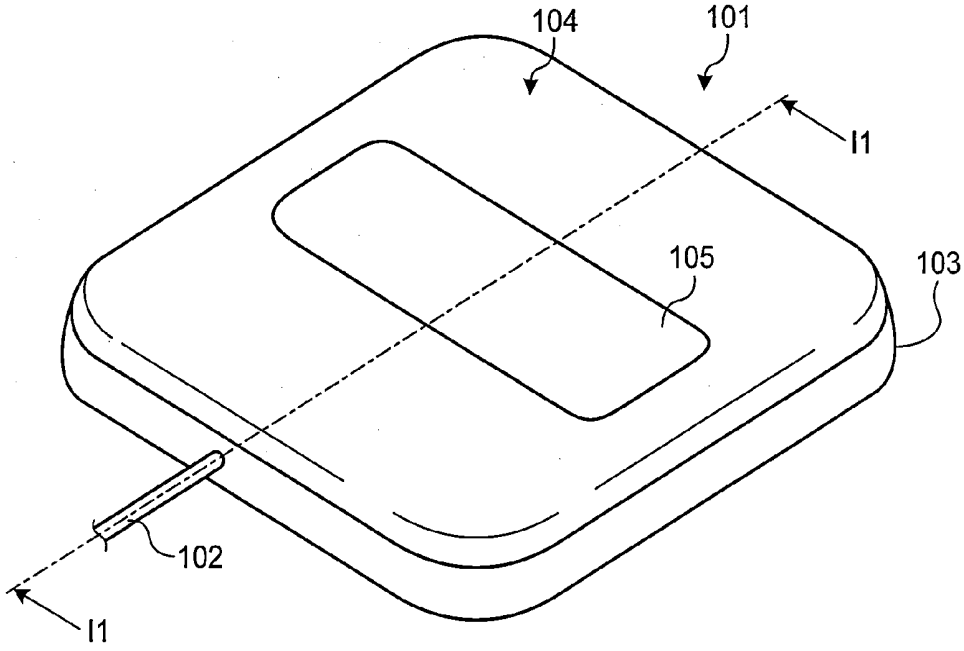


FIG.6

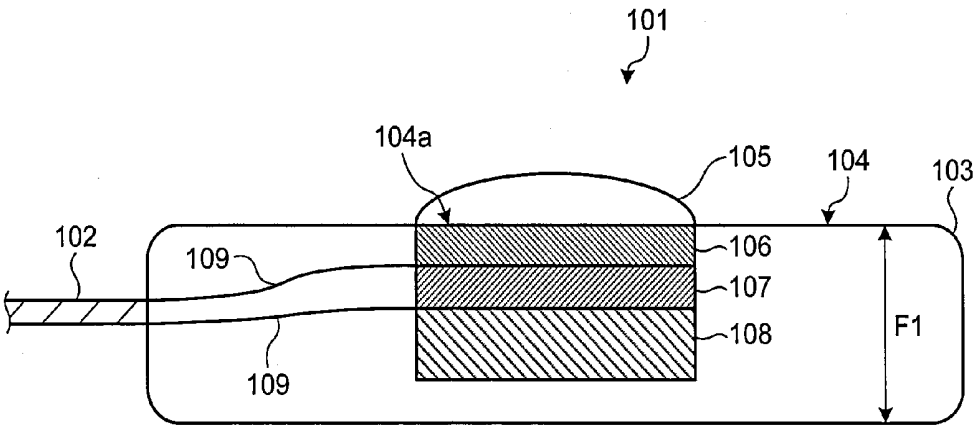



FIG.7

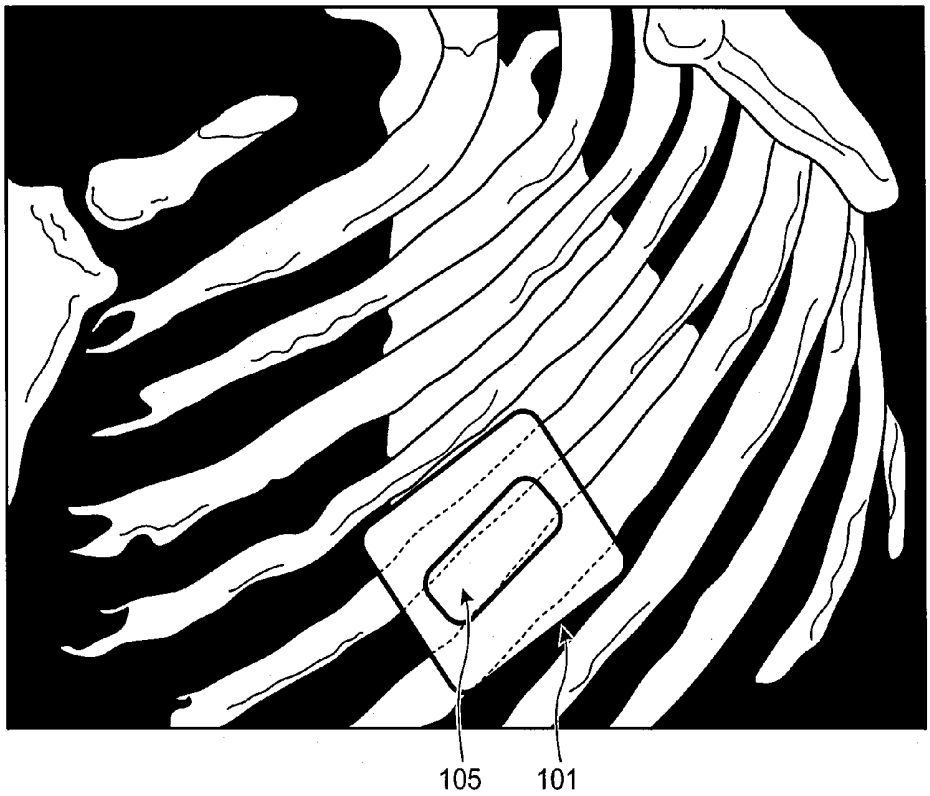


FIG.8

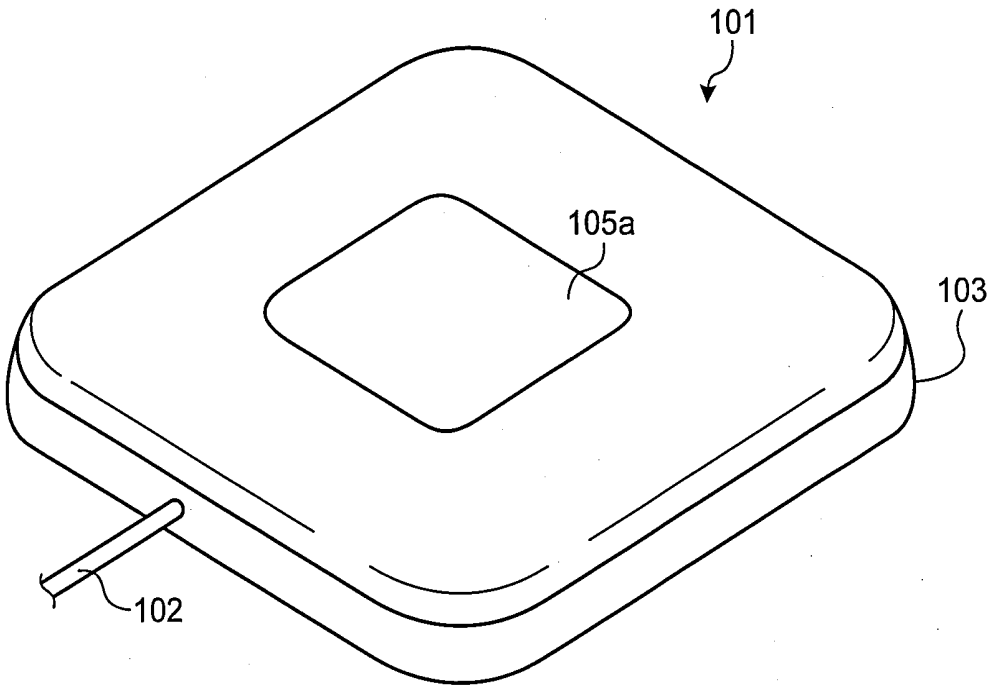


FIG.9

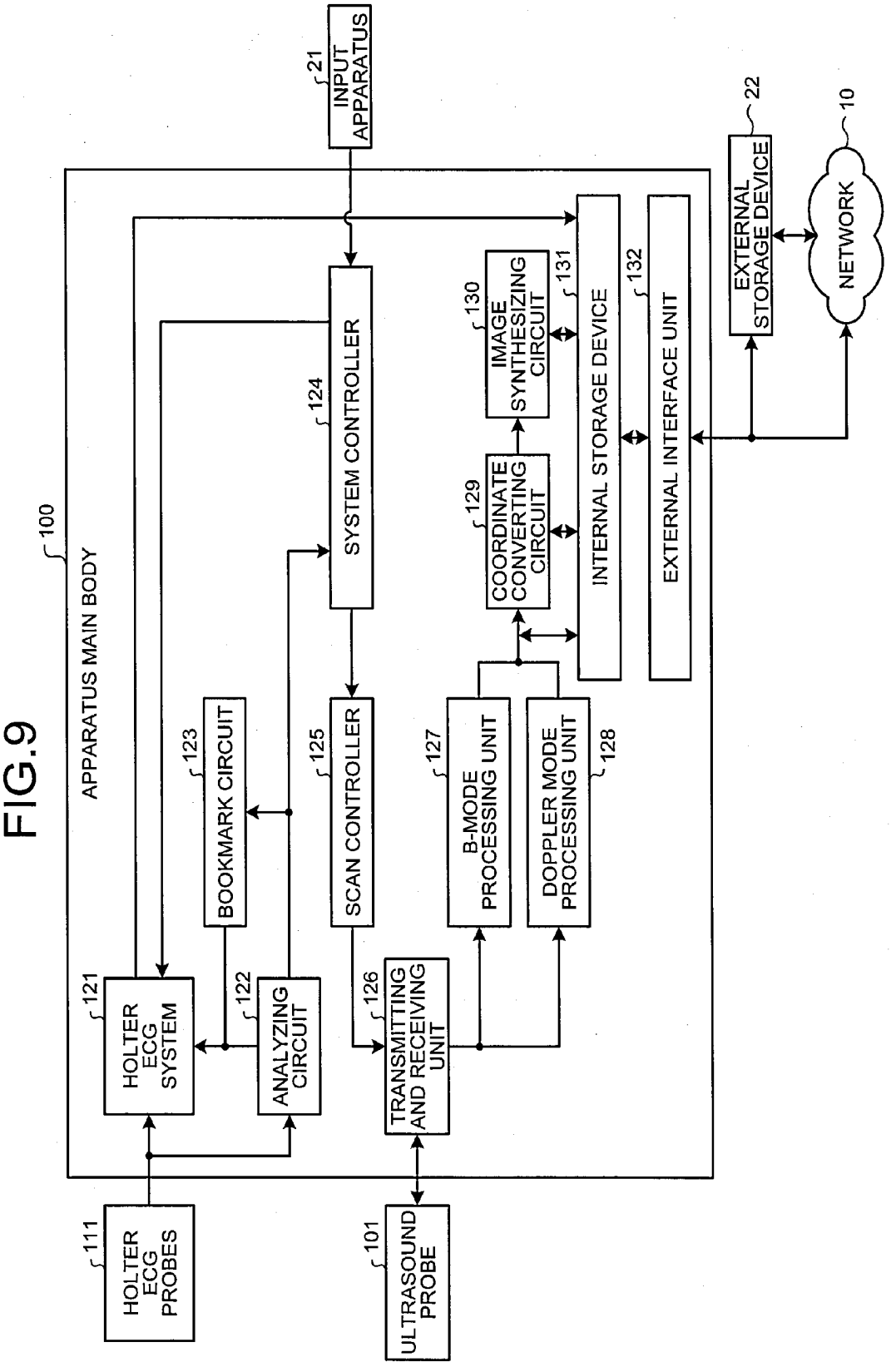

100
APPARATUS MAIN BODY
21
INPUT APPARATUS
22
EXTERNAL STORAGE DEVICE
10
NETWORK
124
SYSTEM CONTROLLER
130
IMAGE SYNTHESIZING CIRCUIT
131
132
INTERNAL STORAGE DEVICE
EXTERNAL INTERFACE UNIT
129
COORDINATE CONVERTING CIRCUIT
123
BOOKMARK CIRCUIT
125
SCAN CONTROLLER
127
B-MODE PROCESSING UNIT
128
DOPPLER MODE PROCESSING UNIT
121
HOLTER ECG SYSTEM
122
ANALYZING CIRCUIT
126
TRANSMITTING AND RECEIVING UNIT
111
HOLTER ECG PROBES
101
ULTRASOUND PROBE

FIG.10

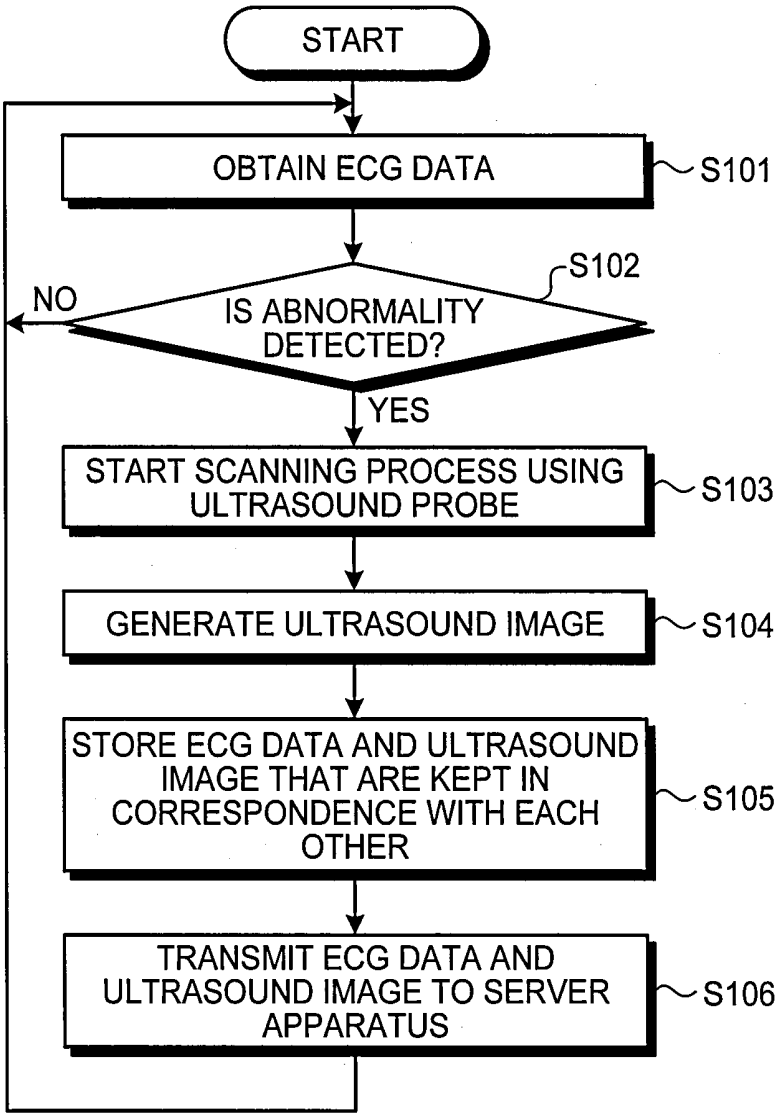

START
OBTAIN ECG DATA
S101
S102
NO
IS ABNORMALITY DETECTED?
YES
START SCANNING PROCESS USING ULTRASOUND PROBE
S103
GENERATE ULTRASOUND IMAGE
S104
STORE ECG DATA AND ULTRASOUND IMAGE THAT ARE KEPT IN CORRESPONDENCE WITH EACH OTHER
S105
TRANSMIT ECG DATA AND ULTRASOUND IMAGE TO SERVER APPARATUS
S106

FIG.11

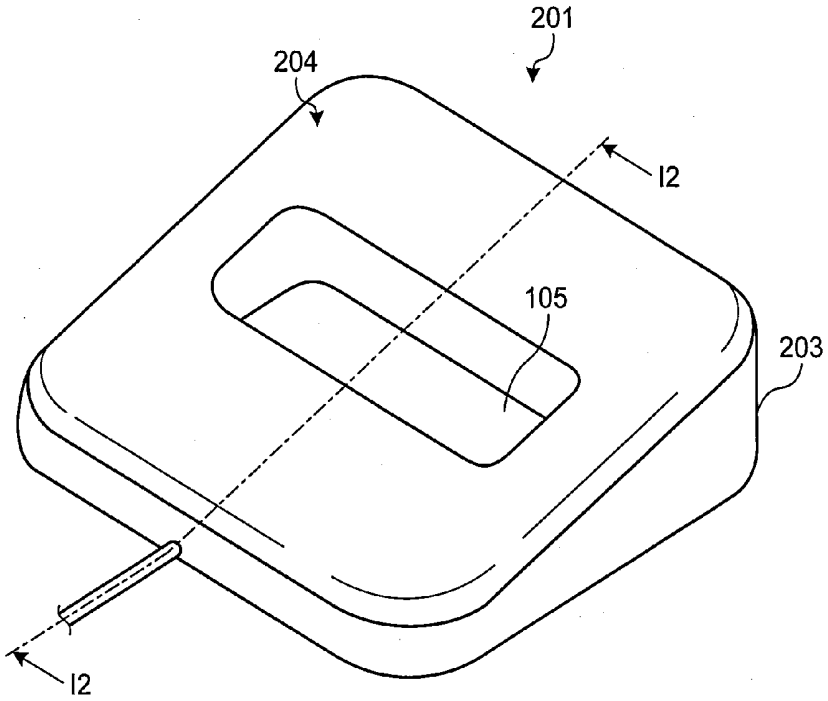

201
204
I2
105
203
I2

FIG.12

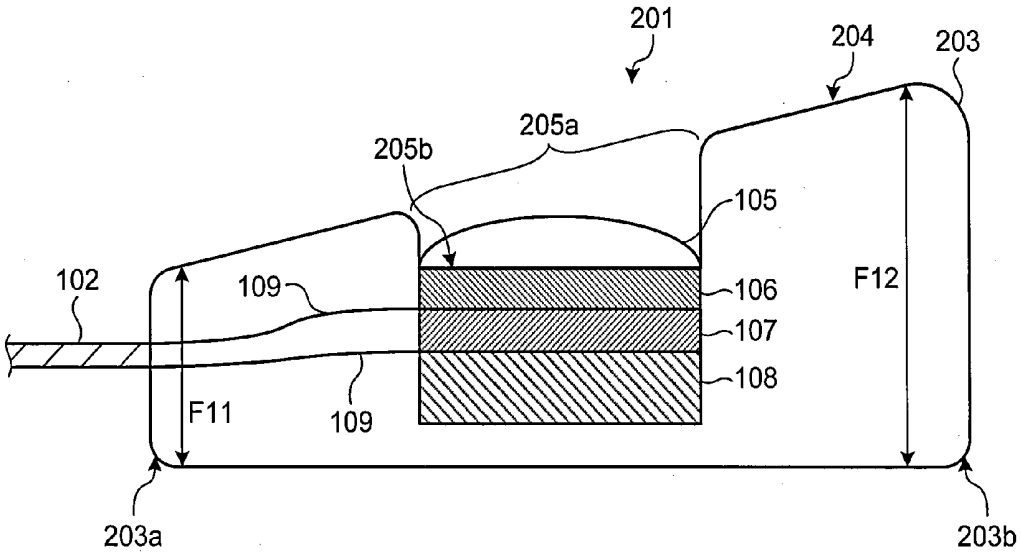

201
204
203
205a
205b
105
102
109
106
107
108
F12
F11
109
203a
203b

FIG.13

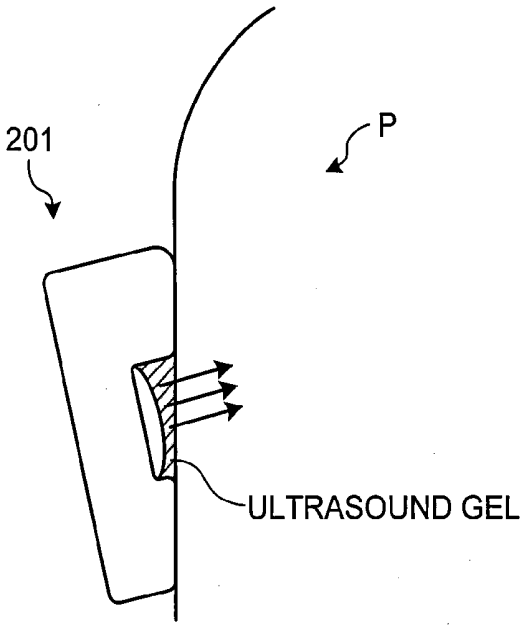



FIG.14

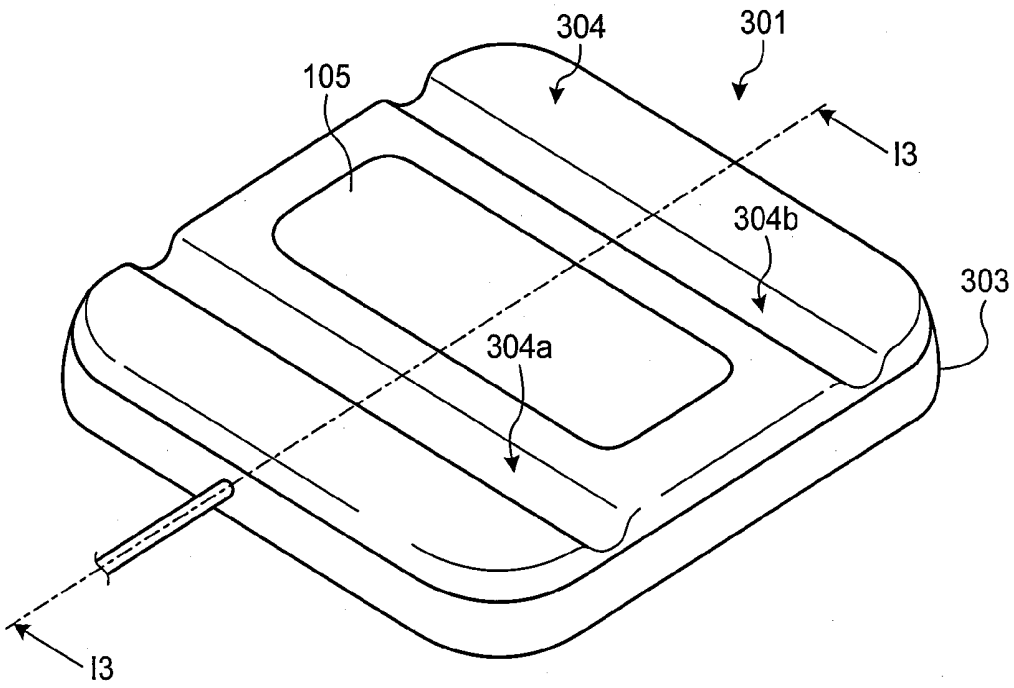


FIG.15

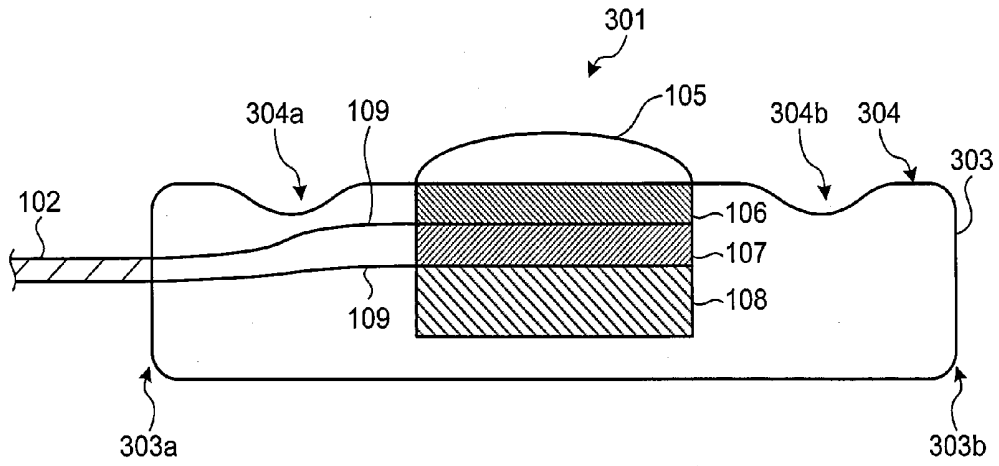

301
304a
109
105
304b
304
303
102
106
107
108
109
303a
303b

FIG.16

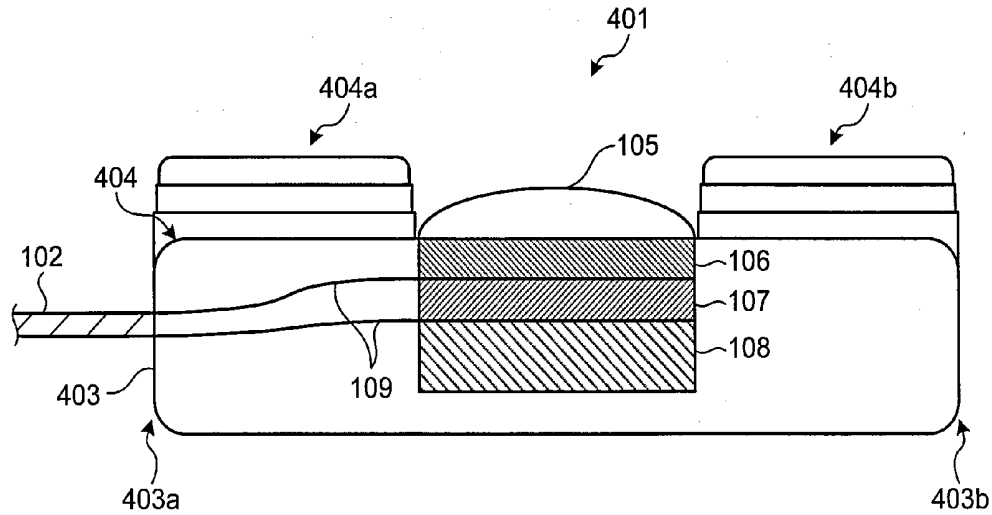
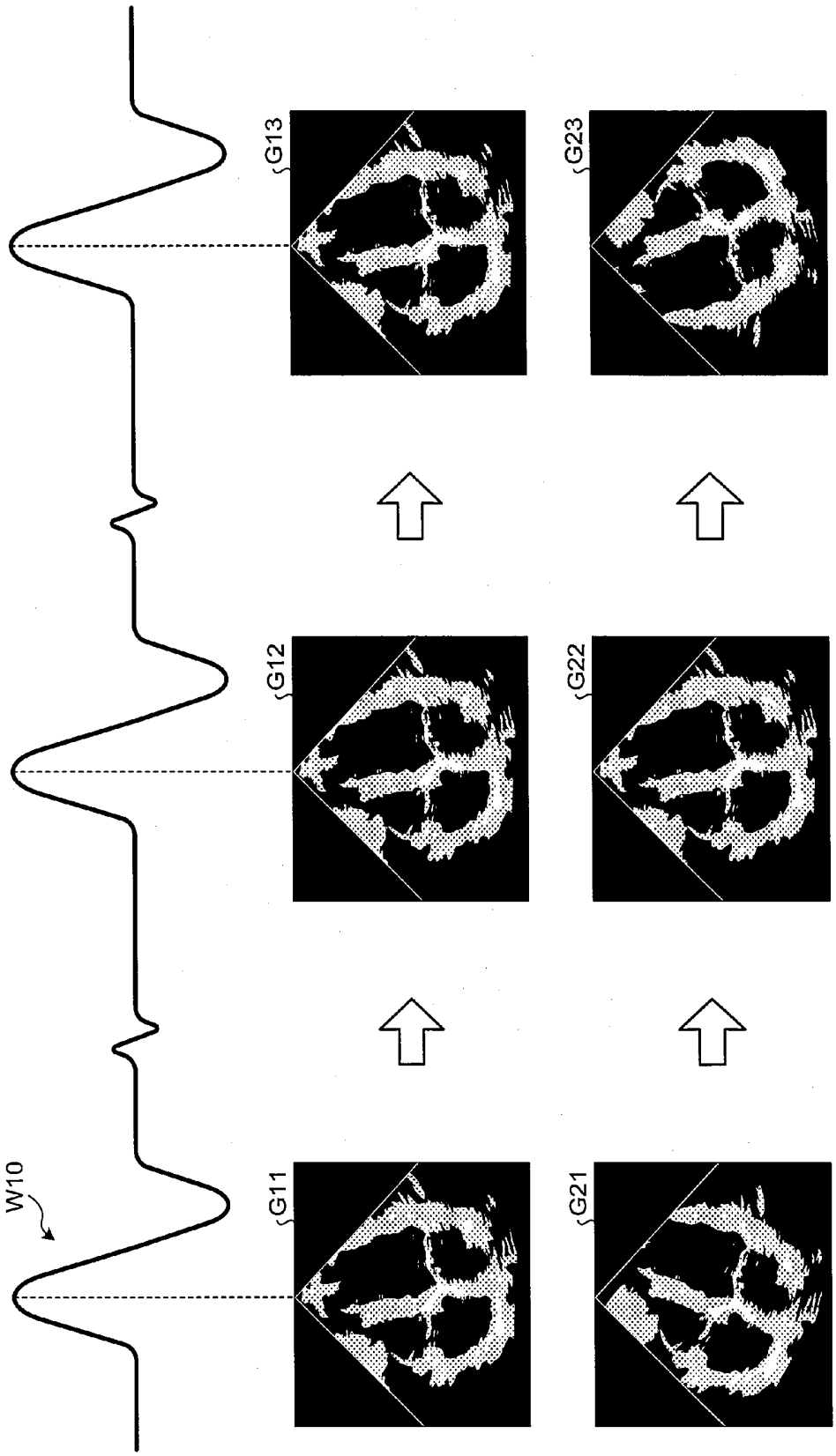

401
404a
404b
105
404
102
106
107
108
403
109
403a
403b

FIG.17



# ULTRASOUND DIAGNOSIS APPARATUS

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of PCT international application Ser. No. PCT/JP2012/074262 filed on Sep. 21, 2012 which designates the United States, incorporated herein by reference, and which claims the benefit of priority from Japanese Patent Application No. 2011-207203, filed on Sep. 22, 2011; and Japanese Patent Application No. 2012-208086, filed on Sep. 21, 2012, the entire contents of which are incorporated herein by reference.

## FIELD

**[0002]** Embodiments described herein relate generally to an ultrasound diagnosis apparatus.

## BACKGROUND

**[0003]** Conventionally, ultrasound diagnosis apparatuses have been used in today's medicine for performing a medical examination and making a diagnosis on various tissues in the body of an examined subject (hereinafter, "subject") such as the heart, the liver, a kidney, a mammary gland, and the like, because ultrasound diagnosis apparatuses have advantages realized by simpler operability and non-invasiveness (i.e., no possibility of causing radiation exposures) over other medical image diagnosis apparatuses such as X-ray diagnosis apparatuses and X-ray computed tomography apparatuses. For example, an ultrasound diagnosis apparatus is configured to, when an ultrasound probe is pressed against a subject by an operator such as a medical doctor, generate an ultrasound image that is an image of a structure of a tissue inside the subject, by receiving a reflected-wave signal obtained when an ultrasound wave transmitted from the ultrasound probe is reflected by the tissue inside the subject. Consequently, the ultrasound diagnosis apparatus is capable of generating ultrasound images of mutually-different tissues in correspondence with the sites against which the ultrasound probe is pressed by the operator.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0004]** FIG. **1** is a drawing of an exemplary configuration of a diagnosis system according to a first embodiment;

**[0005]** FIG. **2** is a drawing for schematically illustrating an exterior appearance of a diagnosis apparatus according to the first embodiment;

**[0006]** FIG. **3** is a drawing for schematically illustrating an exterior appearance of an ultrasound probe according to the first embodiment being attached to a subject P;

**[0007]** FIG. **4** is an enlarged view of an exterior appearance of the ultrasound probe in the direction of an arrow A1 in FIG. **3**;

**[0008]** FIG. **5** is an enlarged view of an exterior appearance of the ultrasound probe in the direction of an arrow A2 in FIG. **3**;

**[0009]** FIG. **6** is a cross-sectional view of the ultrasound probe at a line I1-I1 in FIG. **5**;

**[0010]** FIG. **7** is a schematic drawing of a state of the ultrasound probe fixed in an intercostal region;

**[0011]** FIG. **8** is an enlarged view of an exterior appearance of a two-dimensional ultrasound probe according to the first embodiment;

**[0012]** FIG. **9** is a diagram of an exemplary configuration of an apparatus main body according to the first embodiment;

**[0013]** FIG. **10** is a flowchart of a processing procedure performed by the diagnosis apparatus according to the first embodiment;

**[0014]** FIG. **11** is an enlarged view of an exterior appearance of an ultrasound probe according to a first modification example;

**[0015]** FIG. **12** is a cross-sectional view of the ultrasound probe at a line I2-I2 in FIG. **11**;

**[0016]** FIG. **13** is a drawing of an exterior appearance of the ultrasound probe according to the first modification example being fixed onto a subject;

**[0017]** FIG. **14** is an enlarged view of an exterior appearance of an ultrasound probe according to a second modification example;

**[0018]** FIG. **15** is a cross-sectional view of the ultrasound probe at a line I3-I3 in FIG. **14**;

**[0019]** FIG. **16** is a cross-sectional view of an ultrasound probe according to a third modification example; and

**[0020]** FIG. **17** is a drawing of an example of an exercise-stress cardiac echo test performed by a diagnosis apparatus according to an exemplary embodiment.

## DETAILED DESCRIPTION

**[0021]** An ultrasound diagnosis apparatus according to an aspect includes an ultrasound probe and a processing apparatus. The ultrasound probe is configured so that a contact face thereof to be in contact with a subject for the purpose of adhering thereto is formed so as to have a shape that can be fitted to a projection part of the subject. The processing apparatus processes a reflected-wave signal of an ultrasound wave that is transmitted from the ultrasound probe attached to the subject toward the subject.

**[0022]** First, a diagnosis system according to a first embodiment will be explained, with reference to FIG. **1**. FIG. **1** is a drawing of an exemplary configuration of the diagnosis system according to the first embodiment. As shown in FIG. **1**, the diagnosis system according to the first embodiment in an exemplary mode includes: a diagnosis apparatus **1** attached to a subject P who is in a personal residence; an access point **11** such as a wireless router installed in the personal residence of the subject P; and a server apparatus **12** installed in a hospital. The access point **11** and the server apparatus **12** are capable of communicating with each other via a network **10**. For example, the access point **11** and the server apparatus **12** communicate with each other via a secure circuit such as a Virtual Private Network (VPN).

**[0023]** The diagnosis apparatus **1** is a portable ultrasound diagnosis apparatus that is carried by the subject P and is integrally provided with a Holter electrocardiography device. The diagnosis apparatus **1** is configured to wirelessly communicate with the access point **11**. More specifically, the diagnosis apparatus **1** includes an apparatus main body **100** and an ultrasound probe **101** that is thin and can be fixed onto the subject P. The apparatus main body **100** is configured to regularly record an electrocardiogram (ECG) while the subject P is leading a daily life and to generate ultrasound images from reflected-wave signals of ultrasound waves transmitted from the ultrasound probe **101** to the subject P. Further, the apparatus main body **100** transmits the ECGs and the ultrasound images to the server apparatus **12** via the network **10**, by regularly transmitting the ECGs and the ultrasound images to the access point **11**.

**[0024]** The server apparatus **12** stores therein, for each examined subject (i.e., subject), personal information regarding the subject and various types of medical data such as ECGs and ultrasound images obtained from the subject. The server apparatus **12** according to the first embodiment is configured to accumulate therein the ECGs and the ultrasound images that are obtained from the subject P while the subject P is leading a daily life, by receiving the ECGs and the ultrasound images that are regularly transmitted from the apparatus main body **100**. With this arrangement, a medical doctor or the like who is in the hospital is able to view the ECGs and the ultrasound images obtained from the subject P who is in the personal residence, by accessing the server apparatus **12** via a portable terminal or a personal computer.

**[0025]** In this situation, the apparatus main body **100** according to the first embodiment is configured to analyze the ECGs regularly acquired from the subject P. Further, when having detected an abnormality in the subject P as a result of analyzing the ECGs, the apparatus main body **100** generates an ultrasound image of the subject P by causing the ultrasound probe **101** to transmit an ultrasound wave. In other words, when there is a possibility that the subject P may have an abnormality as a result of the analysis using the ECGs, the apparatus main body **100** generates the ultrasound image by immediately scanning the subject P by using the ultrasound probe **101**. Further, every time an ultrasound image is generated, the apparatus main body **100** transmits the ultrasound image to the server apparatus **12**, together with the ECG corresponding to the time when the abnormality was detected. As a result, the diagnosis apparatus **1** according to the first embodiment makes it possible to examine the subject P while using not only the ECGs but also the ultrasound images, when there is a possibility that subject P may have an abnormality. Generally speaking, because ECGs are obtained from small electric signals flowing in the subject P, waveforms of the ECGs may change due to changes in the posture of the subject P, and waveforms of the ECGs may have noise due to body movements of the subject. However, the diagnosis apparatus **1** according to the first embodiment makes it possible to examine the subject P in an integral manner while using the ECGs and the ultrasound images. Thus, even if the waveforms of the ECGs are disturbed by the posture changes and/or the body movements of the subject P, it is possible to improve the level of precision of the diagnoses made by the medical doctor.

**[0026]** Next, the diagnosis apparatus **1** described above will be explained further in detail. In the following sections, the ultrasound probe **101** that makes it possible to examine the subject P in an integral manner will be explained first. Secondly, a configuration and a processing procedure of the apparatus main body **100** will be explained. In the first embodiment, an example will be explained in which the diagnosis apparatus **1** is configured to regularly record an ECG of the subject P and also to generate, when an abnormality has been detected, an ultrasound image of the chest (e.g., the heart) of the subject P. It should be noted, however, that it is acceptable to configure the diagnosis apparatus **1** so as to generate ultrasound images of a site (e.g., the abdomen) other than the chest.

**[0027]** FIG. **2** is a drawing for schematically illustrating an exterior appearance of the diagnosis apparatus **1** according to the first embodiment. As shown in FIG. **2**, the diagnosis apparatus **1** according to the first embodiment includes the apparatus main body **100**, the ultrasound probe **101**, and Holter electrocardiograph (ECG) probes **111**.

**[0028]** The apparatus main body **100** and the ultrasound probe **101** are connected to each other by a cable **102** so as to allow electric communication therebetween, whereas the apparatus main body **100** and the Holter ECG probes **111** are connected to each other by a cable **112** so as to allow electric communication therebetween. The cable **102** and the cable **112** are bendable members and are configured with, for example, metal wires each covered with an electrically-insulating material such as rubber.

**[0029]** The Holter ECG probes **111** are fixed onto the body surface of the subject P by adhesive pads or the like and are configured to obtain ECG data by detecting small electric signals from the inside of the subject P. The ultrasound probe **101** is configured so that a contact face thereof to be in contact with the subject P for the purpose of adhering thereto is formed so as to have a shape that can be fitted to a projection part (e.g., a rib) of the subject P. The ultrasound probe **101** transmits an ultrasound wave to the subject P and receives a reflected-wave signal obtained when the ultrasound wave is reflected on the inside of the subject P. The apparatus main body **100** is a processing apparatus that processes the reflected-wave signal of the ultrasound wave that is transmitted from the ultrasound probe **101** attached to the subject P toward the subject P. More specifically, the apparatus main body **100** is configured to receive the ECG data obtained by the Holter ECG probes **111** and to generate an ultrasound images by using the reflected-wave signal received by the ultrasound probe **101**.

**[0030]** Because the diagnosis apparatus **1** is configured so as to be attachable to the subject P, the diagnosis apparatus **1** is able to obtain the ECG data and the ultrasound images from the subject P, while the subject P is leading a daily life. In particular, because the ultrasound probe **101** according to the first embodiment is configured so as to be thin and have a plate-like shape, it is possible to fix the ultrasound probe **101** onto the subject P.

**[0031]** Next, the shape of the ultrasound probe **101** according to the first embodiment will be explained, with reference to FIGS. **3** to **5**. FIG. **3** is a drawing for schematically illustrating an exterior appearance of the ultrasound probe **101** according to the first embodiment being attached to the subject P. FIG. **3** illustrates an exemplary side view of the subject P to whom the ultrasound probe **101** is attached.

**[0032]** In the example shown in FIG. **3**, the ultrasound probe **101** is attached to the body surface of the subject P in the vicinity of the chest and is connected, via the cable **102**, to the apparatus main body **100** attached to the vicinity of the waist of the subject P. The ultrasound probe **101** is fixed onto the subject P by a fixing-purpose belt, an adhesive pad, or the like. For example, as shown with the subject P in FIG. **1**, the ultrasound probe **101** may be fixed onto the subject P by using a fixing-purpose belt configured with an elastic member that closely adheres to the body surface. In another example, the ultrasound probe **101** may be fixed onto the subject P via an adhesive pad that has adhesiveness and is applied to the subject. The ultrasound probe **101** does not have any protruding grips used by a medical doctor or the like for holding the ultrasound probe **101**, so that the shape of the ultrasound probe **101** is unlikely to hinder movements of the subject P, even while the ultrasound probe **101** is fixed onto the subject P. This aspect will be explained, with reference to FIGS. **4** and **5**.

**[0033]** FIGS. **4** and **5** are enlarged views of exterior appearances of the ultrasound probe **101** according to the first embodiment. FIG. **4** is an enlarged view of an exterior appearance of the ultrasound probe **101** in the direction of an arrow A1 in FIG. **3**. FIG. **5** is an enlarged view of an exterior appearance of the ultrasound probe **101** in the direction of an arrow A2 in FIG. **3**.

**[0034]** As shown in FIGS. **4** and **5**, the ultrasound probe **101** has an exterior case **103** that has a plate-like shape and is hollow. In the example shown in FIGS. **4** and **5**, the exterior case **103** has the shape of a substantially rectangular parallelepiped and is formed by using a synthetic resin, for example. More specifically, in the state illustrated in FIG. **4**, the exterior case **103** is formed so that the upper and the lower faces each have a predetermined area, whereas the thickness (i.e., the dimension in the height direction) is small. Further, the exterior case **103** is shaped so that the twelve sides of the rectangular parallelepiped are roundish.

**[0035]** Further, as shown in FIG. **5**, the ultrasound probe **101** has an opening formed in a contact face **104**, which is a face of the exterior case **103** to be brought into contact with the subject P. An acoustic lens **105** is provided in the opening. The acoustic lens **105** is configured to converge the ultrasound waves generated from piezoelectric elements **107** (explained later). This aspect will be explained with reference to FIG. **6**.

**[0036]** FIG. **6** is a cross-sectional view of the ultrasound probe **101** at a line I1-I1 in FIG. **5**. As shown in FIG. **6**, the exterior case **103** of the ultrasound probe **101** according to the first embodiment has an opening **104***a* formed in the contact face **104**, the opening **104***a* being a hole that has substantially the same shape as that of the lower face of the acoustic lens **105**. Further, the acoustic lens **105** is fixed to the opening **104***a*. In other words, the acoustic lens **105** is provided so that a curved portion thereof is disposed on the exterior case **103**, the curved portion being formed so as to have a convex shape that can be fitted to a space between bones, each of which is a projection part of the subject P.

**[0037]** Further, the ultrasound probe **101** is structured so that, when the contact face **104** of the exterior case **103** is considered as the upper face, an acoustic matching layer **106**, the piezoelectric elements **107**, and a backing member **108** are laminated in the direction from the acoustic lens **105** toward the lower face of the exterior case **103**. As mentioned above, the acoustic lens **105** is configured to converge the ultrasound waves. The acoustic matching layer **106** mitigates mismatches of acoustic impedances between the piezoelectric elements **107** and the subject P.

**[0038]** The piezoelectric elements **107** are connected to the cable **102** by electrodes **109** of a flexible cable or the like and are configured to transmit and receive electric signals to and from the apparatus main body **100** via the electrodes **109**. The piezoelectric elements **107** generate ultrasound waves based on transmission signals supplied from the apparatus main body **100** and receive reflected-wave signals from the subject P. More specifically, the piezoelectric elements **107** according to the first embodiment generate the ultrasound waves in a substantially thickness direction F1 of the exterior case **103**. Although not shown in the drawing, the piezoelectric elements **107** include two or more piezoelectric elements each of which generates an ultrasound wave and receives a reflected-wave signal. It is assumed that, in the example illustrated in FIG. **6**, a plurality of piezoelectric vibrators are arranged in a row. Accordingly, the ultrasound probe **101** described above corresponds to a one-dimensional ultrasound probe. The backing member **108** is configured to prevent the ultrasound waves from propagating rearward (toward the lower face of the exterior case **103**) from the piezoelectric elements **107**.

**[0039]** For example, when an ultrasound wave is transmitted from the ultrasound probe **101** to the subject P, the transmitted ultrasound wave is repeatedly reflected on a surface of discontinuity of acoustic impedances at a tissue in the body of the subject and is received as a reflected-wave signal by the piezoelectric elements **107** included in the ultrasound probe **101**. The amplitude of the received reflected-wave signal is dependent on the difference between the acoustic impedances on the surface of discontinuity on which the ultrasound wave is reflected. When the transmitted ultrasound pulse is reflected on the surface of a flowing bloodstream or a cardiac wall, the reflected-wave signal is, due to the Doppler effect, subject to a frequency shift, depending on a velocity component of the moving members with respect to the ultrasound wave transmission direction. Further, the reflected-wave signal received by the ultrasound probe **101** is transmitted to the apparatus main body **100** via the cable **102**. By using the reflected-wave signals received from the ultrasound probe **101**, the apparatus main body **100** generates the ultrasound image of the subject P.

**[0040]** As explained above, the ultrasound probe **101** according to the first embodiment includes the plate-like exterior case **103** as illustrated in the examples in FIGS. **3** to **6**. Further, the acoustic lens **105** is provided on the contact face **104** of the exterior case **103** that is brought into contact with the subject P. The exterior case **103** has, on the inside thereof, the piezoelectric elements **107** that generate the ultrasound waves emitted in the substantially thickness direction F1 of the exterior case **103**, via the acoustic lens **105**. Because the ultrasound probe **101** is thin and has a plate-like shape, the ultrasound probe **101** can easily be fixed onto the subject P and is unlikely to hinder movements of the subject P, even while being fixed onto the subject P.

**[0041]** The ultrasound waves emitted from the ultrasound probe **101** described above are substantially totally reflected by the bones and the like inside the subject P. For this reason, even if the user wishes to have an ultrasound image of the heart generated, there is a possibility that the heart may not properly be rendered in the ultrasound image when a bone is positioned between the ultrasound probe **101** and the heart serving as the image taking target. Consequently, when an ultrasound image of the chest of the subject P is to be generated as described in the exemplary embodiment above, it is desirable to arrange the ultrasound waves emitted from the ultrasound probe **101** so as to arrive at the heart or the like while avoiding the ribs of the subject P. For this reason, it is desirable to arrange the acoustic lens **105** included in the ultrasound probe **101** described above so as to have a convex shape that fits an intercostal region of the subject P. This aspect will be explained, with reference to FIG. **7**.

**[0042]** FIG. **7** is a schematic drawing of a state of the ultrasound probe **101** fixed in an intercostal region. To clearly indicate the shape of the acoustic lens **105**, FIG. **7** illustrates the state as if the acoustic lens **105** was directly fitted to the intercostal region of the subject P. However, in actuality, the ultrasound probe **101** is adhered to the body surface of the subject P and is not in direct contact with the ribs. As shown in the example in FIG. **6**, the acoustic lens **105** is formed so as to have a convex shape curving away from the contact face **104** of the exterior case **103**. In this situation, as shown in the

example in FIG. **7**, the acoustic lens **105** is formed so that the curved portion thereof has a shape that can be fitted to an intercostal region of the subject P. With this arrangement, when the ultrasound probe **101** is fixed onto the subject P in such a manner that the acoustic lens **105** is positioned in the intercostal region, the ultrasound waves emitted from the ultrasound probe **101** are able to advance while avoiding the ribs. As a result, the apparatus main body **100** is able to generate an ultrasound image in which the heart or the like surrounded by the ribs are rendered, by using the reflected-wave signals received by the ultrasound probe **101**. Further, the acoustic lens **105** having the convex shape that fits the intercostal region can easily be fitted to the intercostal region. Consequently, the configuration makes it easy to fix the ultrasound probe **101** onto the subject P.

**[0043]** Further, in the first embodiment described above, the example is explained in which the ultrasound probe **101** is a one-dimensional ultrasound probe in which the plurality of piezoelectric vibrators are arranged in a row. However, it is acceptable to configure the ultrasound probe **101** with a two-dimensional ultrasound probe in which a plurality of piezoelectric vibrators are two-dimensionally arranged in a grid formation. FIG. **8** is an enlarged view of an exterior appearance of a two-dimensional ultrasound probe **101** according to the first embodiment. FIG. **8** corresponds to FIG. **5**. In the two-dimensional ultrasound probe **101**, because the plurality of piezoelectric vibrators are two-dimensionally arranged in the grid formation, an acoustic lens **105***a* is provided of which the dimensions in the length direction and the width direction are substantially equal, as shown in the example in FIG. **8**. It is also desirable to arrange the acoustic lens **105***a* so as to have a convex shape that fits an intercostal region of the subject P.

**[0044]** Next, the apparatus main body **100** according to the first embodiment will be explained, with reference to FIG. **9**. FIG. **9** is a diagram of an exemplary configuration of the apparatus main body **100** according to the first embodiment. The apparatus main body **100** shown in FIG. **9** has a battery (not shown) or the like installed therein and is configured to operate on the battery. As shown in FIG. **9**, the apparatus main body **100** according to the first embodiment has connected thereto the ultrasound probe **101**, the Holter ECG probes **111**, and an input apparatus **21**.

**[0045]** The input apparatus **21** is configured with input devices such as a panel switch, a touch command screen, a trackball, a button, and/or the like. These input devices are provided on a lateral face of the apparatus main body **100**, for example. The apparatus main body **100** receives an operation instruction from a user (e.g., the subject P) via the input apparatus **21**.

**[0046]** Further, the apparatus main body **100** is connected to the network **10** and an external storage device **22**. In the first embodiment, it is assumed that the apparatus main body **100** is wirelessly connected to the network **10** and the external storage device **22**. The external storage device **22** is, for example, the server apparatus **12** installed in the hospital as illustrated in FIG. **1** or a storage server connected to the server apparatus **12**.

**[0047]** Further, as shown in FIG. **9**, the apparatus main body **100** includes a Holter ECG system **121**, an analyzing circuit **122**, a bookmark circuit **123**, a system controller **124**, a scan controller **125**, a transmitting and receiving unit **126**, a B-mode processing unit **127**, a Doppler mode processing unit **128**, a coordinate converting circuit **129**, an image synthesizing circuit **130**, an internal storage device **131**, and an external interface unit **132**.

**[0048]** The Holter ECG probes **111** obtain the ECG data by detecting the small electric signals from the inside of the subject P, while being fixed to the body surface of the subject P by the adhesive pad or the like. The Holter ECG system **121** receives the ECG data obtained by the Holter ECG probes **111**. Further, the Holter ECG system **121** stores the ECG data into the internal storage device **131**. The Holter ECG system **121** according to the first embodiment is configured to constantly receive the ECG data from the Holter ECG probes **111** and to accumulate the received ECG data into the internal storage device **131**.

**[0049]** The analyzing circuit **122** receives the ECG data from the Holter ECG probes **111** and judges whether any abnormality is occurring in the subject P by analyzing the received ECG data in a real-time manner. Further, when having determined that there is a possibility that an abnormality may be occurring in the subject P as a result of the analysis, the analyzing circuit **122** transmits an abnormality occurrence notification to the bookmark circuit **123** and to the system controller **124**.

**[0050]** The analyzing process performed by the analyzing circuit **122** can be explained as follows: For example, the analyzing circuit **122** obtains, from the ECG data, a P-wave, QRS waves (a Q-wave, an R-wave, and an S-wave), and a T-wave representing a waveform of cardiac cycles and judges whether an abnormality is occurring in the subject P by using these waves. For example, a time period between the Q-wave and the S-wave denotes a ventricular systolic period, whereas a time period between the S-wave and the T-wave denotes a ventricular diastolic period. Thus, the analyzing circuit **122** judges whether the subject P is suspected to have an ischemic heart disease or a myocardial infarction, by analyzing the motions of the heart in the S-T period (the time period between the S-wave and the T-wave). As another example, a section where the waveform is horizontal at 0 mv can be observed in an S-T period. Angina pectoris makes the horizontal portion lower than that in a normal state, whereas a myocardial infarction makes the horizontal portion higher. Thus, by analyzing the S-T period, the analyzing circuit **122** judges whether the subject P is suspected to have angina pectoris.

**[0051]** When having received an abnormality occurrence notification from the analyzing circuit **122**, the bookmark circuit **123** stores therein an abnormality occurrence time indicating the time at which the abnormality occurrence notification was received. For example, the bookmark circuit **123** stores the abnormality occurrence time into a predetermined storage memory as a log. In addition, the bookmark circuit **123** may add the abnormality occurrence time, as a piece of data, to the ECG data from which the abnormality was detected by the analyzing circuit **122**.

**[0052]** The system controller **124** is configured by using an electronic circuit such as a Central Processing Unit (CPU) or a Micro Processing Unit (MPU) or an integrated circuit such as an Application Specific Integrated Circuit (ASIC) or a Field Programmable Gate Array (FPGA) and is configured to exercise overall control of the processes performed by the apparatus main body **100**. Although the controlling lines are not illustrated in FIG. **9**, the system controller **124** controls

processes performed by functional units in the apparatus main body **100** by transmitting control signals to the functional units.

**[0053]** When having received an abnormality occurrence notification from the analyzing circuit **122**, the system controller **124** according to the first embodiment controls the scan controller **125** so as to perform a scanning process using the ultrasound probe **101** until a predetermined period of time (e.g., one second, two seconds, or five seconds) has elapsed since the time at which the abnormality occurrence notification is received.

**[0054]** By controlling the transmitting and receiving unit **126**, the scan controller **125** causes the ultrasound probe **101** to start a scan. In this situation, the scan controller **125** controls the transmitting and receiving unit **126** so as to perform the scan for the time period specified by the system controller **124**.

**[0055]** The transmitting and receiving unit **126** performs an ultrasound transmitting and receiving process. More specifically, to transmit ultrasound waves, the transmitting and receiving unit **126** causes a pulser therein to sequentially generate high-voltage pulses in correspondence with predetermined delay periods. When the high-voltage pulses are sequentially applied to the vibrator cells of the piezoelectric elements **107** included in the ultrasound probe **101**, an ultrasound wave is generated in each of the vibrator cells.

**[0056]** Further, to receive the ultrasound waves, the vibrator cells of the piezoelectric elements **107** within the ultrasound probe **101** receive the reflected waves of the ultrasound beams, so that reception signals corresponding to a plurality of channels are input to the transmitting and receiving unit **126**. After a gain correcting process is applied to the reception signals by a pre-amplifier, the transmitting and receiving unit **126** performs an Analog/Digital (A/D) conversion thereon. Subsequently, after performing delay control and an adding process (a phase-matching addition) on the signals resulting from the A/D conversion for each of the channels in correspondence with each reception focus position, the transmitting and receiving unit **126** generates reflected-wave data by controlling a signal bandwidth by using a quadrature detection and a bandwidth limiting filter and further transmits the generated reflected-wave data to the B-mode processing unit **127** and the Doppler mode processing unit **128**.

**[0057]** The B-mode processing unit **127** receives the reflected-wave data from the transmitting and receiving unit **126** and generates data (B-mode data) in which the strength of each signal is expressed by a degree of brightness, by performing a logarithmic amplification, an envelope detection process, and the like on the received reflected-wave data.

**[0058]** The Doppler mode processing unit **128** extracts bloodstreams, tissues, and contrast echo components under the influence of the Doppler effect by performing a frequency analysis so as to obtain velocity information from the reflected-wave data received from the transmitting and receiving unit **126**, and further generates data (Doppler data) obtained by extracting bloodstream information such as an average velocity, the dispersion, the power, and the like for a plurality of points.

**[0059]** The B-mode data generated by the B-mode processing unit **127** and the Doppler data generated by the Doppler mode processing unit **128** may be referred to as raw data and are stored in the internal storage device **131**. The raw data is also transmitted to the coordinate converting circuit **129**.

**[0060]** The coordinate converting circuit **129** converts the raw data received from the B-mode processing unit **127** and the Doppler mode processing unit **128**, from a coordinate system used when the data was reception beams, into a rectangular coordinate system used for displaying images.

**[0061]** The image synthesizing circuit **130** stores a B-mode image and a Doppler-mode/color-mode image of which the coordinate systems were changed into the rectangular coordinate system by the coordinate converting circuit **129**, into the internal storage device **131** and further performs an image synthesizing process thereon so as to synthesize the images with text information indicating an image acquisition condition or the like. After that, the image synthesizing circuit **130** assigns Red-Green-Blue (RGB) map values thereto. Thus, the image synthesizing circuit **130** generates synthesized images as the ultrasound images.

**[0062]** The internal storage device **131** is a storage device configured with a Random Access Memory (RAM), a flash memory, a flash Solid State Drive (SSD), or the like. The internal storage device **131** stores therein the raw data generated by the B-mode processing unit **127** and the Doppler mode processing unit **128**, as well as the ultrasound images and the like generated by the image synthesizing circuit **130**.

**[0063]** The external interface unit **132** transmits and receives various types of data to and from external apparatuses via wireless communications. More specifically, the system controller **124** has a wireless communication function and is capable of storing the raw data, the ultrasound images, and the like stored in the internal storage device **131** into the external storage device **22**.

**[0064]** In this situation, when the system controller **124** according to the first embodiment has received the abnormality occurrence notification from the analyzing circuit **122** and has controlled the scan controller **125** so as to perform the scanning process for the predetermined period of time, the system controller **124** stores the abnormality occurrence time recorded by the bookmark circuit **123**, the ECG data from which the abnormality was detected by the analyzing circuit **122**, and the ultrasound image generated as a result of controlling the scan controller **125**, into the internal storage device **131** while keeping these items in correspondence with one another. Further, the system controller **124** transmits the group of data that is stored in the internal storage device **131** and in which the abnormality occurrence time, the ECG data, and the ultrasound image are kept in correspondence with one another to the server apparatus **12**. The system controller **124** may regularly obtain such a group of data from the internal storage device **131** and transmit the obtained group of data to the server apparatus **12** or may transmit such a group of data to the server apparatus **12** every time an abnormality is detected by the analyzing circuit **122**.

**[0065]** Next, a processing procedure performed by the diagnosis apparatus **1** according to the first embodiment will be explained, with reference to FIG. **10**. FIG. **10** is a flowchart of the processing procedure performed by the diagnosis apparatus **1** according to the first embodiment.

**[0066]** As shown in FIG. **10**, the apparatus main body **100** of the diagnosis apparatus **1** sequentially obtains pieces of ECG data of the subject P via the Holter ECG probes **111** (step S**101**). After that, the analyzing circuit **122** included the apparatus main body **100** judges whether an abnormality is occurring in the subject P, by analyzing the pieces of ECG data sequentially obtained (step S**102**). Subsequently, as long as no abnormality is detected in the subject P by the analyzing

circuit **122** (step S**102**: No), the apparatus main body **100** sequentially obtains pieces of ECG data of the subject P via the Holter ECG probes **111** (step S**101**).

**[0067]** On the contrary, when an abnormality is detected in the subject P by the analyzing circuit **122** (step S**102**: Yes), the system controller **124** included in the apparatus main body **100** starts a scanning process using the ultrasound probe **101** by controlling the scan controller **125** (step S**103**). As a result, the ultrasound probe **101**, the transmitting and receiving unit **126**, the B-mode processing unit **127**, the Doppler mode processing unit **128**, the coordinate converting circuit **129**, the image synthesizing circuit **130**, and the like perform processes, and the apparatus main body **100** thus generates an ultrasound image (step S**104**).

**[0068]** After that, the system controller **124** stores the ECG data from which the abnormality was detected at step S**102** and the ultrasound image generated at step S**104**, into the internal storage device **131**, while keeping these items in correspondence with each other (step S**105**). Subsequently, the system controller **124** transmits the set that is made up of the ECG data and the ultrasound image and is stored in the internal storage device **131** to the server apparatus **12** (step S**106**).

**[0069]** As explained above, according to the first embodiment, it is possible to attach the ultrasound probe **101** to the subject P.

**[0070]** Further, according to the first embodiment, it is possible to examine the subject in an integral manner while using the ECGs and the ultrasound images. Thus, even if the waveforms of the ECGs are disturbed by the posture changes and/or the body movements of the subject P, it is possible to improve the level of precision of the diagnosis made by the medical doctor.

**[0071]** In the first embodiment, the example is explained in which the diagnosis apparatus **1** generates an ultrasound image when an abnormality is detected by analyzing the ECG. However, it is acceptable to configure the diagnosis apparatus **1** so as to generate an ultrasound image even if no abnormality is detected in an analysis result of the ECG. For example, it is acceptable to configure the diagnosis apparatus **1** so as to start the scanning process using the ultrasound probe **101** and to generate an ultrasound image every time a predetermined period of time has elapsed.

**[0072]** In another example, it is also acceptable to configure the diagnosis apparatus **1** so as to generate an ultrasound image at a specific time. For example, generally speaking, it is known that arrhythmias and coronary spastic angina involving a spasm of a coronary artery often occur at night or in the early morning regardless of physical exertion. Thus, it is sometimes difficult to make a diagnosis from an ECG test or a stress ECG test performed at a hospital. Consequently, it is acceptable to configure the diagnosis apparatus **1** so that the process of causing the ultrasound probe **101** to start the scanning process is performed in a concentrated manner at night and in the early morning. With this arrangement, the diagnosis apparatus **1** may be able to generate an ultrasound image that makes it possible to diagnose coronary spastic angina or the like of the subject P.

**[0073]** Further, when the diagnosis apparatus **1** is used for the purpose of regularly generating ultrasound images or for the purpose of generating ultrasound images in specific periods of time as described in the examples above, the diagnosis apparatus **1** does not necessarily have to include the ECG system. More specifically, the diagnosis apparatus **1** does not necessarily have to include the Holter ECG probes **111**, the Holter ECG system **121**, the analyzing circuit **122**, and the bookmark circuit **123** shown in FIG. **9**.

**[0074]** Further, in the first embodiment described above, the example is explained in which, if occurrence of an abnormality is detected by analyzing an ECG, the diagnosis apparatus **1** performs the scanning process using the ultrasound probe **101**, until the predetermined period of time has elapsed since the abnormality occurrence time. However, it is also acceptable to configure the diagnosis apparatus **1** so as to, if occurrence of an abnormality is detected, perform the scanning process using the ultrasound probe **101** until a predetermined number of ultrasound images have been generated.

**[0075]** Further, in the first embodiment described above, it is acceptable to configure the diagnosis apparatus **1** so as to identify cardiac phases by analyzing the ECG and to intermittently perform the scanning process using the ultrasound probe **101** at times in a specific cardiac phase. Further, it is acceptable to configure the diagnosis apparatus **1** so as to transmit the intermittently-generated ultrasound images and such ECGs that were obtained when the ultrasound images were generated, to the server apparatus **12**. In that situation, it is acceptable to configure the server apparatus **12** so as to analyze, in a real-time manner, the ultrasound images and the ECGs transmitted from the diagnosis apparatus **1** and so as to, if an abnormality is detected in motions of the cardiac walls or the like, store an abnormality occurrence time into a predetermined storage memory as a log.

**[0076]** Further, in the first embodiment described above, it is acceptable to configure the diagnosis apparatus **1** so as to obtain volume data, which is three-dimensional medical image data, if the ultrasound probe **101** is configured with a two-dimensional ultrasound probe as illustrated in FIG. **8**.

**[0077]** Further, in the first embodiment described above, it is acceptable to configure the system controller **124** included in the diagnosis apparatus **1** so as to send, via e-mail for example, an alert to a portable terminal or the like that is held by a medical doctor or the like, when the number of times an abnormality is detected by the analyzing circuit **122** has exceeded a predetermined value or when the analyzing circuit **122** has kept detecting abnormalities for a predetermined period of time.

**[0078]** Further, in the first embodiment described above, it is acceptable to configure the diagnosis apparatus **1** so as to include a wrist-watch-style pulse measuring apparatus configured to obtain a pulse rate of the subject P, instead of the Holter ECG probes **111**. In that situation, the analyzing circuit **122** determines that an abnormality has occurred in the subject P when, for example, the pulse rate is not in a predetermined threshold range.

**[0079]** Further, in the first embodiment described above, it is acceptable to configure the transmitting and receiving unit **126**, the B-mode processing unit **127**, the Doppler mode processing unit **128**, the coordinate converting circuit **129**, the image synthesizing circuit **130**, and the like illustrated in FIG. **9** so as to operate in a power-saving mode (i.e., a standby state) and so as to, when an abnormality is detected by the analyzing circuit **122**, exit the power-saving mode (i.e., the standby state) and operate in a normal power-supply mode, according to the control of the system controller **124**.

**[0080]** Further, in the first embodiment described above, it is acceptable to configure the diagnosis apparatus **1** so as not to generate the ultrasound images, but so as to transmit the reflected-wave signals received by the ultrasound probe **101**

to the server apparatus **12**. In that situation, the ultrasound probe **101** does not necessarily have to include the B-mode processing unit **127**, the Doppler mode processing unit **128**, the coordinate converting circuit **129**, and the image synthesizing circuit **130** illustrated in FIG. **9**. With this arrangement, it is possible to make the ultrasound probe **101** more compact. Further, in that situation, the server apparatus **12** has functions equivalent to those of the B-mode processing unit **127**, the Doppler mode processing unit **128**, the coordinate converting circuit **129**, and the image synthesizing circuit **130** illustrated in FIG. **9** and generates ultrasound images by using the reflected-wave signals received from the diagnosis apparatus **1**.

**[0081]** In the examples described above, it is acceptable to configure the diagnosis apparatus **1** so as to perform up to the process of generating the raw data from the reflected-wave signals received by the ultrasound probe **101** and to transmit the generated raw data to the server apparatus **12**. In that situation, the ultrasound probe **101** does not necessarily have to include the coordinate converting circuit **129** and the image synthesizing circuit **130** illustrated in FIG. **9**. Further, in that situation, the server apparatus **12** has functions equivalent to those of the coordinate converting circuit **129** and the image synthesizing circuit **130** illustrated in FIG. **9** and generates ultrasound images by using the raw data received from the diagnosis apparatus **1**. In this example, because the raw data generated by the B-mode processing unit **127** or the Doppler mode processing unit **128** is smaller in data size than the reflected-wave signals, it is possible to prevent the communication bandwidth between the diagnosis apparatus **1** and the access point **11** from being congested. Similarly, it is also possible to prevent the communication bandwidth between the access point **11** and the server apparatus **12** from being congested.

**[0082]** Further, in the examples described above, it is acceptable to configure the diagnosis apparatus **1** so that the transmission is directed to a desktop personal computer, a notebook personal computer, a tablet personal computer, a portable terminal, or the like used by a medical doctor, a nurse, or the like. Further, it is also acceptable to configure the diagnosis apparatus **1** so as to transmit only the ECGs or only the ultrasound images to the server apparatus **12** or to a personal computer or the like used by a medical doctor or the like, instead of transmitting the sets each made up of an ECG and an ultrasound image. Further, it is also acceptable to configure the diagnosis apparatus **1** so as to transmit sets made up of ECGs and ultrasound images obtained before and after the time at which an abnormality is detected by the analyzing circuit **122**.

**[0083]** In the first embodiment, the shape of the ultrasound probe **101** that is thin and has a plate-like shape was explained, with reference to FIGS. **3** to **8**. However, the shape of an ultrasound probe connected to the diagnosis apparatus **1** is not limited to the one described in the first embodiment. In a second embodiment, other exemplary shapes of the ultrasound probe will be explained.

**[0084]** Sloped Face

**[0085]** In the first embodiment, the example is explained in which the ultrasound probe has the exterior case **103** having the shape of a substantially rectangular parallelepiped in which the upper face and the lower face are positioned substantially parallel to each other. However, it is acceptable to configure an ultrasound probe so as to have an exterior case in which the two faces are not positioned parallel to each other. This aspect will be explained with reference to FIGS. **11** and **12**. FIG. **11** is an enlarged view of an exterior appearance of an ultrasound probe **201** according to a first modification example. FIG. **12** is a cross-sectional view of the ultrasound probe **201** at a line I2-I2 in FIG. **11**.

**[0086]** As shown in FIG. **11**, the ultrasound probe **201** according to the first modification example is shaped so that a contact face **204** to be brought into contact with the subject P is a sloped face. More specifically, in the example shown in FIG. **12**, an exterior case **203** of the ultrasound probe **201** is shaped so that a thickness F12 of a lateral face **203***b* is larger than a thickness F11 of a lateral face **203***a* to which the cable **102** is connected, the lateral face **203***b* being positioned opposite to the lateral face **203***a*. The thickness of the exterior case **203** increases from the lateral face **203***a* toward the lateral face **203***b*. In other words, in the example shown in FIG. **11**, the ultrasound probe **201** according to the first modification example is configured so that an opening **205***a* having a bottom **205***b* that is substantially parallel to the lower face of the ultrasound probe **201** is formed in a part of the contact face **204**, which is formed as the sloped face that is not positioned parallel to the lower face. The acoustic lens **105** is fixed to the bottom **205***b* of the opening **205***a*.

**[0087]** FIG. **13** is a drawing of an exterior appearance of the ultrasound probe **201** according to the first modification example being fixed onto the subject P. As shown in FIG. **13**, when the ultrasound probe **201** according to the first modification example is fixed onto the subject P, the direction of the ultrasound waves emitted through the acoustic lens **105** is tilted in accordance with the slope of the contact face **204**. As a result, even if the piezoelectric elements included therein are not of a swingable type, the ultrasound probe **201** according to the first modification example is able to transmit the ultrasound waves in the directions other than the direction substantially perpendicular to the body surface, in accordance with the angle formed by the upper and the lower faces of the exterior case **203**. As shown in FIG. **13**, ultrasound gel is applied to the space between the subject P and the acoustic lens **105** of the ultrasound probe **201** so as to fill in the space.

**[0088]** Grooves

**[0089]** In the first embodiment described above, the example is explained in which the ultrasound probe has the plate-like exterior case **103** having the shape of a substantially rectangular parallelepiped in which the upper face and the lower face are positioned substantially parallel to each other. However, it is also acceptable to configure an ultrasound probe so as to have an exterior case in which concave portions to be engaged with projection parts (e.g., bones) of the subject P are formed in the contact face which is one of the upper and the lower faces that has the acoustic lens **105** provided thereon. This aspect will be explained with reference to FIGS. **14** and **15**. FIG. **14** is an enlarged view of an exterior appearance of an ultrasound probe **301** according to a second modification example. FIG. **15** is a cross-sectional view of the ultrasound probe **301** at a line I3-I3 in FIG. **14**.

**[0090]** As shown in FIGS. **14** and **15**, the ultrasound probe **301** according to the second modification example has an exterior case **303** in which concave portions **304***a* and **304***b*, which are substantially linear grooves, are formed in a contact face **304** to be brought into contact with the subject P. In the example shown in FIGS. **14** and **15**, the exterior case **303** has the concave portions **304***a* and **304***b* formed so that the acoustic lens **105** is interposed therebetween. More specifically, in the example shown in FIG. **15**, the exterior case **303** of the

ultrasound probe **301** has the concave portion **304***a* formed so as to be positioned between a lateral face **303***a* to which the cable **102** is connected and the acoustic lens **105** and has the concave portion **304***b* formed so as to be positioned between a lateral face **303***b* positioned opposite to the lateral face **303***a* and the acoustic lens **105**. The concave portions **304***a* and **304***b* are grooves that cave into the contact face **304** in the direction toward the lower face (i.e., the bottom) and are configured to be engaged with the projection parts of the subject P.

**[0091]** Because the concave portions **304***a* and **304***b* are shaped so as to be easily fitted to an intercostal region, it is possible to easily fix the ultrasound probe **301** onto the subject P. More specifically, because the ultrasound probe **301** has the exterior case **303** in which the concave portions **304***a* and **304***b* are formed on either side of the acoustic lens **105**, the concave portions **304***a* and **304***b* are positioned at the ribs of the subject P, in the example illustrated in FIG. **7**. Consequently, it is possible to easily fix the ultrasound probe **301** onto the subject P. As a result, the configuration makes it possible to regularly take images of a fixedly-selected site (e.g., the heart) inside the subject P.

**[0092]** Adaptors

**[0093]** In the first embodiment described above, the example is explained in which the ultrasound probe has the plate-like exterior case **103** having the shape of a substantially rectangular parallelepiped in which the upper face and the lower face are positioned substantially parallel to each other. However, it is also acceptable to configure an ultrasound probe so as to have an exterior case provided with expandable members that are expandable in a direction away from the contact face (i.e., a plurality of plate-like adhesive members among which one or more are piled up). This aspect will be explained with reference to FIG. **16**. FIG. **16** is a cross-sectional view of an ultrasound probe **401** according to a third modification example.

**[0094]** As shown in FIG. **16**, the ultrasound probe **401** according to the third modification example is configured so that adaptors **404***a* and **404***b* are provided as the expandable members that are expandable in the direction away from a contact face **404**, on at least such an area of the contact face **404** of an exterior case **403** that excludes a central part. In the example shown in FIG. **16**, the adaptors **404***a* and **404***b* are provided on the contact face **404** of the exterior case **403** so that the acoustic lens **105** is interposed therebetween. More specifically, in the example illustrated in FIG. **16**, the adaptor **404***a* is provided on the contact face **404** of the exterior case **403** so as to be positioned between a lateral face **403***a* of the exterior case **403** to which the cable **102** is connected and the acoustic lens **105**. The adaptor **404***b* is provided on the contact face **404** of the exterior case **403** so as to be positioned between a lateral face **403***b* positioned opposite to the lateral face **403***a* and the acoustic lens **105**.

**[0095]** The adaptors **404***a* and **404***b* are members that are capable of freely expanding and contracting in the thickness direction of the exterior case **403**. For example, as shown in the example in FIG. **16**, the adaptors **404***a* and **404***b* are each structured by joining together a plurality of circular columnar members having mutually-different diameters in an expandable/contractible manner. In the example in FIG. **16**, the adaptors **404***a* and **404***b* are in an expanded state in which the circular columnar members are piled on top of one another with the smallest overlapping area.

**[0096]** Even if the piezoelectric elements included therein are not of a swingable type, the ultrasound probe **401** according to the third modification example is able to transmit the ultrasound waves in the directions other than the direction substantially perpendicular to the body surface, in accordance with the expansion/contraction state of the adaptors **404***a* and **404***b*. Further, by changing the expansion/contraction state of the adaptors **404***a* and **404***b*, it is possible to adjust the emission directions of the ultrasound waves of the ultrasound probe **401**. Like in the example shown in FIG. **13**, ultrasound gel is applied to the space between the subject P and the acoustic lens **105** of the ultrasound probe **401** so as to fill in the space.

**[0097]** Further, although not shown in the drawings, it is acceptable to configure the ultrasound probe **401** according to the third modification example so as to be provided with another member that is expandable/contractible or an elastic member, instead of the adaptors **404***a* and **404***b*. With this arrangement, when the ultrasound probe **401** is adhered, with pressure, to the body surface of the subject P by a fixation band or the like, it is possible to adjust the angle formed by the contact face **404** and the body surface by changing the shape of the expandable/contractible member or the like. Consequently, like in the example in FIG. **13**, the ultrasound probe **401** is able to transmit the ultrasound waves in the directions other than the direction substantially perpendicular to the body surface. In that situation, to adjust the angle, it is possible to correct the tilt angle by using together elastic members having mutually-different degrees of hardness (i.e., members having mutually-different shape-change ratios). Thus, like in the example in FIG. **16**, it is possible to make a fine adjustment so as to be able to transmit the ultrasound waves in desired directions other than the direction substantially perpendicular. Further, like in the example in FIG. **13**, ultrasound gel is applied to the space between the subject P and the acoustic lens **105** of the ultrasound probe **401** so as to fill in the space.

**[0098]** Further, although not shown in the drawings, it is also acceptable to configure the ultrasound probe **101** according to the first embodiment in such a manner that adhesive pads having mutually-different thicknesses are pasted on the contact face **104**. In this situation also, the ultrasound probe **101** is able to transmit the ultrasound waves in the directions other than the direction substantially perpendicular to the body surface, like in the example in FIG. **13**. In addition, it is possible to easily correct the tilt angle by changing the thicknesses of the adhesive pads. Consequently, like in the example in FIG. **16**, it is possible to make a fine adjustment so as to be able to transmit the ultrasound waves in desired directions other than the direction substantially perpendicular. Further, like in the example in FIG. **13**, ultrasound gel is applied to the space between the subject P and the acoustic lens **105** of the ultrasound probe **101** so as to fill in the space.

**[0099]** The shapes of the ultrasound probes **101**, **201**, **301**, and **401** are not limited to the examples described above. For instance, in the examples described above, the faces (e.g., the contact face) of the exterior case are substantially rectangular. However, the faces of the exterior case may have an arbitrary shape that is circular, oval, trapezoidal, or the like. Further, in the examples described above, the acoustic lens **105** is provided near the center of the contact face. However, it is acceptable to provide the acoustic lens **105** in an area other than the area near the center of the contact face.

**[0100]** Further, in the example shown in FIG. **11**, the contact face **204** and the bottom of the exterior case **203** form the predetermined angle therebetween. However, the contact face **204** and the bottom of the ultrasound probe **201** may be positioned substantially parallel to each other. In that situation, the bottom **205***b* of the opening **205***a* and the contact face **204** of the exterior case **203** shown in FIG. **12** have such a relationship so as to form a predetermined angle therebetween. Even in that situation, it is possible to transmit the ultrasound waves in the directions other than the direction perpendicular to the body surface.

**[0101]** Further, in the example in FIG. **14**, the substantially linear concave portions **304***a* and **304***b* are formed in the contact face **304** of the exterior case **303**. However, the concave portions **304***a* and **304***b* do not necessarily have to be substantially linear and may have any shape as long as the concave portions **304***a* and **304***b* are able to engage with projection parts (e.g., bones) of the subject P.

**[0102]** Further, it is effective to apply the ultrasound probes of which the ultrasound transmission directions are controllable as shown in FIGS. **11** to **13** and **16**, to a one-dimensional ultrasound probe. In other words, although the ultrasound transmission directions of one-dimensional ultrasound probes are fixed, it becomes possible to control the ultrasound transmission directions by using the structures shown in FIGS. **11** to **13** and **16**.

**[0103]** Stationary-Type Apparatus

**[0104]** In the exemplary embodiments explained with reference to FIGS. **1** to **16**, it is assumed that the diagnosis apparatus **1** is carried by the subject P. However, it is also acceptable to configure the diagnosis apparatus **1** so as to be of a stationary type that is not carried by the subject P. More specifically, of the diagnosis apparatus **1** described above, the ultrasound probe **101** and the Holter ECG probes **111** may be carried by the subject P, whereas the apparatus main body **100** may be installed in a clinic room or the like without being carried by the subject P.

**[0105]** An exemplary embodiment of the diagnosis apparatus **1** of a stationary type will be explained, while using a stress echo test as an example. In recent years, tests called "stress echo tests" are performed for the purpose of checking for heart diseases such as an ischemic heart disease. A stress echo test is an ultrasound examination performed while stress is applied to the heart, for the purpose of checking for the changes in the motions of myocardia and in the blood flows that cannot be observed while the subject is at rest. Examples of stress echo tests include exercise-stress cardiac echo tests and drug-stress cardiac echo tests. The heart rate and the blood pressure are raised, by prompting the subject to do physical exercise of mutually-different levels of stress in the former example and by changing the amount of the drug (e.g., dobutamine) in stages in the latter example. When the subject is not capable of doing physical exercise, a drug-stress test is performed. However, exercise-stress tests are preferred because exercise-stress tests use no drug and are safer. During an exercise-stress cardiac echo test, after the subject P does physical exercise as described above, the ultrasound probe is pressed against the subject P so as to record ultrasound images in the form of a moving picture or a group of still images for the duration of one heartbeat or longer, and an ECG is also recorded by attaching the ECG probes to the subject P. In this situation, during the exercise-stress cardiac echo test, it is required to record the ultrasound images and the ECG before a predetermined period of time (e.g., 90 seconds) elapses since the end of the physical exercise of the subject P. In other words, the operator such as the medical doctor is required to press the ultrasound probe against the subject P and to attach the ECG probes to the subject P, immediately after the subject P has finished the physical exercise. To record the ultrasound images, it is necessary to press the ultrasound probe against the subject P, while ensuring that the observation target site (e.g., the heart) is irradiated by the ultrasound waves. Consequently, operators who give stress echo tests are required to be highly skillful.

**[0106]** In contrast, when the diagnosis apparatus **1** of a stationary type according to the exemplary embodiment described above is used, the operator is not required to be highly skillful and is able to easily record the ultrasound images and the ECG. More specifically, while the ultrasound probe **101** and the Holter ECG probes **111** according to the embodiment are attached to the subject P, the subject P is prompted to do physical exercise. After that, when the subject P has finished the physical exercise, the operator is able to immediately record the ultrasound images and the ECG of the subject P who has finished the physical exercise, by operating the apparatus main body **100**. As explained above, because the ultrasound probe **101** according to the embodiment is fixed onto the subject P while being fitted to the intercostal region or the like, it is possible to prevent the ultrasound probe **101** from making positional shifts even while the subject P is doing the physical exercise. Consequently, the operator is able to attach the ultrasound probe **101** to the subject P before the start of the physical exercise, spending sufficient time to ensure that the observation target site (e.g., the heart) is irradiated by the ultrasound waves. Further, even after the subject P has finished the physical exercise, the operator is able to record the ultrasound images of the observation target without the need to adjust the attachment position of the ultrasound probe **101**.

**[0107]** As explained above, even if the apparatus main body **100** is of a stationary type, the diagnosis apparatus **1** described above is able to realize a medical examination such as a stress echo test that has a high level of precision and is efficient, because the ultrasound probe **101** and the Holter ECG probes **111** are fixed onto the subject P. Further, by attaching the ultrasound probe **101** to the same location of the subject P again and again, it is possible to record ultrasound images of the same observation target many times. Thus, it is possible to utilize the diagnosis apparatus **1** described above as an ultrasound diagnosis apparatus having high reproducibility.

**[0108]** It is also acceptable to configure the diagnosis apparatus **1** described above so as to include a plurality of ultrasound probes **101**. In that situation, when there are a plurality of observation targets, the operator is able to record a plurality of ultrasound images at once, by attaching the ultrasound probes **101** to the subject P in such a manner that the observation targets are irradiated by the ultrasound waves. For example, during an exercise-stress cardiac echo test, to record ultrasound images on a specific cross-sectional plane of the heart that can be viewed from a plurality of observation positions in intercostal regions such as an apical window and a parasternal window, which are called cardiac acoustic windows, a certain skill is required to be able to press the ultrasound probe against the subject at an appropriate angle in the observation positions, within a predetermined period of time since the end of the physical exercise. In some situations, it may be required to have the subject P do the physical exercise

many times. However, because the diagnosis apparatus **1** according to the embodiment is able to record a plurality of ultrasound images at once, it is possible to realize a stress echo test without the need to have the subject P do the physical exercise many times. If the reflected waves of the ultrasound waves from the probes interfere with one another, time-difference control is exercised so that the transmissions and the receptions are performed while sequentially switching among the probes.

**[0109]** Automatic Exercise-Stress Cardiac Echo Test

**[0110]** In the description above, the example is explained in which the exercise-stress cardiac echo test is performed by the operator who operates the apparatus main body **100** after the subject P does the physical exercise. However, it is also acceptable to configure the apparatus main body **100** so as to automatically record the ultrasound images and the ECG immediately after the physical exercise by detecting the point in time at which the subject P has finished the physical exercise. This aspect will be specifically explained with reference to FIG. **17**. FIG. **17** is a drawing of an example of an exercise-stress cardiac echo test performed by the diagnosis apparatus **1** according to the exemplary embodiment.

**[0111]** In the example shown in FIG. **17**, let us assume that the Holter ECG probes **111** have recorded an ECG waveform W10. Also, let us assume that ultrasound images G11 to G13 and G21 and G23 are generated at the times at each of which an R-wave is detected in the ECG waveform W10. The system controller **124** included in the apparatus main body **100** intermittently generates the ultrasound images by controlling the scan controller **125** only at the times when the R-waves are detected in the ECG waveform W10. In the present example, the ultrasound images are sequentially generated at the times at each of which an R-wave is detected. It is, however, acceptable to configure the apparatus main body **100** so as to intermittently generate ultrasound images at the times when the R-waves are detected, after a predetermined period of time (e.g., one minute) has elapsed.

**[0112]** Further, by analyzing the ultrasound images G11 to G13 and G21 to G23, the apparatus main body **100** judges whether the subject P is currently exercising. More specifically, even if the subject P is not exercising, the shape and the position of the heart change due to the expansion and contraction motions of the heart. However, at the times when the R-waves are detected, the shape and the position of the heart are considered to be substantially the same, as long as the subject is not exercising. For this reason, by analyzing (e.g., by applying a cross-correlation process to) a motion vector or the like among the ultrasound images generated at the times when the R-waves are detected, the apparatus main body **100** detects whether the shape and the position of the heart are changing. Further, the apparatus main body **100** determines that the subject P is not exercising if the magnitude of the motion vector is smaller than a predetermined value and determines that the subject P is exercising if the magnitude of the motion vector is equal to or larger than the predetermined value.

**[0113]** For instance, in the example in FIG. **17**, let us assume that the ultrasound images G11 to G13 corresponding to the R-waves are consecutively generated. In this example, the positions of the heart rendered in the ultrasound images G11 to G13 are substantially the same as one another. Consequently, because the position of the heart is unchanged at the points in time when the ultrasound images G11 to G13 are generated, the apparatus main body **100** is able to determine that the subject P is not exercising.

**[0114]** As another example, in the example in FIG. **17**, let us assume that the ultrasound images G21 to G23 corresponding to the R-waves are consecutively generated. In this example, the positions of the heart rendered in the ultrasound images G21 to G23 are different from one another. Consequently, because the positions of the heart are different among the points in time when the ultrasound images G21 to G23 are generated, the apparatus main body **100** is able to determine that the subject P is exercising.

**[0115]** By analyzing the ultrasound images corresponding to the R-waves in the ECG waveform W10 in this manner, the apparatus main body **100** determines whether the subject P is currently exercising. Further, the apparatus main body **100** generates the ultrasound images consecutively when the subject P has transitioned from an exercising state into a non-exercising state. In other words, the apparatus main body **100** transitions from the state in which the apparatus main body **100** intermittently generates the ultrasound images at the times when the R-waves are detected to the state in which the apparatus main body **100** consecutively generates the ultrasound images regardless of the timing with which the R-waves are detected. In that situation, a moving picture or a group of still images for the duration of one heartbeat or longer is acquired and stored. The user is able to specify, in advance, the acquisition period or the number of heartbeats. Further, it is also judged in parallel, as necessary, whether the subject P is exercising during the acquisition period. When it has been detected that the subject P is exercising during the acquisition period, the moving picture or the group of still images is discarded or information indicating that there have been movements is added thereto, and at the same time, the user is informed by a display on a screen.

**[0116]** With these arrangements, the apparatus main body **100** consecutively generates the ultrasound images automatically, when the subject P who is doing the physical exercise comes to a halt. Thus, the stress echo test is automatically performed without the operator's having to operate the apparatus main body **100**.

**[0117]** The process of judging whether the subject P is exercising or not described above may be performed by the system controller **124** included in the apparatus main body **100** or may be performed by a dedicated computer chip or a dedicated computer program included in the apparatus main body **100**. Further, in the description above, the example is explained in which the ultrasound images are generated at the times when the R-waves are detected; however, it is acceptable to configure the apparatus main body **100** so as to generate the ultrasound images at the times when other waves such as P-waves, Q-waves, S-waves, T-waves, or U-waves are detected or at the times defined by arbitrary delay periods since an easily-detected wave.

**[0118]** As explained above, according to the first and the second embodiments, it is possible to attach the ultrasound probe to the subject.

**[0119]** While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying

claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

**1**. An ultrasound diagnosis apparatus comprising:

an ultrasound probe of which a contact face to be in contact with a subject for a purpose of adhering thereto is formed so as to have a shape that can be fitted to a projection part of the subject; and

a processing apparatus configured to process a reflected-wave signal of an ultrasound wave that is transmitted from the ultrasound probe attached to the subject toward the subject.

**2**. The ultrasound diagnosis apparatus according to claim **1**, wherein the ultrasound probe includes:

a plate-like exterior case having the contact face;

a lens of which a curved portion is disposed on the exterior case, the curved portion being formed so as to have a convex shape that can be fitted to a space between bones, each of which is the projection part of the subject; and

a piezoelectric element configured to generate the ultrasound wave transmitted in a substantially thickness direction of the exterior case via the lens.

**3**. The ultrasound diagnosis apparatus according to claim **1**, wherein the ultrasound probe includes:

an exterior case having the contact face that has formed therein a concave portion to be engaged with a bone, which is the projection part of the subject;

a lens provided on the exterior case; and

a piezoelectric element configured to generate the ultrasound wave transmitted in a substantially thickness direction of the exterior case via the lens.

**4**. The ultrasound diagnosis apparatus according to claim **1**, wherein the ultrasound probe is configured so that a transmission angle of the ultrasound wave is changeable by disposing, on the contact face, a member that expands and contracts or a plurality of plate-like adhesive members among which one or more are piled up.

**5**. The ultrasound diagnosis apparatus according to claim **1**, wherein the processing apparatus includes: a controlling unit configured to control the ultrasound probe so as to perform a process of transmitting the ultrasound wave and a process of receiving the reflected-wave signal at one or more points in time that are set in advance.

**6**. The ultrasound diagnosis apparatus according to claim **1** further comprising: a pulse measuring apparatus that is carried by the subject and is configured to measure a pulse wave or a pulse rate of the subject, wherein

the processing apparatus further includes:

a detecting unit configured to detect whether the subject has an abnormality or not based on the pulse wave or the pulse rate measured by the pulse measuring apparatus; and

a controlling unit configured to, when the detecting unit has detected the abnormality, control the ultrasound probe so as to start a process of transmitting the ultrasound wave and a process of receiving the reflected-wave signal and control the ultrasound probe so as to keep performing the transmitting process and the receiving process until a predetermined period of time has elapsed since the abnormality is detected by the detecting unit.

**7**. The ultrasound diagnosis apparatus according to claim **6**, further comprising: an electrocardiography device configured to obtain an electrocardiogram of the subject, wherein

the processing apparatus further includes: a judging unit configured to judge whether the subject is at a halt by analyzing ultrasound images generated at times when a predetermined waveform is detected in the electrocardiogram, and

the controlling unit controls the ultrasound probe so as to perform the process of transmitting the ultrasound wave and the process of receiving the reflected-wave signal when, as a result of the judging by the judging unit, the subject has transitioned from a moving state into a halt state.

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摘要(译)

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