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(54) ULTRASOUND DIAGNOSIS APPARATUS AND METHOD OF CONTROLLING THE ULTRASOUND DIAGNOSIS APPARATUS

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(57) **ABSTRACT**

An ultrasound diagnosis apparatus and a method of controlling the same are provided. The ultrasound diagnosis apparatus includes an ultrasound probe configured to transmit an ultrasound signal to an object and receive an ultrasound echo signal from the object to form a reception signal; a body configured to receive the reception signal from the ultrasound probe and process the reception signal; an impedance matching circuit configured to match an impedance of the ultrasound probe with an impedance of the body; and a controller configured to control the impedance matching circuit to operate as at least one filter that passes or rejects a signal of a specific frequency band, based on the impedance of the ultrasound probe, the impedance of the body, and relevant frequency characteristics of the reception signal. The at least one filter is controlled to match the impedance of the ultrasound probe with the impedance of the body and is controlled so that the reception signal has the relevant frequency characteristics.

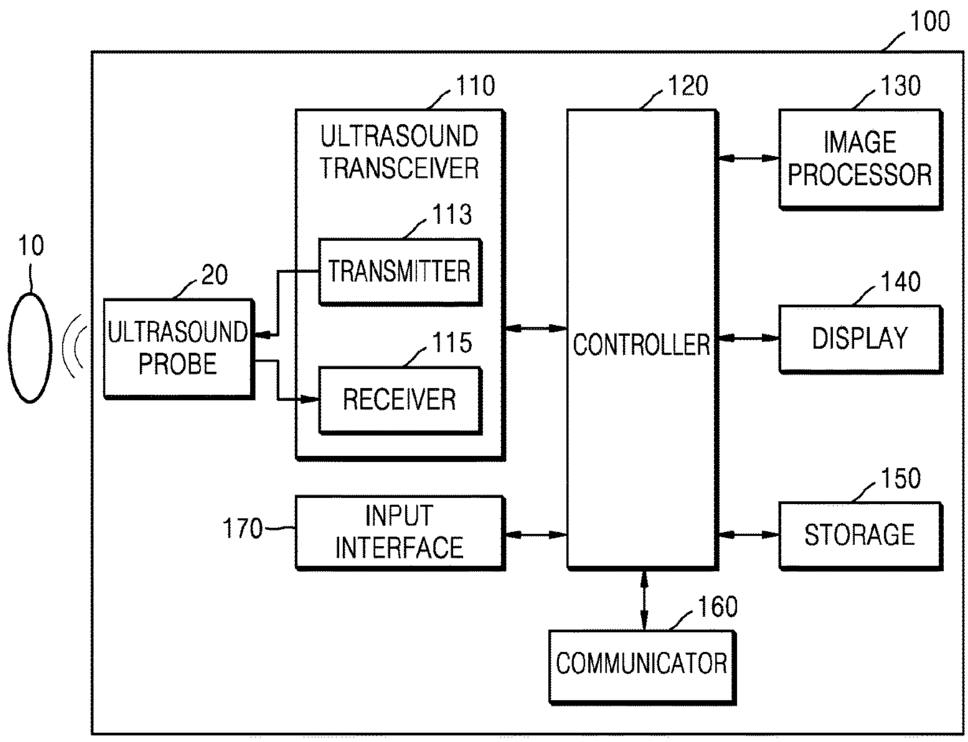


FIG. 1

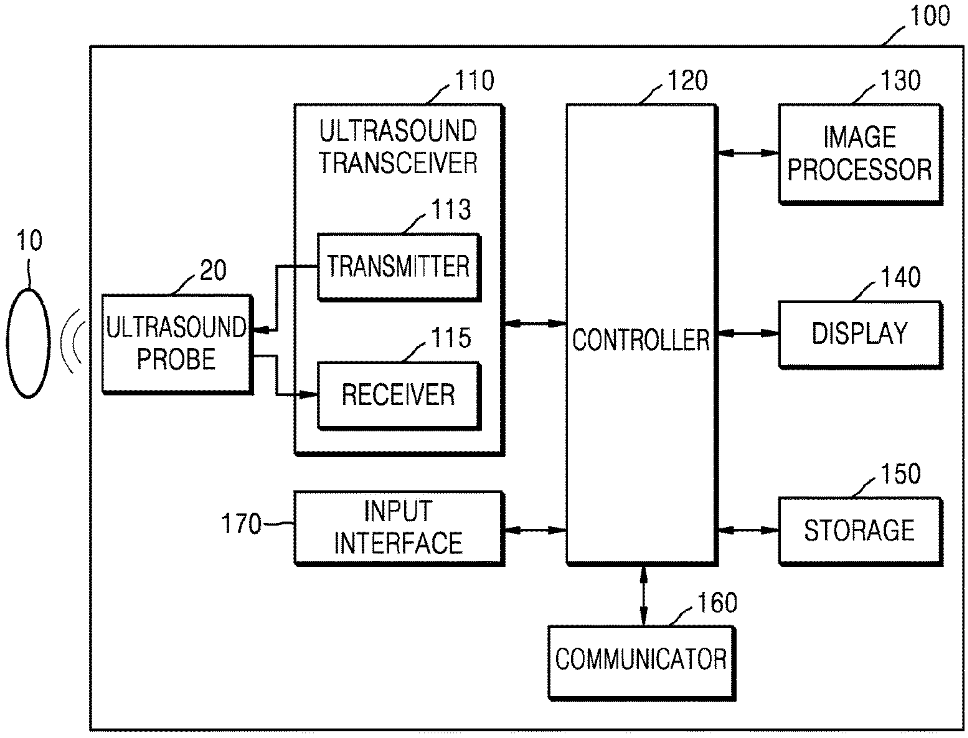

100
110
ULTRASOUND TRANSCEIVER
113
TRANSMITTER
115
RECEIVER
120
CONTROLLER
130
IMAGE PROCESSOR
140
DISPLAY
150
STORAGE
160
COMMUNICATOR
170
INPUT INTERFACE
10
20
ULTRASOUND PROBE

FIG. 2

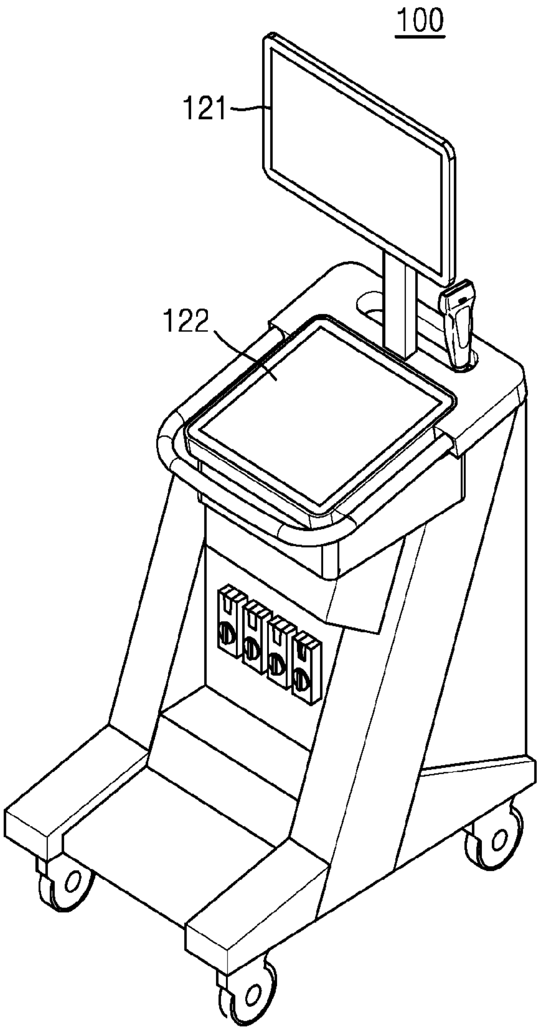

100
121
122

FIG. 3

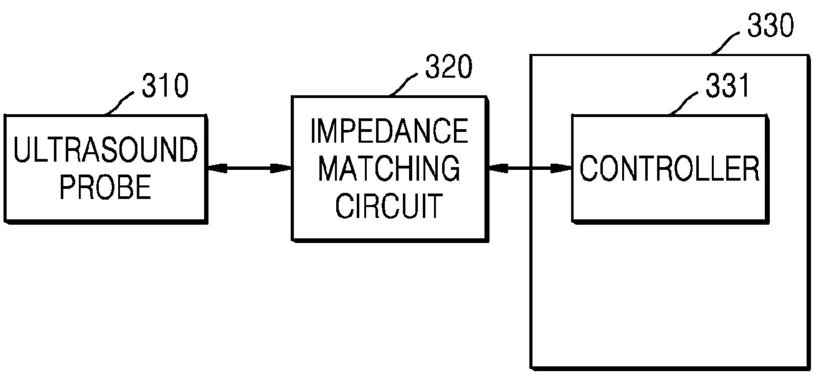

310
ULTRASOUND PROBE
320
IMPEDANCE MATCHING CIRCUIT
330
331
CONTROLLER

FIG. 4

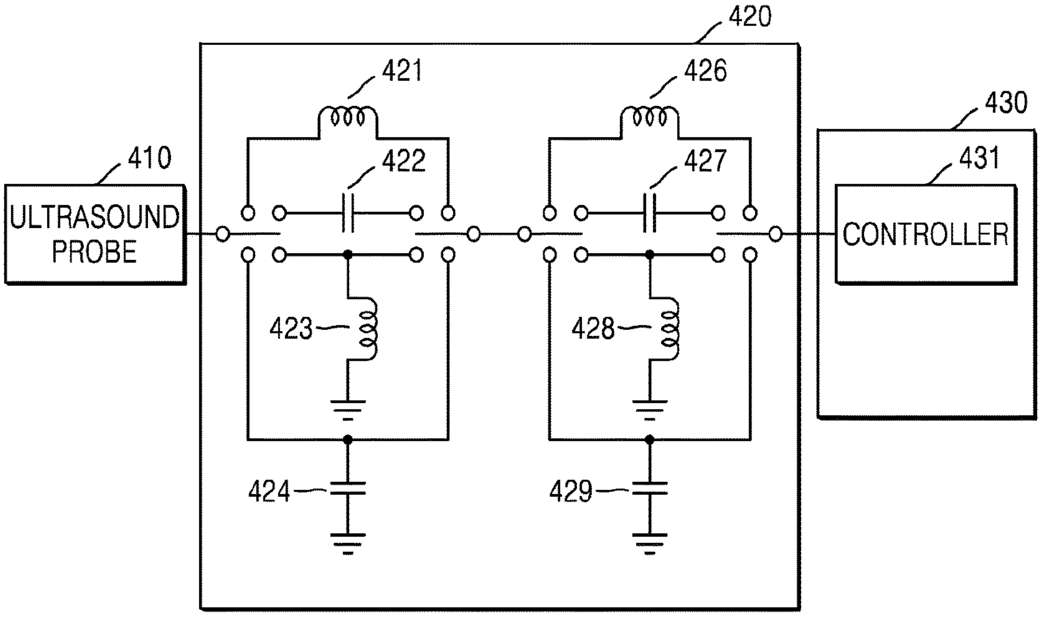

420
421
426
430
410
422
427
431
ULTRASOUND PROBE
CONTROLLER
423
428
424
429

FIG. 5

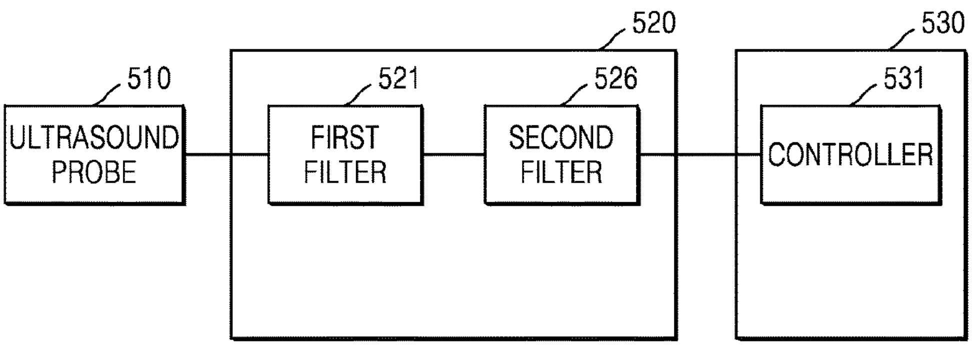

520
530
510
521
526
531
ULTRASOUND PROBE
FIRST FILTER
SECOND FILTER
CONTROLLER

FIG. 6

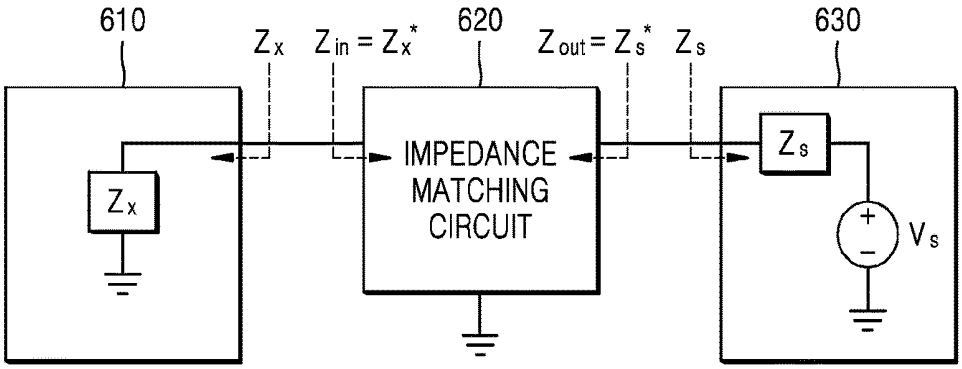

610
Zx
Zin = Zx*
620
Zout = Zs*
Zs
630
Zx
IMPEDANCE MATCHING CIRCUIT
Zs
Vs

FIG. 7

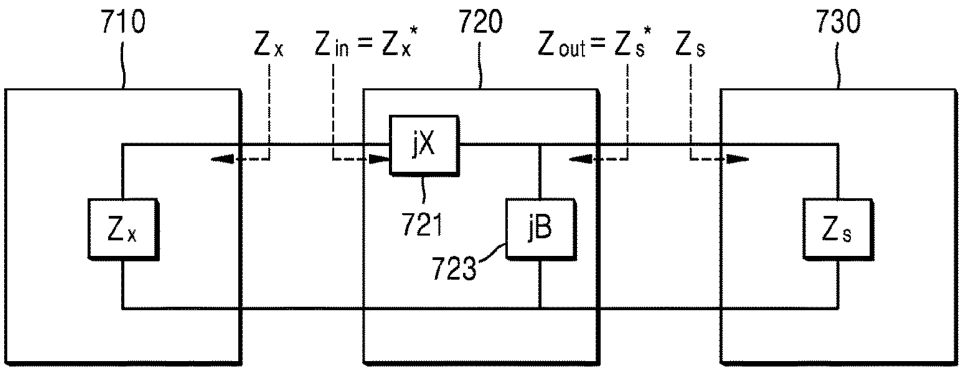

710
Zx
Zin = Zx*
720
Zout = Zs*
Zs
730
jX
721
jB
723
Zx
Zs

FIG. 8

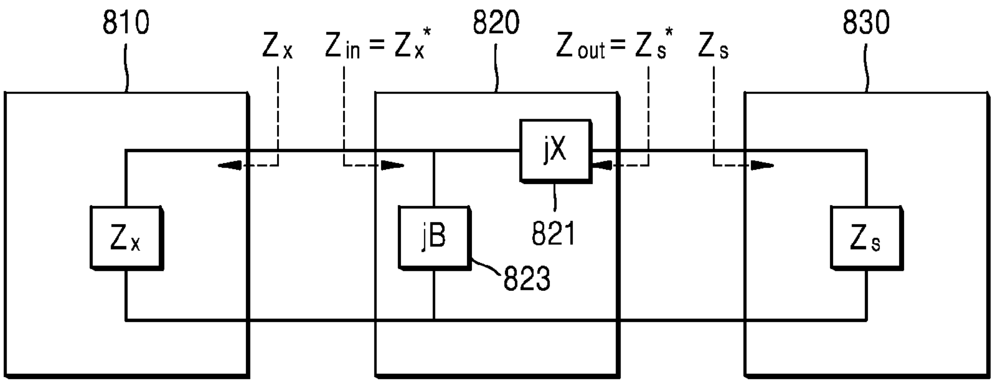

810
820
830
Zx
Zin = Zx*
Zout = Zs*
Zs
jX
821
jB
823
Zx
Zs

FIG. 9

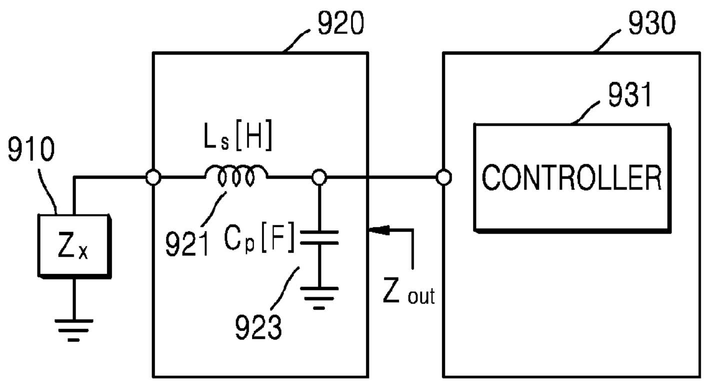

920
930
931
910
Ls[H]
CONTROLLER
Zx
921
Cp[F]
923
Z out

FIG. 10

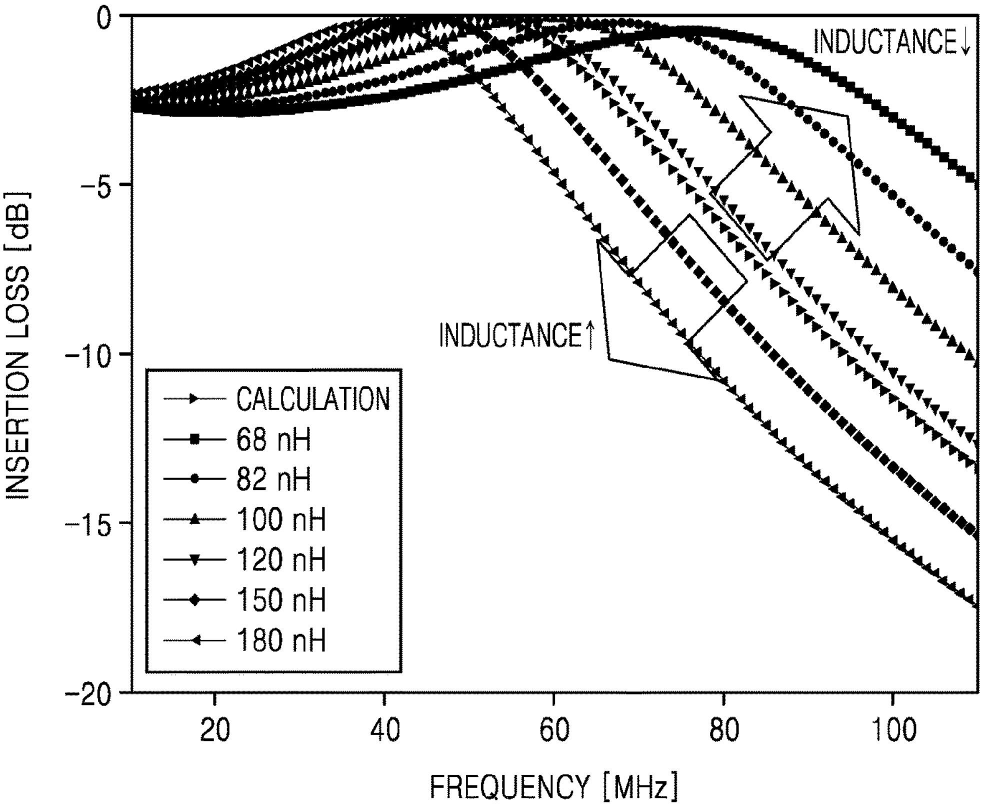

0
-5
-10
-15
-20
INSERTION LOSS [dB]
20
40
60
80
100
FREQUENCY [MHz]
INDUCTANCE↓
INDUCTANCE↑
CALCULATION
68 nH
82 nH
100 nH
120 nH
150 nH
180 nH

FIG. 11

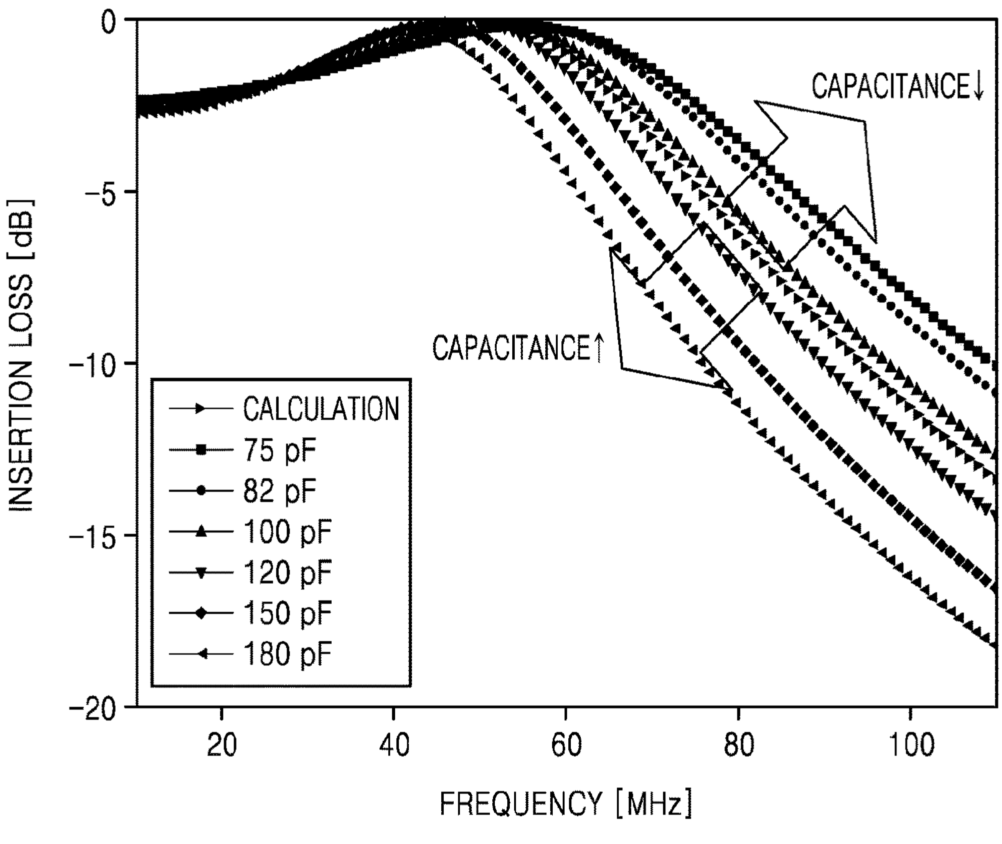
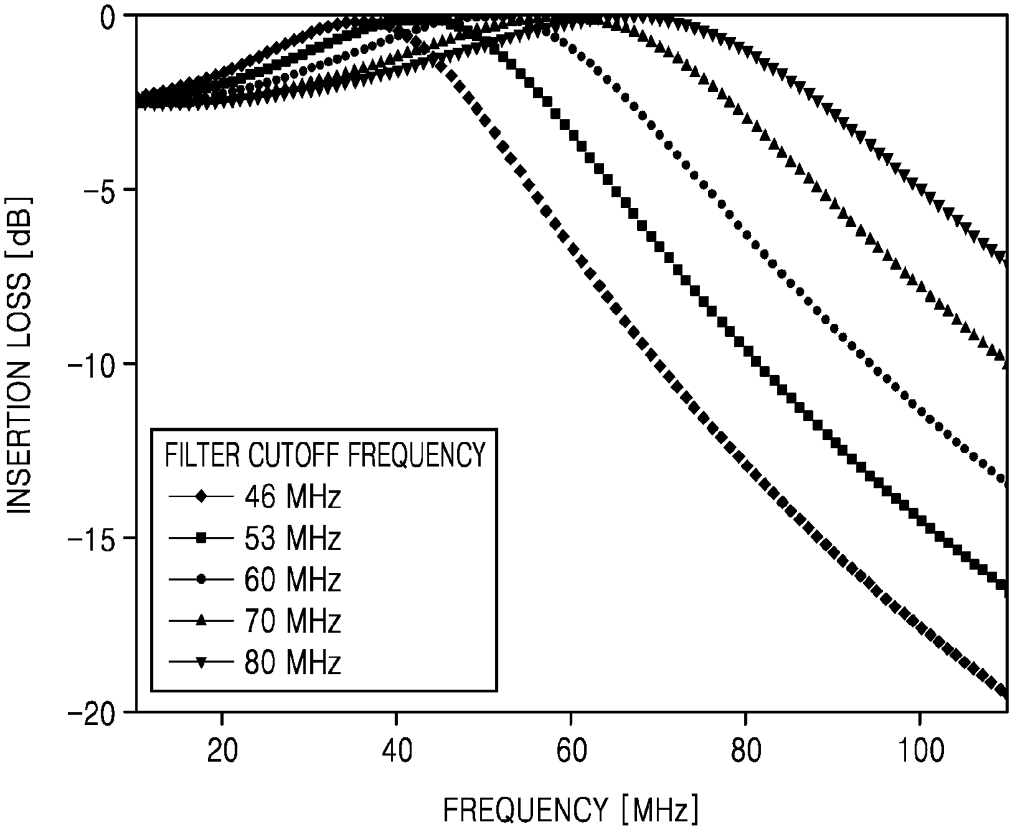
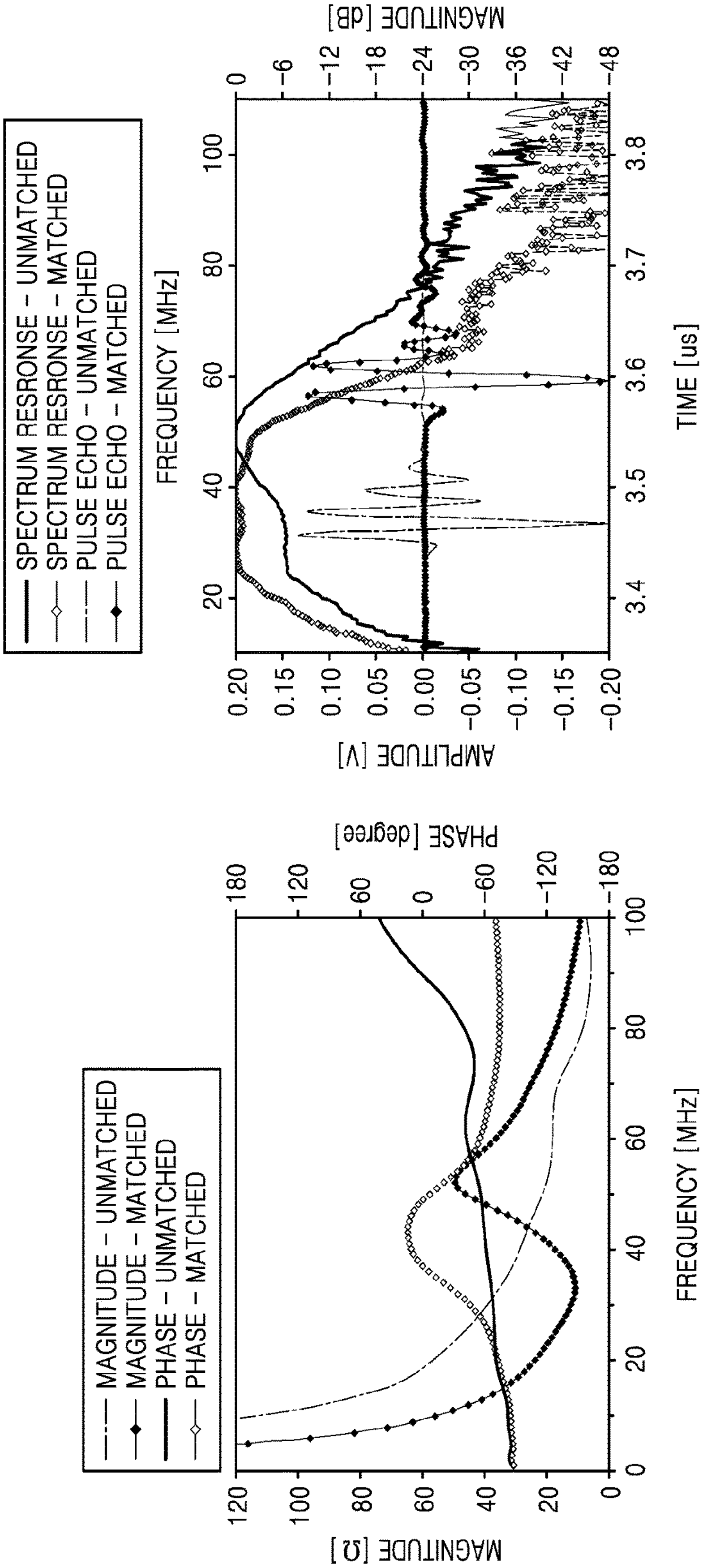

0
-5
-10
-15
-20
20
40
60
80
100
INSERTION LOSS [dB]
FREQUENCY [MHz]
CAPACITANCE↓
CAPACITANCE↑
CALCULATION
75 pF
82 pF
100 pF
120 pF
150 pF
180 pF

FIG. 12



0
-5
-10
-15
-20
INSERTION LOSS [dB]
20
40
60
80
100
FREQUENCY [MHz]
FILTER CUTOFF FREQUENCY
46 MHz
53 MHz
60 MHz
70 MHz
80 MHz

FIG. 13



MAGNITUDE - UNMATCHED
MAGNITUDE - MATCHED
PHASE - UNMATCHED
PHASE - MATCHED
MAGNITUDE [Ω]
PHASE [degree]
FREQUENCY [MHz]
SPECTRUM RESRONSE - UNMATCHED
SPECTRUM RESRONSE - MATCHED
PULSE ECHO - UNMATCHED
PULSE ECHO - MATCHED
FREQUENCY [MHz]
MAGNITUDE [dB]
AMPLITUDE [V]
TIME [us]

FIG. 14

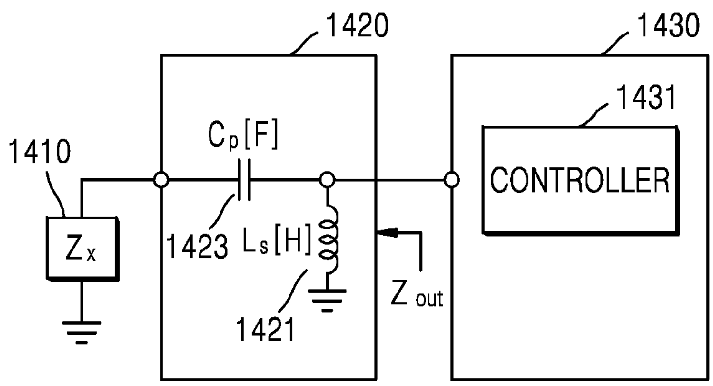


FIG. 15

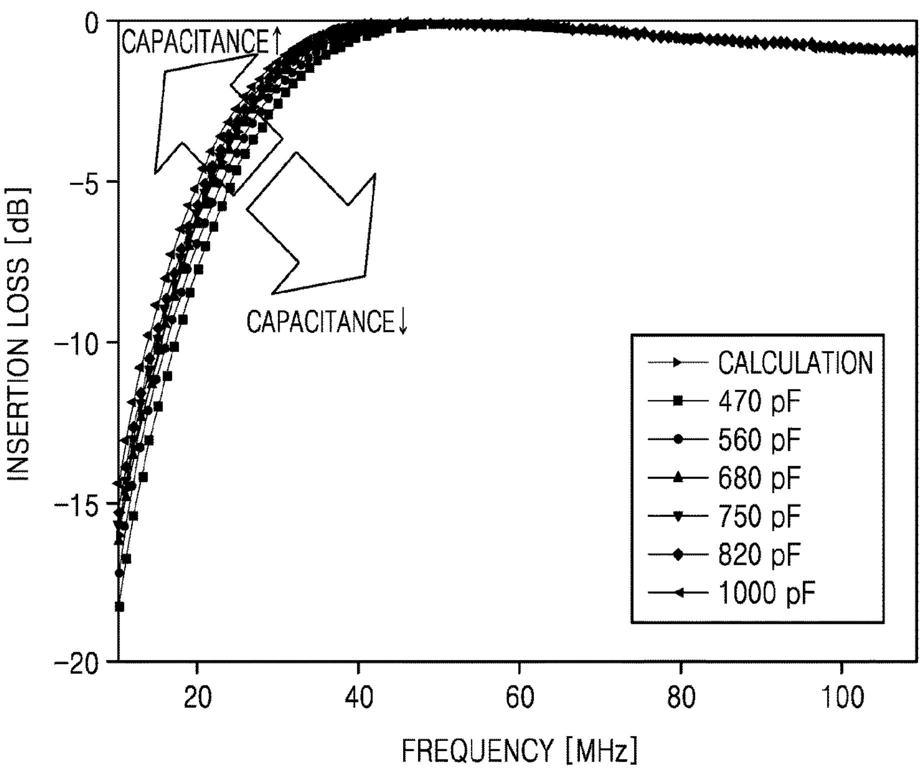
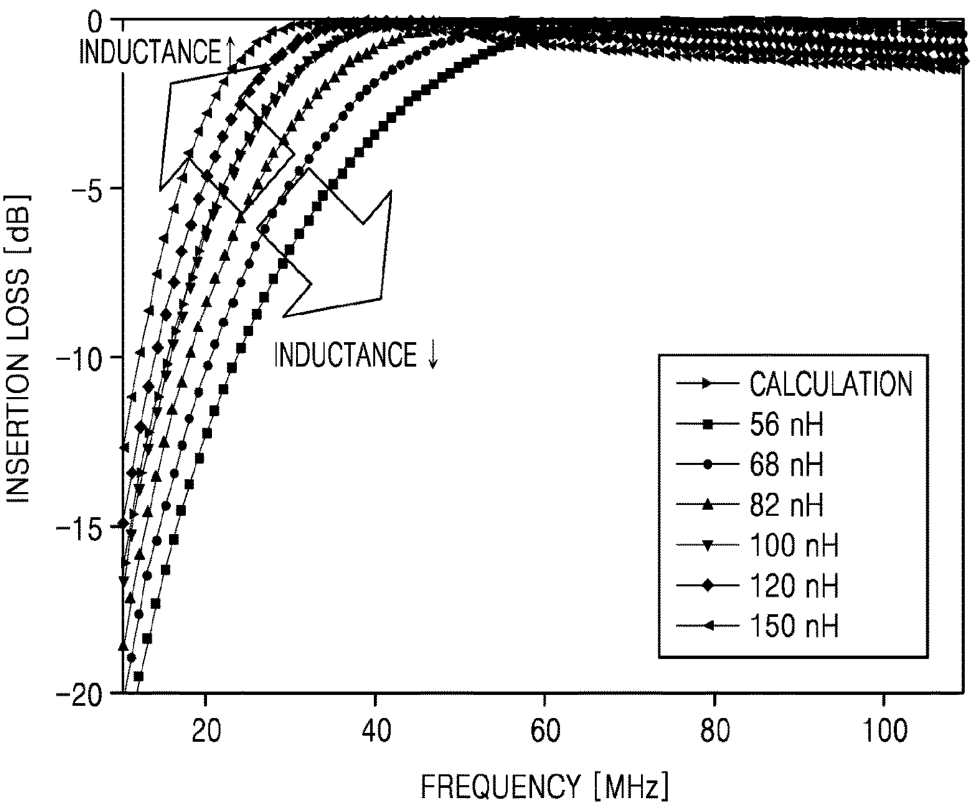

0
-5
-10
-15
-20
INSERTION LOSS [dB]
20
40
60
80
100
FREQUENCY [MHz]
CAPACITANCE↑
CAPACITANCE↓
CALCULATION
470 pF
560 pF
680 pF
750 pF
820 pF
1000 pF

FIG. 16



INSERTION LOSS [dB]
FREQUENCY [MHz]
0
-5
-10
-15
-20
20
40
60
80
100
INDUCTANCE↑
INDUCTANCE↓
CALCULATION
56 nH
68 nH
82 nH
100 nH
120 nH
150 nH

FIG. 17

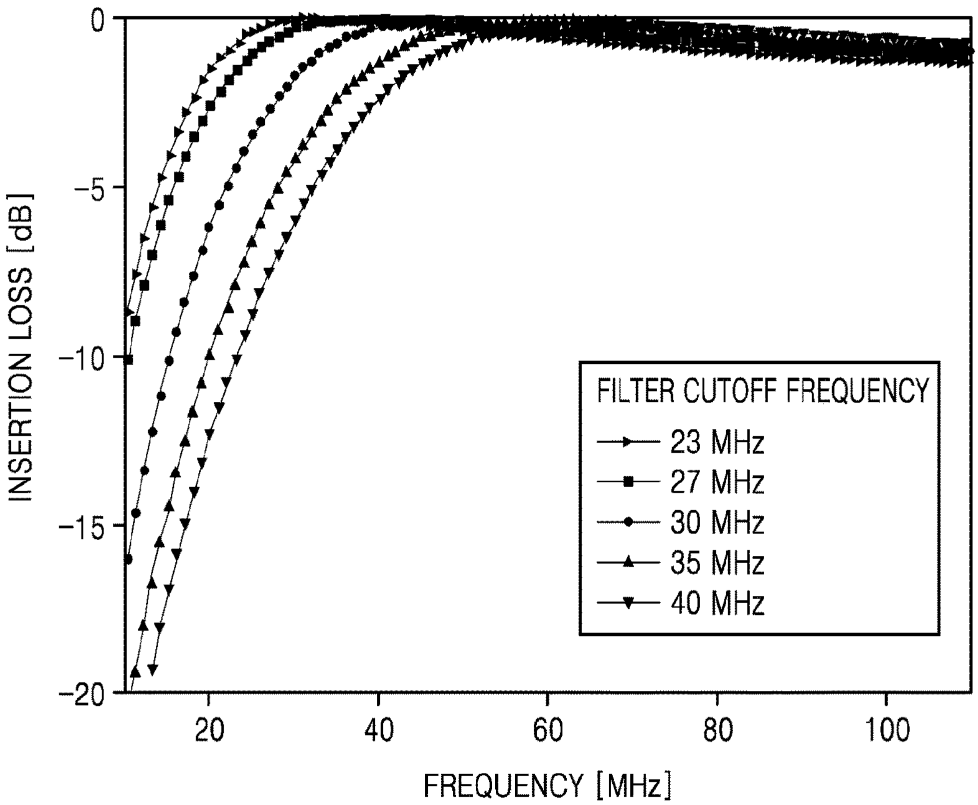

0
−5
−10
−15
−20
20
40
60
80
100
INSERTION LOSS [dB]
FREQUENCY [MHz]
FILTER CUTOFF FREQUENCY
23 MHz
27 MHz
30 MHz
35 MHz
40 MHz

FIG. 18

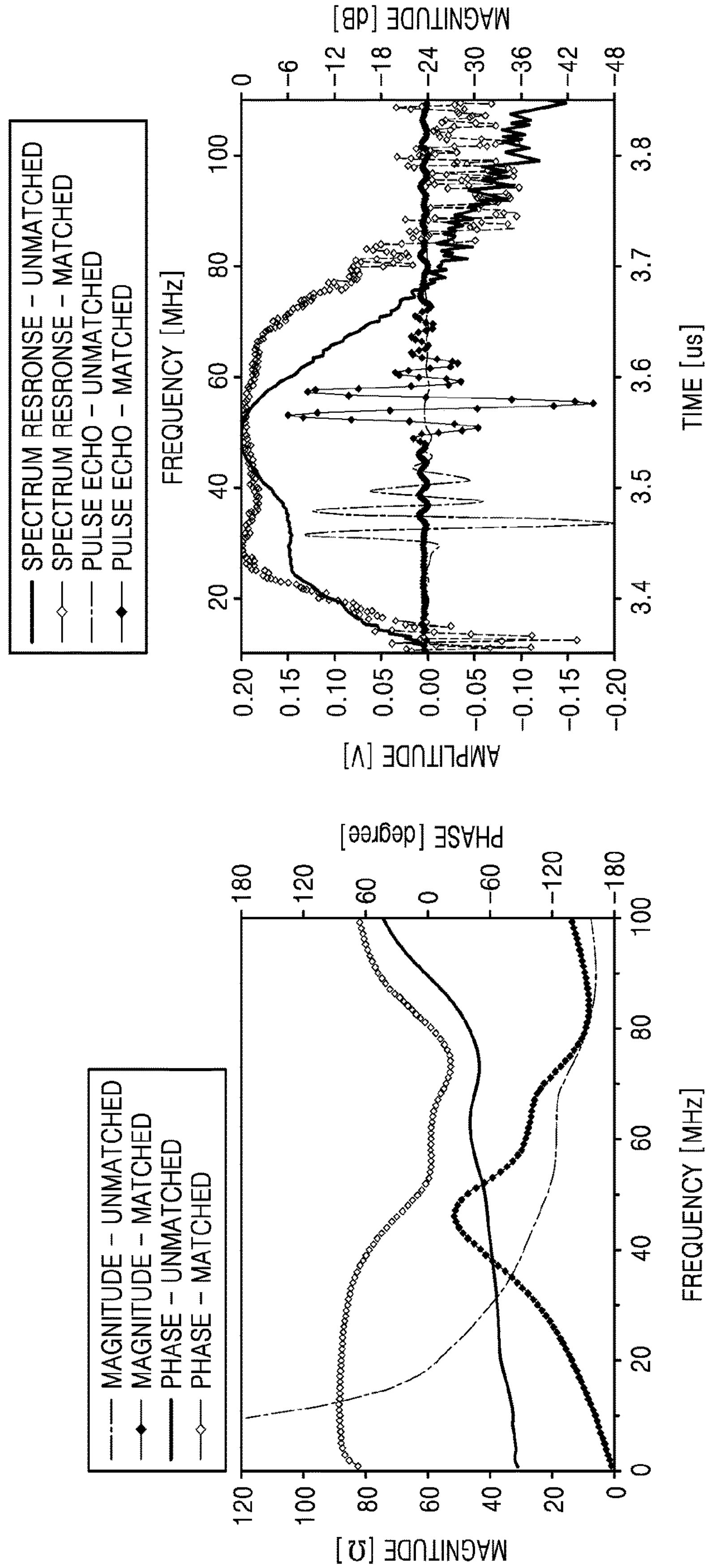

SPECTRUM RESRONSE - UNMATCHED
SPECTRUM RESRONSE - MATCHED
PULSE ECHO - UNMATCHED
PULSE ECHO - MATCHED
FREQUENCY [MHz]
MAGNITUDE [dB]
0
-6
-12
-18
-24
-30
-36
-42
-48
20
40
60
80
100
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
AMPLITUDE [V]
3.4
3.5
3.6
3.7
3.8
TIME [us]
MAGNITUDE - UNMATCHED
MAGNITUDE - MATCHED
PHASE - UNMATCHED
PHASE - MATCHED
PHASE [degree]
180
120
60
0
-60
-120
-180
120
100
80
60
40
20
0
MAGNITUDE [Ω]
0
20
40
60
80
100
FREQUENCY [MHz]

FIG. 19

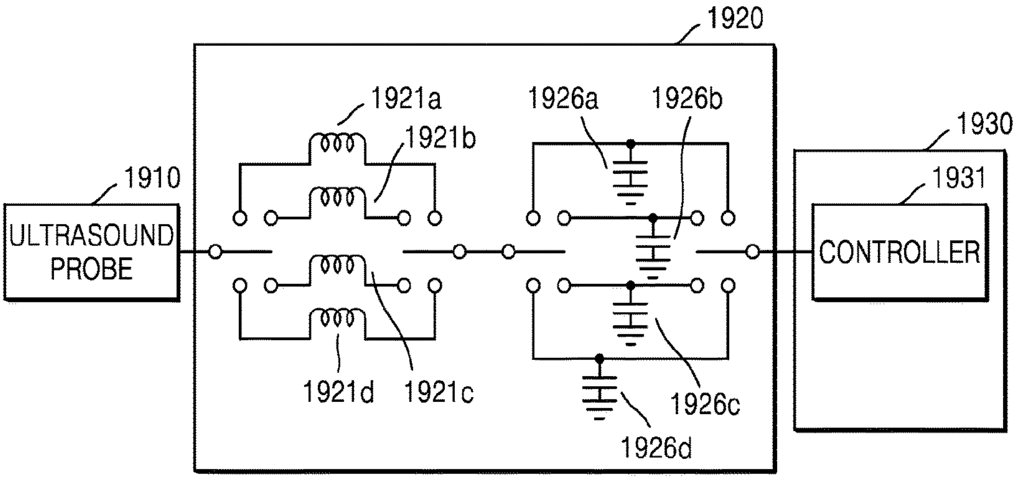

1920
1921a
1921b
1926a
1926b
1930
1931
1910
ULTRASOUND PROBE
CONTROLLER
1921d
1921c
1926c
1926d

FIG. 20

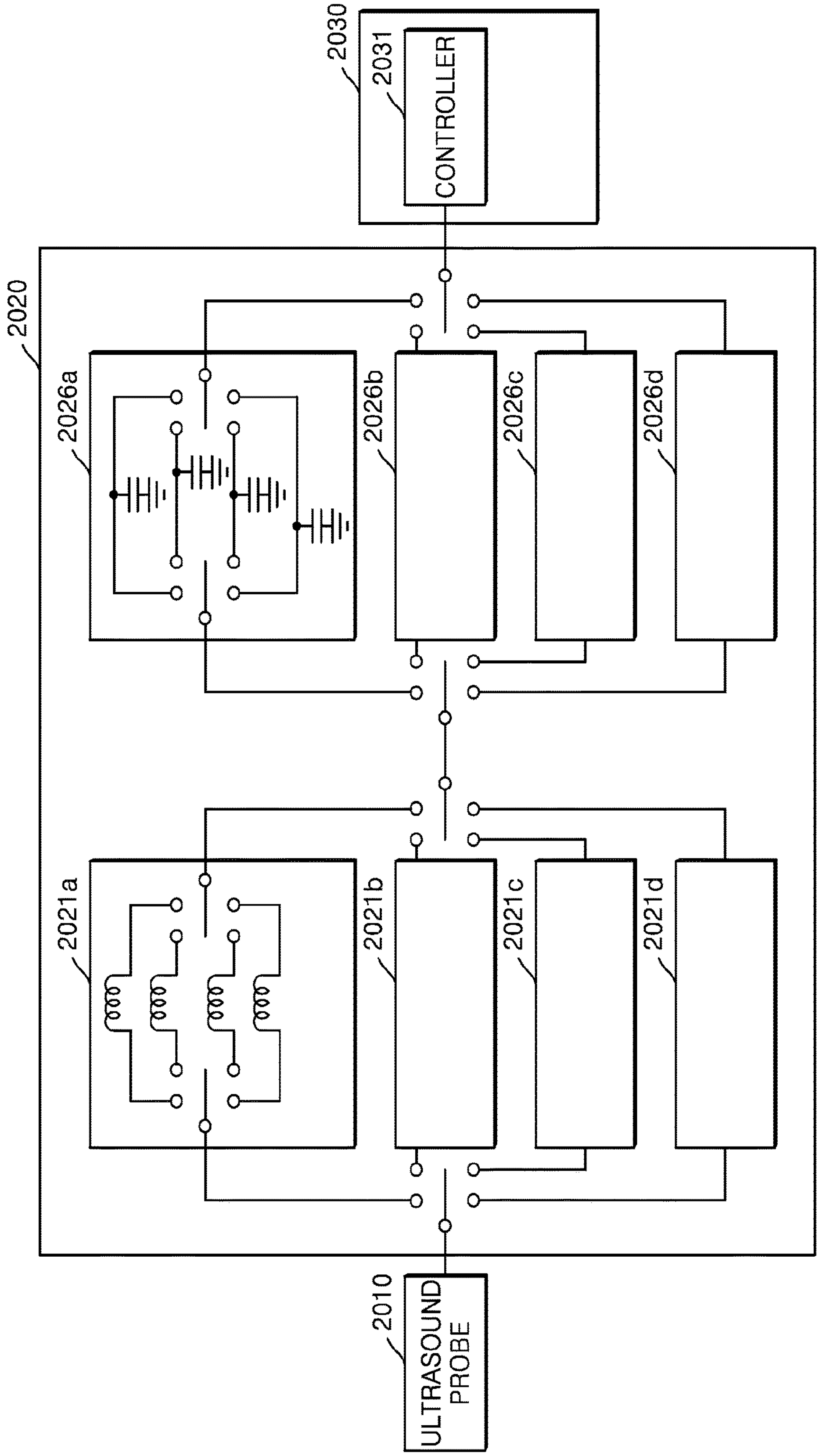

2030
2031
CONTROLLER
2020
2026a
2026b
2026c
2026d
2021a
2021b
2021c
2021d
2010
ULTRASOUND PROBE

FIG. 21

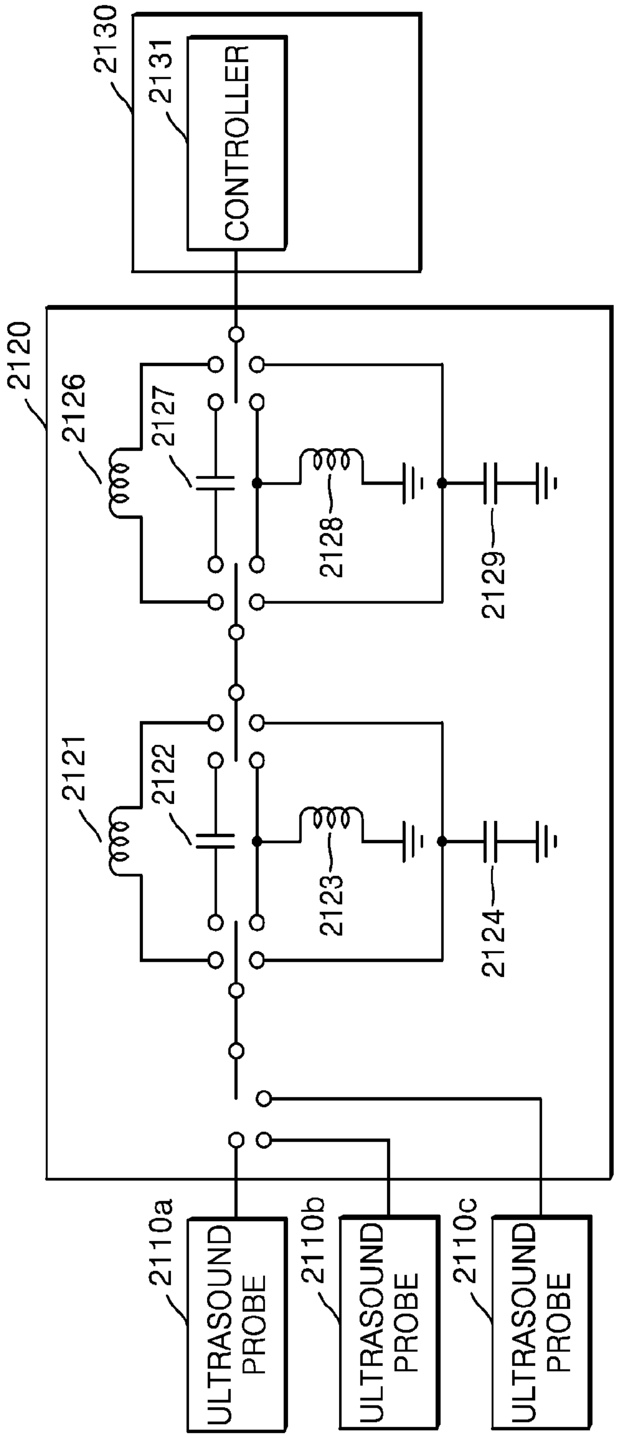

2130
2131
CONTROLLER
2120
2126
2127
2128
2129
2121
2122
2123
2124
2110a
ULTRASOUND PROBE
2110b
ULTRASOUND PROBE
2110c
ULTRASOUND PROBE

FIG. 22

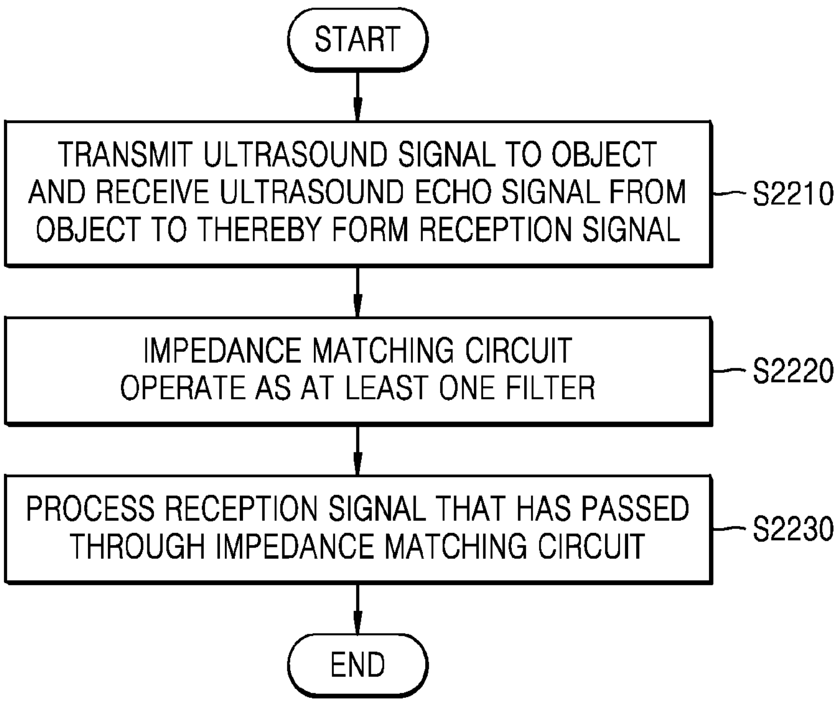
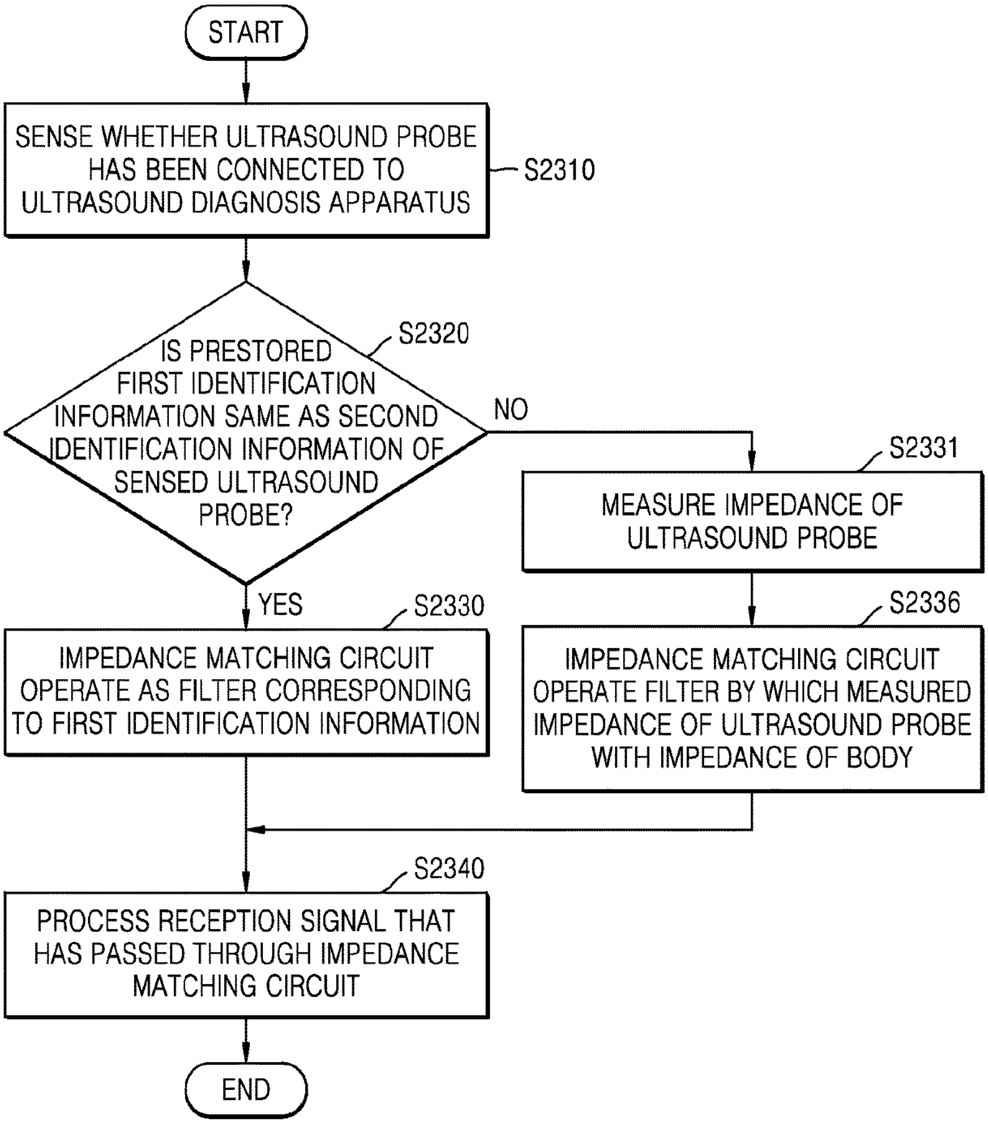

START
TRANSMIT ULTRASOUND SIGNAL TO OBJECT AND RECEIVE ULTRASOUND ECHO SIGNAL FROM OBJECT TO THEREBY FORM RECEPTION SIGNAL
S2210
IMPEDANCE MATCHING CIRCUIT OPERATE AS AT LEAST ONE FILTER
S2220
PROCESS RECEPTION SIGNAL THAT HAS PASSED THROUGH IMPEDANCE MATCHING CIRCUIT
S2230
END

FIG. 23


START
SENSE WHETHER ULTRASOUND PROBE HAS BEEN CONNECTED TO ULTRASOUND DIAGNOSIS APPARATUS
S2310
IS PRESTORED FIRST IDENTIFICATION INFORMATION SAME AS SECOND IDENTIFICATION INFORMATION OF SENSED ULTRASOUND PROBE?
S2320
NO
S2331
MEASURE IMPEDANCE OF ULTRASOUND PROBE
YES
S2330
IMPEDANCE MATCHING CIRCUIT OPERATE AS FILTER CORRESPONDING TO FIRST IDENTIFICATION INFORMATION
S2336
IMPEDANCE MATCHING CIRCUIT OPERATE FILTER BY WHICH MEASURED IMPEDANCE OF ULTRASOUND PROBE WITH IMPEDANCE OF BODY
S2340
PROCESS RECEPTION SIGNAL THAT HAS PASSED THROUGH IMPEDANCE MATCHING CIRCUIT
END

ULTRASOUND DIAGNOSIS APPARATUS AND METHOD OF CONTROLLING THE ULTRASOUND DIAGNOSIS APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/320,037, filed on Apr. 8, 2016, in the U.S. Patent and Trademark Office, and the benefit of Korean Patent Application No. 10-2016-0094820, filed on Jul. 26, 2016, in the Korean Intellectual Property Office, the disclosures of which are incorporated herein in their entireties by reference.

BACKGROUND

1. Field

[0002] One or more embodiments relate to an ultrasound diagnosis apparatus and a method of controlling the ultrasound diagnosis apparatus.

2. Description of the Related Art

[0003] Ultrasound diagnosis apparatuses transmit an ultrasound signal generated by a transducer of a probe to an object and detects information regarding an echo signal reflected from the object, thereby obtaining at least one image of a part (e.g., a soft tissue or a blood stream) inside the object.

[0004] However, a difference between the impedance value of a body of an ultrasound diagnosis apparatus and the impedance value of an ultrasound probe exists. Due to this difference between the impedance values of the ultrasound diagnosis apparatus body and the ultrasound probe, a reception signal received by the ultrasound probe is not fully delivered to the ultrasound diagnosis apparatus. In other words, when the reception signal is transmitted from the ultrasound probe to the ultrasound diagnosis apparatus, a portion of the electrical energy of the reception signal is lost. In addition, a reception signal received by the ultrasound diagnosis apparatus body has a reduced frequency band compared to the reception signal received by the ultrasound probe.

[0005] One method to address the loss of the electrical energy of the received signal and the reduction of the frequency band of the received signal due to the difference between the impedance values of the ultrasound diagnosis apparatus body and the ultrasound probe is to match the impedance of the ultrasound diagnosis apparatus body with the impedance of the ultrasound probe by using an impedance matching circuit located between the ultrasound diagnosis apparatus body and the ultrasound probe. When the impedance of the ultrasound probe is matched with the impedance of the ultrasound diagnosis apparatus body, loss of the electrical energy of the reception signal received by the ultrasound diagnosis apparatus body is minimized.

[0006] Conventional impedance matching circuits are designed to remove a reactance value of the ultrasound probe at a specific frequency. In this case, loss of the electrical energy of a reception signal in a not-considered frequency band may not be minimized. Moreover, the frequency band of the reception signal received by the ultrasound diagnosis apparatus body via a conventional impedance matching circuit may be reduced more than in the case wherein no impedance matching circuits are used.

SUMMARY

[0007] Loss of the electrical energy of a reception signal formed by an ultrasound probe is minimized and the frequency band of the reception signal is reduced so that a reception signal corresponding to a result of the minimizations is transmitted to a body of an ultrasound diagnosis apparatus.

[0008] Loss of the electrical energy of a reception signal is minimized according to the type, application, and diagnosis application of an ultrasound probe, reduction of the frequency band of the reception signal is minimized, and a reception signal corresponding to a result of the minimizations is transmitted to a body of an ultrasound diagnosis apparatus.

[0009] Loss of the electrical energy of a reception signal is minimized according to relevant frequency characteristics of a user, and reduction of the frequency band of the reception signal is minimized, and a reception signal corresponding to a result of the minimizations is transmitted to a body of an ultrasound diagnosis apparatus.

[0010] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0011] According to an aspect of an embodiment, an ultrasound diagnosis apparatus includes an ultrasound probe configured to transmit an ultrasound signal to an object and receive an ultrasound echo signal from the object to form a reception signal; a body configured to receive the reception signal from the ultrasound probe and process the reception signal; an impedance matching circuit configured to match an impedance of the ultrasound probe with an impedance of the body; and a controller configured to control the impedance matching circuit to operate as at least one filter that passes or rejects a signal of a specific frequency band, based on the impedance of the ultrasound probe, the impedance of the body, and relevant frequency characteristics of the reception signal, wherein the at least one filter is controlled to match the impedance of the ultrasound probe with the impedance of the body and is controlled so that the reception signal has the relevant frequency characteristics.

[0012] According to an aspect of another embodiment, a method of controlling an ultrasound diagnosis apparatus including an ultrasound probe and a body for processing a reception signal received from the ultrasound probe includes the operations of transmitting an ultrasound signal to an object and receiving an ultrasound echo signal from the object to form the reception signal; controlling an impedance matching circuit for matching an impedance of the ultrasound probe with an impedance of the body to operate as at least one filter that passes or rejects a signal of a specific frequency band, based on the impedance of the ultrasound probe, the impedance of the body, and relevant frequency characteristics of the reception signal; and processing a reception signal that has passed through the impedance matching circuit, wherein the reception signal that has passed through the impedance matching circuit has the relevant frequency characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

[0014] FIG. **1** is a block diagram of a structure of an ultrasound diagnosis apparatus according to an embodiment;

[0015] FIG. **2** is a diagram of an ultrasound diagnosis apparatus according to an embodiment;

[0016] FIG. **3** is a block diagram of a structure of an ultrasound diagnosis apparatus according to an embodiment;

[0017] FIG. **4** is a block diagram illustrating, in detail, an impedance matching circuit included in an ultrasound diagnosis apparatus according to an embodiment;

[0018] FIG. **5** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit operating as a 2-stage filter, according to an embodiment;

[0019] FIG. **6** is a circuit diagram for explaining a process of determining elements that are included in an impedance matching circuit, and element values of the elements, according to an embodiment;

[0020] FIG. **7** is a circuit diagram for explaining a process of determining elements that are included in an impedance matching circuit, and element values of the elements, according to an embodiment;

[0021] FIG. **8** is a circuit diagram for explaining a process of determining elements that are included in an impedance matching circuit, and element values of the elements, according to an embodiment;

[0022] FIG. **9** is a circuit diagram a structure of an impedance matching circuit operating as a low pass filter, according to an embodiment;

[0023] FIG. **10** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to inductance values when the impedance matching circuit operates as a low-pass filter;

[0024] FIG. **11** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to capacitance values when the impedance matching circuit operates as a low-pass filter;

[0025] FIG. **12** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to cutoff frequencies when the impedance matching circuit operates as a low-pass filter;

[0026] FIG. **13** is a graph showing a result of impedance matching performed by using an impedance matching circuit according to an embodiment operating as a low pass filter;

[0027] FIG. **14** is a circuit diagram a structure of an impedance matching circuit operating as a high pass filter, according to an embodiment;

[0028] FIG. **15** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to capacitance values when the impedance matching circuit operates as a high-pass filter;

[0029] FIG. **16** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to inductance values when the impedance matching circuit operates as a high-pass filter;

[0030] FIG. **17** is a graph showing the characteristics of an impedance matching circuit according to an embodiment respectively corresponding to cutoff frequencies when the impedance matching circuit operates as a high-pass filter;

[0031] FIG. **18** is a graph showing a result of impedance matching performed by using an impedance matching circuit according to an embodiment operating as a high pass filter;

[0032] FIG. **19** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit including a plurality of circuit elements of an identical type having different values, according to an embodiment;

[0033] FIG. **20** is a circuit diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit including a plurality of circuit element banks, according to an embodiment;

[0034] FIG. **21** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit to which a plurality of ultrasound probes is connected, according to an embodiment;

[0035] FIG. **22** is a flowchart of a method of controlling an ultrasound diagnosis apparatus, according to an embodiment; and

[0036] FIG. **23** is a flowchart of a method of controlling an ultrasound diagnosis apparatus, according to an embodiment.

DETAILED DESCRIPTION

[0037] The principle of the present invention is explained and embodiments are disclosed so that the scope of the present invention is clarified and one of ordinary skill in the art to which the present invention pertains implements the present invention. The disclosed embodiments may have various forms.

[0038] Like reference numerals refer to like elements throughout the specification. In the specification, all elements of embodiments are not explained, but general matters in the technical field of the present invention or redundant matters between embodiments will not be described. Terms 'part' and 'portion' used herein may be implemented using software or hardware, and, according to embodiments, a plurality of 'parts' or 'portions' may be implemented using a single unit or element, or a single 'part' or 'portion' may be implemented using a plurality of units or elements. The operational principle of the present invention and embodiments thereof will now be described more fully with reference to the accompanying drawings.

[0039] An image used herein may be a medical image captured by a medical imaging apparatus, such as a magnetic resonance imaging (MRI) apparatus, a computed tomography (CT) apparatus, an ultrasound imaging apparatus, or an X-ray apparatus.

[0040] Throughout the specification, a term 'object' is a thing to be imaged, and may include a human, an animal, or a part of a human or animal. For example, the object may include a part of a body (i.e., an organ), a phantom, or the like.

[0041] Throughout the specification, an "ultrasound image" refers to an image of an object processed based on ultrasound signals transmitted to the object and reflected therefrom.

[0042] Throughout the specification, a "relevant frequency" refers to a frequency necessary for image generation when an ultrasound diagnosis apparatus body generates an image by processing a reception signal received via an ultrasound probe.

[0043] Embodiments now will be described more fully hereinafter with reference to the accompanying drawings.

[0044] FIG. **1** is a block diagram showing a configuration of an ultrasound diagnosis apparatus **100** according to an embodiment. An ultrasound diagnosis apparatus **100** according to an embodiment may include an ultrasound probe **20**, an ultrasound transceiver **110**, a controller **120**, an image processor **130**, a display **140**, a storage **150**, a communicator **160**, and an input interface **170**.

[0045] The ultrasound diagnosis apparatus **100** may be of a cart-type or a portable-type ultrasound diagnosis apparatus. Examples of the portable-type ultrasound imaging apparatus **200** may include a smartphone, a laptop computer, a personal digital assistant (PDA), and a tablet personal computer (PC), each of which may include a probe and an application, but embodiments are not limited thereto.

[0046] The ultrasound probe **20** may include a plurality of transducers. The plurality of transducers may transmit ultrasound signals to an object **10** in response to transmitting signals applied by a transmitter **113**. The plurality of transducers may receive ultrasound signals reflected from the object **10** to generate reception signals. In addition, the ultrasound probe **20** and the ultrasound diagnosis apparatus **100** may be formed in one body, or the ultrasound probe **20** and the ultrasound diagnosis apparatus **100** may be formed separately but linked wirelessly or via wires. In addition, the ultrasound diagnosis apparatus **100** may include one or more probes **20** according to embodiments.

[0047] The controller **120** may control the transmitter **113** to generate transmitting signals to be applied to each of the plurality of transducers based on a position and a focal point of the plurality of transducers included in the ultrasound probe **20**.

[0048] The controller **120** may control the ultrasound receiver **115** to generate ultrasound data by converting reception signals received from the ultrasound probe **20** from analogue to digital signals and summing the digital reception signals based on a position and a focal point of the plurality of transducers.

[0049] The image processor **130** may generate an ultrasound image by using ultrasound data generated from the ultrasound receiver **115**.

[0050] The display **140** may display the generated ultrasound image and various pieces of information processed by the ultrasound diagnosis apparatus **100**. The ultrasound diagnosis apparatus **100** may include two or more displays **140** according to embodiments. The display **140** may include a touch screen in combination with a touch panel.

[0051] The controller **120** may control the operations of the ultrasound diagnosis apparatus **100** and flow of signals between the internal elements of the ultrasound diagnosis apparatus **100**. The controller **120** may include a memory for storing a program or data to perform functions of the ultrasound diagnosis apparatus **100** and a processor and/or a microprocessor (not shown) for processing the program or data. For example, the controller **120** may control the operation of the ultrasound diagnosis apparatus **100** by receiving a control signal from the input interface **170** or an external apparatus.

[0052] The ultrasound diagnosis apparatus **100** may include the communicator **160** and may be connected to external apparatuses, for example, servers, medical apparatuses, and portable devices such as smart phones, tablet personal computers (PCs), wearable devices, etc., via the communicator **160**.

[0053] The communicator **160** may include at least one element capable of communicating with the external apparatus. For example, the communicator **160** may include at least one among a short-range communication module, a wired communication module, and a wireless communication module.

[0054] The communicator **160** may receive a control signal and data from an external apparatus and transmit the received control signal to the controller **120**, so that the controller **120** may control the ultrasound diagnosis apparatus **100** in response to the received control signal.

[0055] The controller **120** may transmit a control signal to an external apparatus via the communicator **160** so that the external apparatus may be controlled in response to the control signal of the controller **220**.

[0056] For example, the external apparatus connected to the ultrasound diagnosis apparatus **100** may process data of the external apparatus in response to control signal of the controller **220** received via the communicator **160**.

[0057] A program for controlling the ultrasound diagnosis apparatus **100** may be installed in the external apparatus. The program may include command languages to perform part of operation of the controller **120** or the entire operation of the controller **220**.

[0058] The program may be pre-installed in the external apparatus or may be installed by a user of the external apparatus by downloading the program from a server that provides applications. The server that provides applications may include a recording medium where the program is stored.

[0059] The storage **150** may store various data or programs for driving and controlling the ultrasound diagnosis apparatus **100**, input and/or output ultrasound data, ultrasound images, applications, etc.

[0060] The input interface **170** may receive a user's input to control the ultrasound diagnosis apparatus **100** and may include a key pad, button, keypad, mouse, trackball, jog switch, knob, a touchpad, a touch screen, a microphone, a motion input means, a biometrics input means, etc. For example, the user's input may include inputs for manipulating buttons, keypads, mice, track balls, jog switches, or knobs, inputs for touching a touchpad or a touch screen, a voice input, a motion input, and a bioinformation input, for example, iris recognition or fingerprint recognition, but an exemplary embodiment is not limited thereto.

[0061] The storage **150** may store information about the ultrasound probe **20** and a body of the ultrasound diagnosis apparatus **100**. According to an embodiment, the storage **150** may store information about the type of ultrasound probe **20**, identification information for identifying the type of ultrasound probe **20**, and information about applications of the ultrasound probe **20**.

[0062] The storage **150** may also store information about the impedance of the ultrasound probe **20**. According to an embodiment, the storage **150** may store information about impedance corresponding to the type of ultrasound probe **20**. In detail, the ultrasound probe **20** may include an ultrasound probe including a single transducer element, and an ultrasound probe including a transducer array comprised of a plurality of transducer elements.

[0063] The storage **150** may store information about the impedance of an ultrasound probe including a single transducer element. In this case, a plurality of ultrasound probes each including a single transducer element may be different in terms of impedance, and the storage **150** may store information about the respective impedances of the plurality of ultrasound probes different from one another in terms of impedance. A plurality of ultrasound probes each including a transducer array may be different in terms of impedance, and the storage **150** may store information about the respective impedances of the plurality of ultrasound probes that are different from one another in terms of impedance.

[0064] The storage **150** may store information about an impedance matching circuit corresponding to the information about the impedance corresponding to the type of ultrasound probe **20** and information about the impedance of the body. According to an embodiment, the storage **150** may store information about elements that are included in an impedance matching circuit that matches the impedance of the body with the impedance of the ultrasound probe **20**. In this case, the storage **150** may store information about the types of elements that are included in the impedance matching circuit, and information about element values of the elements that are included in the impedance matching circuit.

[0065] The storage **150** may store information about elements that are included in an impedance matching circuit corresponding to the relevant frequency characteristics of a reception signal applied to the body. In this case, the information about the elements that are included in the impedance matching circuit may include information about the types of the elements, information about the element values of the elements, and information about a method of connecting the elements. According to an embodiment, the storage **150** may include information about elements that are included in an impedance matching circuit corresponding to a cutoff frequency of an impedance matching circuit that operates as a filter. In this case, the storage **150** may include information about elements that are included in an impedance matching circuit respectively corresponding to a plurality of cutoff frequencies.

[0066] The storage **150** may store diagnosis applications executable by the ultrasound diagnosis apparatus **100**. According to an embodiment, the storage **150** may store diagnosis applications corresponding to parts of a human body. According to an embodiment, the diagnosis applications stored in the storage **150** may be applications regarding abdominal, musculoskeletal, heart, and ob/gyn diagnoses. In this case, the abdominal diagnosis application stored in the storage **150** may include diagnosis applications regarding thyroid, liver, kidney, heart, stomach, pancreas, gallbladder, spleen, esophagus, large intestine, small intestine, and rectum, and the musculoskeletal diagnosis application stored in the storage **150** may include diagnosis applications regarding respective muscles and blood vessels (such as carotid and aorta) of parts of a human body.

[0067] The storage **150** may store at least one image processing application capable of processing and displaying various types of images, such as a planar image and a three-dimensional (3D) image.

[0068] The storage **150** may store relevant frequency characteristics of reception signals corresponding to applications stored therein. The storage **150** may also include information about elements that are included in an impedance matching circuit corresponding to the relevant frequency characteristics.

[0069] The communicator **160** may transmit or receive the information about the ultrasound probe **20** and the ultrasound diagnosis apparatus body to or from an external apparatus. According to an embodiment, the communicator **160** may transmit or receive the information about the type of ultrasound probe **20**, the identification information for identifying the type of ultrasound probe **20**, and the information about applications of the ultrasound probe **20** to or from an external apparatus.

[0070] According to an embodiment, the communicator **160** may transmit or receive the information about the impedance of the ultrasound probe **20** to or from an external apparatus.

[0071] According to an embodiment, the communicator **160** may transmit or receive the information about the impedance matching circuit corresponding to the information about the impedance corresponding to the type of ultrasound probe **20** and the information about the impedance of the body to or from an external apparatus.

[0072] According to an embodiment, the communicator **160** may transmit or receive the information about the elements that are included in the impedance matching circuit that matches the impedance of the body with the impedance of the ultrasound probe **20**, to or from an external apparatus. In this case, the communicator **160** may transmit or receive the information about the types of elements that are included in the impedance matching circuit, and the information about the element values of the elements that are included in the impedance matching circuit, to or from an external apparatus.

[0073] The communicator **160** may transmit or receive the information about the elements that are included in the impedance matching circuit corresponding to the relevant frequency characteristics of the reception signal applied to the body to or from an external apparatus.

[0074] The communicator **160** may transmit or receive the information about the applications executed by the ultrasound diagnosis apparatus **100** to or from an external apparatus. The communicator **160** may transmit or receive the information about the relevant frequency characteristics of the reception signals corresponding to the applications stored in the ultrasound diagnosis apparatus **100**, to or from an external apparatus.

[0075] The input interface **170** may receive a user input for selecting a type of the ultrasound probe **20**. The input interface **170** may receive a user input of selecting one from a plurality of applications. The input interface **170** may receive a user input of selecting one from a plurality of ultrasound probes connected to the body. The input interface **170** may receive a user input of changing the relevant frequency characteristics of a reception signal input to the body. The input unit **170** may receive a user input of changing the cutoff frequency of an impedance matching circuit.

[0076] The controller **120** may control measurement of the impedance of the ultrasound probe **20** connected to the body of the ultrasound diagnosis apparatus **100**. The controller **120** may control measurement of the impedance of the body of the ultrasound diagnosis apparatus **100**. The controller **120** may control an impedance matching circuit to match the measured impedance of the ultrasound probe **20** with the measured impedance of the body of the ultrasound diagnosis apparatus **100**.

[0077] The controller **120** may control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body of the ultrasound diagnosis apparatus **100**. According to an embodiment, the controller **120** may control the impedance matching circuit to act as at least one filter that passes or stops a specific frequency band of a reception signal that passes through the impedance matching circuit. In this case, the controller **120** may control the impedance matching circuit so that the reception signal that passes through the impedance matching circuit includes relevant frequency characteristics. The controller **120** may control the impedance matching circuit to operate as a multi-stage filter.

[0078] The controller **120** may select circuit elements that are included in the impedance matching circuit. According to an embodiment, the controller **120** may select the types of circuit elements that are included in the impedance matching circuit, a method of connecting the circuit elements, and the values of the circuit elements.

[0079] The controller **120** may select at least one circuit element from among a plurality of circuit elements of an identical type, and control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body by using the selected circuit element.

[0080] The controller **120** may select at least one circuit element from among a plurality of circuit elements of different types, and control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body by using the selected circuit element.

[0081] The controller **120** may select at least one circuit element from a plurality of circuit element banks of different types each including circuit elements of an identical type having different values, and control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body by using the selected circuit element.

[0082] The controller **120** may select circuit elements constituting an impedance matching circuit, based on a user input of changing relevant frequency characteristics, and control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body by using the selected circuit elements.

[0083] The controller **120** may detect an ultrasound probe currently-being-used by a user from among a plurality of ultrasound probes connected to the body. According to an embodiment, the controller **120** may transmit an ultrasound signal to an object and detect an ultrasound probe that is currently receiving an ultrasound echo signal from the object, thereby detecting the ultrasound probe currently-being-used by the user. According to another embodiment, the controller **120** may detect the ultrasound probe currently-being-used by the user, by detecting movements of the ultrasound probes. According to another embodiment, the controller **120** may detect the ultrasound probe currently-being-used by the user, by detecting whether the ultrasound probes have been separated from a probe holder. In this case, a radio frequency identification (RFID) reader may be included in at least one of an ultrasound probe and the probe holder, and an RFID writer may be included in the other one. The controller **120** may detect whether the ultrasound probes have been separated from a probe holder, by using the RFID reader and the RFID writer.

[0084] The controller **120** may control the impedance matching circuit to change the relevant frequency characteristics of the reception signal that passes through the impedance matching circuit, according to an application currently being executed by the ultrasound diagnosis apparatus **100**. The controller **120** may control the impedance matching circuit to change the relevant frequency characteristics of the reception signal passing through the impedance matching circuit, in response to a user input of changing the application currently being executed by the ultrasound diagnosis apparatus **100**.

[0085] According to an embodiment, the controller **120** may control the impedance matching circuit to operate as a high-pass filter, in response to a user input of selecting applications used for musculoskeletal, blood vessel, and thyroid diagnoses. The relevant frequency characteristics of the reception signal corresponding to the applications used for musculoskeletal and blood vessel diagnoses include a high frequency. In detail, as the frequency of an ultrasound signal transmitted by a human body increases, the resolution thereof increases. However, the ultrasound signal does not pass deeply through the human body. Thus, ultrasound waves used for the skeleton and musculature and blood vessels located on the surface of a human body use a high-frequency ultrasound signal. In general, ultrasound signals for use in musculoskeletal and blood vessel diagnoses include a frequency of **4** to **11**MHz and are transmitted by a human body via a linear-type ultrasound probe.

[0086] According to an embodiment, the controller **120** may control the impedance matching circuit to operate as a low-pass filter, in response to a user input of selecting applications for use in abdominal, heart, and ob/gyn diagnoses. The relevant frequency characteristics of a reception signal corresponding to the applications used for abdominal, heart, and ob/gyn diagnoses include a low frequency. In detail, as the frequency of an ultrasound signal transmitted by a human body decreases, the resolution thereof decreases. However, the ultrasound signal may pass deeply through the human body. Thus, ultrasound waves used for diagnosing abdomen and heart located deeply in a human body or for ob/gyn diagnosis use a low-frequency ultrasound signal. In general, ultrasound signals for abdomen, heart, and ob-gyn include a frequency of 3 to 5 MHz and are transmitted by a human body via a curved-type ultrasound probe.

[0087] The controller **120** may detect the type and application of the ultrasound probe **20** connected to the ultrasound diagnosis apparatus **100**. According to an embodiment, the controller **120** may detect the type of ultrasound probe **20**, based on the identification information of the ultrasound probe **20** stored in the storage **150**. The controller **120** may select circuit elements that are included in an impedance matching circuit corresponding to the type of ultrasound probe **20**, and control the impedance matching circuit to match the impedance of the ultrasound probe **20** with the impedance of the body by using the selected circuit elements.

[0088] According to an embodiment, the type of ultrasound probe **20** may vary according to use purposes. In this case, ultrasound probes may be classified into linear-type ultrasound probes, curved-type ultrasound probes, and sector-type ultrasound probes.

[0089] The linear-type ultrasound probes may be used to diagnose tissues located near the skin, such as the skeleton and musculature, blood vessels, and thyroid. Because tissues located near the skin are diagnosed using a high-frequency ultrasound signal as described above, when the controller **120** detects a linear-type ultrasound probe, the controller **120** may control the impedance matching circuit to operate as a high-pass filter.

[0090] The curved-type ultrasound probes may be used to diagnose tissues located deeply within the human body, such as abdomen, heart, and fetus. In detail, the curved-type ultrasound probes may be used to diagnose liver, kidney, heart, stomach, pancreas, gallbladder, spleen, esophagus, large intestine, small intestine, and rectum. Because tissues located deeply within the human body are diagnosed using a low-frequency ultrasound signal as described above, when the controller **120** detects a curved-type ultrasound probe, the controller **120** may control the impedance matching circuit to operate as a low-pass filter.

[0091] An example of the ultrasound diagnosis apparatus **100** according to an embodiment will now be described with reference to FIG. **2**.

[0092] FIG. **2** is a diagram of the ultrasound diagnosis apparatus **100** according to an embodiment.

[0093] Referring to FIG. **2**, the ultrasound diagnosis apparatus **100** may include a main display **121** and a sub-display **122**. One of the main display **121** and the sub-display **122** may be implemented using a touch screen. The main display **121** and the sub-display **122** may display an ultrasound image or various pieces of information that are processed by the ultrasound diagnosis apparatus **100**. The main display **121** and the sub-display **122** may be implemented using touch screens, and may provide graphical user interfaces (GUIs) to receive data for controlling the ultrasound diagnosis apparatus **100** from a user. For example, the main display **121** may display an ultrasound image, and the sub-display **122** may display a control panel for controlling display of the ultrasound image, in a GUI form. The sub-display **122** may receive data for controlling display of an image, via a control panel displayed in a GUI form. The ultrasound diagnosis apparatus **100** may control display of an ultrasound image displayed on the main display **121**, by using the received control data.

[0094] Referring to FIG. **2**, the ultrasound diagnosis apparatus **100** may include a plurality of ultrasound probes connected to a body of the ultrasound diagnosis apparatus **100**. In detail, the plurality of ultrasound probes may be of different types. The plurality of ultrasound probes may be used for different purposes. The plurality of ultrasound probes may have different impedance magnitudes. The plurality of ultrasound probes may generate reception signals having different prevalent frequency characteristics.

[0095] The plurality of ultrasound probes may be connected to the body via impedance matching circuits, respectively. In this case, separate impedance matching circuits may be used in correspondence with the plurality of ultrasound probes, respectively. The impedance matching circuits may be connected to the plurality of ultrasound probes via a plurality of input ports and may be connected to the body via a single output port.

[0096] FIG. **3** is a block diagram of a structure of an ultrasound diagnosis apparatus according to an embodiment.

[0097] According to the embodiment of FIG. **3**, the ultrasound diagnosis apparatus may include an ultrasound probe **310**, an impedance matching circuit **320**, and a body **330**.

[0098] The ultrasound probe **310** may transmit an ultrasound signal to an object and may receive an ultrasound echo signal from the object. The ultrasound probe **310** may form a reception signal by using the received ultrasound echo signal. The reception signal formed by the ultrasound probe **310** may be input to the body **330** via the impedance matching circuit **320**.

[0099] The impedance matching circuit **320** may match impedance of the ultrasound probe **310** with impedance of the body **330** to minimize electrical energy loss of the reception signal input to the body **330**. The impedance matching circuit **320** may operate as a filter that transmits or blocks a specific frequency band of the reception signal that passes through the impedance matching circuit **320**. The impedance matching circuit **320** may be included in the body **330** or in the ultrasound probe **310**. A part of the impedance matching circuit **320** may be included in the ultrasound probe **310**, and the remaining part thereof may be included in the body **330**.

[0100] The body **330** may process the received reception signal. The body **330** may process the received reception signal to generate an ultrasound diagnosis image. The body **330** may include a controller **331** that controls overall operations of the ultrasound diagnosis apparatus. The controller **331** may select circuit elements that are included in the impedance matching circuit **320**. The controller **331** may select circuit elements that are included in the impedance matching circuit **320**, based on the impedance of the ultrasound probe **310**, the impedance of the body **330**, and relevant frequency characteristics of the reception signal. The controller **331** may control the reception signal passing through the impedance matching circuit **320** to include relevant frequency characteristics by using the selected circuit elements. According to an embodiment, the controller **331** may select circuit elements that are included in the impedance matching circuit **320**, so that the impedance matching circuit **320** operates as one of a high-pass filter, a low-pass filter, a band-pass filter, and a band-stop filter in accordance with the relevant frequency characteristics.

[0101] FIG. **4** is a block diagram illustrating, in detail, an impedance matching circuit **420** included in an ultrasound diagnosis apparatus according to an embodiment.

[0102] According to the embodiment of FIG. **4**, the impedance matching circuit **420** may include a plurality of circuit elements of different types. The impedance matching circuit **420** may include a switch or multiplexer (MUX) that connects the circuit elements that are included in the impedance matching circuit **420**.

[0103] The circuit elements included in the impedance matching circuit **420** may be variable elements of which element values are variable. According to an embodiment, a mechanical tab may be installed on a main coil, and inductance of a variable inductor may vary according to locations of the mechanical tab. The variable inductor may change its inductance by using a ratio between the main coil and an auxiliary coil installed together with the variable inductor. The inductance of the variable inductor may be changed according to the amount of current applied to the variable inductor by using a magnetic core formed of different types of magnetic materials. However, the variable inductor is not limited thereto. According to an embodiment, a variable capacitor has a capacitance that may be changed according to a voltage applied to the variable capacitor, but embodiments are not limited thereto.

[0104] The circuit elements that are included in the impedance matching circuit **420** may include a serial inductor, a serial capacitor, a parallel inductor, and a parallel capacitor. The circuit elements that are included in the impedance matching circuit **420** may be selected by using a switch.

[0105] A controller **431** may select at least one from circuit elements **421**, **422**, **423**, **424**, **426**, **427**, **428**, and **429** that are included in the impedance matching circuit **420**, and may control the impedance matching circuit **420** to be reconstructed with the selected circuit element.

[0106] The controller **431** may select an array of the circuit elements that are included in the impedance matching circuit **420**, according to an impedance magnitude of an ultrasound probe **410** and an impedance magnitude of a body **430**. According to an embodiment, when the ultrasound probe **410** includes a single transducer element, because the impedance of the ultrasound probe **410** is smaller than the impedance of the body **430**, the controller **431** may match the impedance of the ultrasound probe **410** with the impedance of the body **430** by selecting the serial inductor **421** and the parallel capacitor **429** from the circuit elements that are included in the impedance matching circuit **420**. The controller **431** may match the impedance of the ultrasound probe **410** with the impedance of the body **430** by selecting the serial capacitor **422** and the parallel inductor **428** from the circuit elements that are included in the impedance matching circuit **420**. According to an embodiment, when the ultrasound probe **410** includes a transducer array of a plurality of transducer elements, because the impedance of the ultrasound probe **410** is larger than the impedance of the body **430**, the controller **431** may match the impedance of the ultrasound probe **410** with the impedance of the body **430** by selecting the parallel inductor **423** and the serial capacitor **427** from the circuit elements that are included in the impedance matching circuit **420**. Alternatively, the controller **431** may match the impedance of the ultrasound probe **410** with the impedance of the body **430** by selecting the parallel capacitor **424** and the serial inductor **426** from the circuit elements that are included in the impedance matching circuit **420**.

[0107] The controller **431** may select circuit elements that are included in the impedance matching circuit **420**, according to relevant frequency characteristics of a reception signal that passes through the impedance matching circuit **420**. According to an embodiment, the controller **431** may select circuit elements of the impedance matching circuit **420** so that the impedance matching circuit **420** operates as a low-pass filter for spurious removal or harmonic removal of the reception signal. The controller **431** may control the impedance matching circuit **420** to operate as a low-pass filter, by selecting the serial inductor **421** and the parallel capacitor **429** from the circuit elements that are included in the impedance matching circuit **420**. According to an embodiment, the controller **431** may select circuit elements of the impedance matching circuit **420** so that the impedance matching circuit **420** operates as a high-pass filter for low-frequency oscillation prevention and ringing prevention of the reception signal. The controller **431** may control the impedance matching circuit **420** to operate as a high-pass filter, by selecting the serial capacitor **422** and the parallel inductor **428** from the circuit elements that are included in the impedance matching circuit **420**.

[0108] According to an embodiment, when the impedance matching circuit **420** operates as a low-pass filter, the controller **431** may select the serial inductor **421** and the parallel capacitor **429** from the circuit elements that are included in the impedance matching circuit **420**. The controller **431** may control a switch to connect the selected serial inductor **421** to the ultrasound probe **410**. The controller **431** may control a switch to connect the selected serial inductor **421** to the selected parallel capacitor **429**. The controller **431** may control a switch to connect the selected parallel capacitor **429** to the body **430**.

[0109] According to an embodiment, when the impedance matching circuit **420** operates as a high-pass filter, the controller **431** may select the serial capacitor **422** and the parallel inductor **428** from the circuit elements that are included in the impedance matching circuit **420**. The controller **431** may control a switch to connect the selected serial capacitor **422** to the ultrasound probe **410**. The controller **431** may control a switch to connect the selected serial capacitor **422** to the selected parallel inductor **428**. The controller **431** may control a switch to connect the selected parallel inductor **428** to the body **430**.

[0110] According to an embodiment, the controller **431** may select circuit elements that are included in the impedance matching circuit **420**, according to the impedance of the ultrasound probe **410** and the impedance of the body **430**. In detail, when the ultrasound probe **410** includes a single transducer element and thus the impedance of the ultrasound probe **410** is smaller than the impedance of the body **430**, the controller **431** may select the serial circuit elements **421** and **422** and the parallel circuit elements **428** and **429**. The controller **431** may control a switch to connect the selected serial circuit elements **421** and **422** to the ultrasound probe **410**. The controller **431** may control a switch to connect the selected serial circuit elements **421** and **422** to the selected parallel circuit elements **428** and **429**. The controller **431** may control a switch to connect the selected parallel circuit elements **428** and **429** to the body **430**.

[0111] On the other hand, when the ultrasound probe **410** includes a transducer array of a plurality of transducer elements and thus the impedance of the ultrasound probe **410** is larger than the impedance of the body **430**, the controller **431** may select the parallel circuit elements **423** and **424** and the serial circuit elements **426** and **427**. The controller **431** may control a switch to connect the selected parallel circuit elements **423** and **424** to the ultrasound probe **410**. The controller **431** may control a switch to connect the selected parallel circuit elements **423** and **424** to the selected serial circuit elements **426** and **427**. The controller **431** may control a switch to connect the selected serial circuit elements **426** and **427** to the body **430**.

[0112] The controller **431** may control the types and element values of the circuit elements that are included in the impedance matching circuit **420** operating as a filter, thereby controlling a cutoff frequency of the filter.

[0113] A method in which the controller **431** selects the types and element values of the circuit elements that are included in the impedance matching circuit **420** will be described later.

[0114] FIG. **5** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit **520** operating as a 2-stage filter, according to an embodiment.

[0115] According to the embodiment of FIG. **5**, the impedance matching circuit **520** may operate as a multi-stage filter. According to an embodiment, the impedance matching circuit **520** may operate as a 2-stage filter or as a filter with three or more stages.

[0116] According to an embodiment, a first filter **521** may be a low-pass filter and a second filter **526** may be a high-pass filter. In this case, the impedance matching circuit **520** may operate as a band-pass filter or a band-stop filter. According to another embodiment, the first filter **521** may be a high-pass filter and the second filter **526** may be a low-pass filter. In this case, the impedance matching circuit **520** may operate as a band-pass filter or a band-stop filter. According to another embodiment, both the first filter **521** and the second filter **526** may be low-pass filters. In this case, a high frequency band of a reception signal that passes through the impedance matching circuit **520** may be securely removed via the impedance matching circuit **520**. According to another embodiment, both the first filter **521** and the second filter **526** may be high-pass filters. In this case, a low frequency band of a reception signal that passes through the impedance matching circuit **520** may be securely removed via the impedance matching circuit **520**.

[0117] FIG. **6** is a circuit view for explaining a process of determining elements that are included in an impedance matching circuit **620**, and element values of the elements, according to an embodiment.

[0118] According to the embodiment of FIG. **6**, the impedance matching circuit **620** may be located between an ultrasound probe **610** and a body **630**. In order for the impedance matching circuit **620** to match impedance of the ultrasound probe **610** with impedance of the body **630**, an input impedance Zin of the impedance matching circuit **620** needs to be equal to a conjugated complex number ZX* of impedance ZX of the ultrasound probe **610**, and an output impedance Zout of the impedance matching circuit **620** needs to be equal to a conjugated complex number Zs* of impedance Zs of the body **630**.

[0119] The impedance ZX of the ultrasound probe **610** is calculated using Equation

$$Z_X R_X(\omega)+fX_X(\omega)=a+jb, \quad \text{[Equation 1]}$$

[0120] The impedance Zs of the body **630** is calculated using Equation 2.

$$Z_S–R_S(\omega)+jX_S(\omega)–c+jd \quad \text{[Equation 2]}$$

[0121] The structure of the impedance matching circuit **620** may be implemented in two types according to the magnitudes of the impedance of the ultrasound probe **610** and the impedance of the body **630**.

[0122] FIG. **7** is a circuit view for explaining a process of determining elements that are included in an impedance matching circuit **720**, and element values of the elements, according to an embodiment.

[0123] According to the embodiment of FIG. **7**, an impedance magnitude of an ultrasound probe **710** is smaller than an impedance magnitude of a body **730** (i.e., $|Z_S|>|Z_X|$), the impedance matching circuit **720** is implemented such that a serial circuit element is connected to the ultrasound probe **710** and a parallel circuit element is connected to the body **730**.

[0124] The types and element values of devices that are included in the impedance matching circuit **720** are calculated using Equation 3 and Equation 4.

$$Z_{in} = Z_X^* = a - jb \quad \text{[Equation 3]}$$

$$Z_{in} = jX + (jB \| Z_s) = jX + \frac{jB\cdot(c+jd)}{jB+(c+jd)} = \frac{c\cdot B^2}{c^2+(d+B)^2} - j\frac{d\cdot B^2+(c^2+d^2)\cdot B+\{c^2+(d+B)^2\}\cdot X}{c^2+(d+B)^2} \quad \text{[Equation 4]}$$

[0125] When the right side of Equation 3 is the same as that of Equation 4, impedance of the ultrasound probe **710** is matched with impedance of the body **730**.

[0126] Therefore, when the right sides of Equations 3 and 4 are arranged to be equal to each other, Equation 5 and Equation 6 are obtained as follows.

$$a = \frac{c\cdot B^2}{c^2+(d+B)^2} \quad \text{[Equation 5]}$$

$$b = -\frac{d\cdot B^2+(c^2+d^2)\cdot B+\{c^2+(d+B)^2\}\cdot X}{c^2+(d+B)^2} \quad \text{[Equation 6]}$$

[0127] The types and element values of elements that are included in the impedance matching circuit **720** are calculated using Equation 7 and Equation 8.

$$Z_{out} = Z_S^* = c - jd \quad \text{[Equation 7]}$$

$$Z_{out} = jB\|(jX+Z_X) = jB\|(jX+c+jd) = \frac{a\cdot B^2}{a^2+(b+B+X)^2} - j\frac{a^2\cdot B+(b+X)\cdot(b+B+X)\cdot B}{a^2+(b+B+X)^2} \quad \text{[Equation 8]}$$

[0128] When the right side of Equation 7 is the same as that of Equation 8, the impedance of the ultrasound probe **710** is matched with the impedance of the body **730**.

[0129] Therefore, when the right sides of Equations 7 and 8 are arranged to be equal to each other, results of Equation 9 and Equation 10 are obtained.

$$c = \frac{a\cdot B^2}{a^2+(b+B+X)^2} \quad \text{[Equation 9]}$$

$$d = -\frac{a^2\cdot B+(b+X)\cdot(b+B+X)\cdot B}{a^2+(b+B+X)^2} \quad \text{[Equation 10]}$$

[0130] When element values X and B of elements that are included in the impedance matching circuit **720** are obtained using Equations 5, 6, 9 and 10, the element values X and B are equal to Equations 11 and 12.

$$B = \frac{-ad \pm \sqrt{ac(c^2+d^2-ac)}}{a-c} \quad \text{[Equation 11]}$$

$$X = \frac{-bc \pm \sqrt{ac(c^2+d^2-ac)}}{c} \quad \text{[Equation 12]}$$

[0131] FIG. **8** is a circuit view for explaining a process of determining elements that are included in an impedance matching circuit **820**, and element values of the elements, according to an embodiment.

[0132] According to the embodiment of FIG. **8**, an impedance magnitude ($|Z_x|$) of an ultrasound probe **810** is larger than an impedance magnitude $|Z_S|$ of a body **830** (i.e., $|Z_S|<|Z_x|$), the impedance matching circuit **820** is implemented such that a parallel circuit element is connected to the ultrasound probe **810** and a serial circuit element is connected to the body **830**.

[0133] The types and element values of elements that are included in the impedance matching circuit **820** are calculated using Equation 13 and Equation 14.

$$Z_{in} = Z_x^* = a - jb \quad \text{[Equation 13]}$$

$$Z_{in} = jB \| (jX + Z_s) = jB \| (jX + c + jd) = \frac{c \cdot B^2}{c^2 + (d + B + X)^2} - j\frac{c^2 \cdot B + (d + X) \cdot (d + B + X) \cdot B}{c^2 + (d + B + X)^2} \quad \text{[Equation 14]}$$

[0134] When the right side of Equation 13 is the same as that of Equation 14, the impedance of the ultrasound probe **810** is matched with the impedance of the body **830**.

[0135] Therefore, when the right sides of Equations 13 and 14 are arranged to be equal to each other, results of Equation 15 and Equation 16 are obtained.

$$a = \frac{c \cdot B^2}{c^2 + (d + B + X)^2} \quad \text{[Equation 15]}$$

$$b = -\frac{c^2 \cdot B + (d + X) \cdot (d + B + X) \cdot B}{c^2 + (d + B + X)^2} \quad \text{[Equation 16]}$$

[0136] The types and element values of elements that are included in the impedance matching circuit **820** are calculated using Equation 17 and Equation 18.

$$Z_{out} = Z_S^* = c - jd \quad \text{[Equation 17]}$$

$$Z_{out} = jX + (jB \| Z_X) = jX + \frac{jB \cdot (a + jb)}{jB + (a + jb)} = \frac{a \cdot B^2}{a^2 + (b + B)^2} - j\frac{b \cdot B^2 + (a^2 + b^2) + \{a^2 + (b + B)^2\} \cdot X}{a^2 + (b + B)^2} \quad \text{[Equation 18]}$$

[0137] When the right side of Equation 17 is the same as that of Equation 18, the impedance of the ultrasound probe **810** is matched with the impedance of the body **830**.

[0138] Therefore, when the right sides of Equations 17 and 18 are arranged to be equal to each other, results of Equation 19 and Equation 20 are obtained.

$$c = \frac{a \cdot B^2}{a^2 + (b + B)^2} \quad \text{[Equation 19]}$$

$$d = -\frac{b \cdot B^2 + (a^2 + b^2) \cdot B + \{a^2 + (b + B)^2\} \cdot X}{a^2 + (b + B)^2} \quad \text{[Equation 20]}$$

[0139] When element values X and B of elements that are included in the impedance matching circuit **820** are obtained using Equations 15, 16, 19 and 20, the element values X and B are equal to Equations 21 and 22.

$$B = \frac{-bc \pm \sqrt{ac(a^2 + b^2 - ac)}}{c - a} \quad \text{[Equation 21]}$$

-continued

$$X = \frac{-ad \pm \sqrt{ac(a^2 + b^2 - ac)}}{a} \quad \text{[Equation 22]}$$

[0140] When the element values X and B of the elements that are included in the impedance matching circuit **820**, which are calculated using Equations 21 and 22, are positive values, the elements are inductors. On the other hand, when the element values X and B of the elements that are included in the impedance matching circuit **820**, which are calculated using Equations 21 and 22, are negative values, the elements are capacitors.

[0141] In order for the impedance matching circuits **720** and **820** to operate as filters that pass or stop specific frequency bands of reception signals that pass through the impedance matching circuits **720** and **820**, the element values of Equations 11 and 12 need to have opposite signs, and the element values of Equations 21 and 22 need to have opposite signs. In other words, circuit elements having element values and constructing the impedance matching circuits **720** and **820** are different types of elements. When different types of circuit elements are included in the impedance matching circuits **720** and **820**, the impedance matching circuits **720** and **820** may operate as filters that pass or stop specific frequency bands.

[0142] FIG. **9** is a circuit diagram a structure of an impedance matching circuit **920** operating as a low pass filter, according to an embodiment.

[0143] According to the embodiment of FIG. **9**, the impedance matching circuit **920** may operate as a low-pass filter. In this case, impedance of an ultrasound probe **910** is smaller than impedance of a body **930**. In order for the impedance matching circuit **920** to operate as a low-pass filter, an inductor **921** is connected to the ultrasound probe **910**, and a capacitor **923** is connected to the body **930**. In this case, a element value of the inductor **921** may be calculated using Equation 12, and a element value of the capacitor **923** may be calculated using Equation 11.

[0144] According to an embodiment, the impedance of the ultrasound probe **910** is equal to Equation 23, and the impedance of the body **930** is equal to Equation 24. In unique frequency characteristics of a transducer element of the ultrasound probe **910**, a central frequency is 47.5 MHz, and a bandwidth is 24 MHz (35 MHz to 59 MHz).

$$Z_x = 21.6 < -55.5° = 12.236 - j17.8\Omega (@\ 50\ \text{MHz}) \quad \text{[Equation 23]}$$

$$Z_s 50 < ° = 50\Omega (@\ 50\ \text{MHz}) \quad \text{[Equation 24]}$$

[0145] When Equation 23 and Equation 24 are substituted into Equation 11 and Equation 12, the element value of the inductor **921** and the element value of the capacitor **923** may be calculated.

L_x=127.44 nH, C_p=107.652 pF

[0146] Characteristics of a low-pass filter with respect to a variation in the inductance of the inductor **921** from a calculated element value, and characteristics of a low-pass filter with respect to a variation in the capacitance of the capacitor **923** from a calculated element value will now be described.

[0147] FIG. **10** is a graph showing the characteristics of the impedance matching circuit **920** respectively corresponding to inductance values when the impedance matching circuit **920** operates as a low-pass filter.

[0148] According to the embodiment of FIG. 10, characteristics of a low-pass filter vary according to a variation in the element value of the inductor 921 of the impedance matching circuit 920. In detail, when the inductance of the inductor 921 increases, a cutoff frequency of the impedance matching circuit 920 operating as a low-pass filter decreases. When the inductance of the inductor 921 decreases, the cutoff frequency of the impedance matching circuit 920 operating as a low-pass filter increases. Thus, when the cutoff frequency of the impedance matching circuit 920 is desired to be changed, a controller 931 of FIG. 9 may control the inductance of the inductor 921 calculated using Equation 12 to be changed. In detail, when it is desired to decrease the cutoff frequency of the impedance matching circuit 920, the controller 931 of FIG. 9 may control the impedance matching circuit 920 to include therein an inductor having a larger inductance than the inductance of the inductor 921 calculated using Equation 12. On the other hand, when it is desired to increase the cutoff frequency of the impedance matching circuit 920, the controller 931 of FIG. 9 may control the impedance matching circuit 920 to include therein an inductor having a smaller inductance than the inductance of the inductor 921 calculated using Equation 12.

[0149] FIG. 11 is a graph showing the characteristics of the impedance matching circuit 920 respectively corresponding to capacitance values when the impedance matching circuit 920 operates as a low-pass filter.

[0150] According to the embodiment of FIG. 11, characteristics of a low-pass filter vary according to a variation in the element value of the capacitor 923 of the impedance matching circuit 920. In detail, when the capacitance of the capacitor 923 increases, a cutoff frequency of the impedance matching circuit 920 operating as a low-pass filter decreases. When the capacitance of the capacitor 923 decreases, the cutoff frequency of the impedance matching circuit 920 operating as a low-pass filter increases.

[0151] Thus, when it is desired to change the cutoff frequency of the impedance matching circuit 920, the controller 931 of FIG. 9 may change the capacitance of the capacitor 923 calculated using Equation 11. In detail, when it is desired to decrease the cutoff frequency of the impedance matching circuit 920, the controller 931 of FIG. 9 may include in the impedance matching circuit 920 a capacitor having a larger capacitance than the capacitance of the capacitor 923 calculated using Equation 11. On the other hand, when it is desired to increase the cutoff frequency of the impedance matching circuit 920, the controller 931 of FIG. 9 may include in the impedance matching circuit 920 a capacitor having a smaller capacitance than the capacitance of the capacitor 923 calculated using Equation 11.

[0152] Referring to FIGS. 10 and 11, when the impedance matching circuit 920 operates as a low-pass filter, a change in the cutoff frequency of the impedance matching circuit 920 according to the variation in the inductance value of the inductor 921, which is connected to the ultrasound probe 910, is larger than a change in the cutoff frequency of the impedance matching circuit 920 according to the variation in the capacitance value of the capacitor 923, which is connected to the body 930. Thus, when the controller 931 selects elements of the impedance matching circuit 920, the controller 931 may select the inductor 921 first and then may select the capacitor 923. When the controller 931 changes the cutoff frequency of the impedance matching circuit 920, the controller 931 may change the inductor 921 included in the impedance matching circuit 920 in preference to the capacitor 923 included in the impedance matching circuit 920.

[0153] FIG. 12 is a graph showing the characteristics of the impedance matching circuit 920 respectively corresponding to cutoff frequencies when the impedance matching circuit 920 operates as a low-pass filter.

[0154] When the impedance matching circuit 920 is constructed within a unique bandwidth range (central frequency is 47.5 MHz and bandwidth is 24 MHz) of a transducer included in an ultrasound probe, the impedance matching circuit 920 has cutoff frequencies and characteristics of a low-pass filter shown in FIG. 12. Thus, the controller 931 of FIG. 9 may select circuit elements of the impedance matching circuit 920, based on the cutoff frequencies and the characteristic of the impedance matching circuit 920 operating as a low-pass filter, which shown in FIG. 12.

[0155] FIG. 13 is a graph of a result of impedance matching performed by using the impedance matching circuit 920 operating as a low pass filter.

[0156] FIG. 13 shows effects obtained by matching the impedance the ultrasound probe 910 with the impedance of the body 930 by using the impedance matching circuit 920 operating as a low-pass filter. The graph of FIG. 13 shows characteristics of a reception signal when the impedance matching circuit 920 exists within the unique bandwidth range (central frequency is 47.5 MHz and bandwidth is 24 MHz) of a transducer included in an ultrasound probe and characteristics of the reception signal when no impedance matching circuits exist.

[0157] When impedance matching is performed using the impedance matching circuit 920, a central frequency of a reception signal input to the body 930 is 36.1MHz, a bandwidth thereof is 32.8 MHz, an output impedance Zout thereof is 46.20, and an impedance phase thereof is −7.4°. On the other hand, when no impedance matching circuits 920 exist, a central frequency of the reception signal input to the body 930 is 47.5 MHz, a bandwidth thereof is 23.5 MHz, an output impedance Zout thereof is 21.6Ω, and an impedance phase thereof is −55.5°.

[0158] When the impedance matching circuit 920 exists, the magnitude of the bandwidth increased, the magnitude of the output impedance Zout increased, and the impedance phase decreased. As the magnitude of the output impedance Zout and the impedance magnitude of the body 930 are similar to each other, electrical energy loss of the reception signal input to the body 930 decreases. Thus, the reception signal input to the body 930 is less lost when the impedance matching circuit 920 exists than when no impedance matching circuits 920 exist.

[0159] In addition, a signal response of a 25 MHz to 45 MHz band is better when the impedance matching circuit 920 is used than when the impedance matching circuit 920 is not used. Thus, loss of the reception signal input to the body 930 is reduced within a unique bandwidth of a transducer included in the ultrasound probe 910 when the impedance matching circuit 920 is used, compared to when no impedance matching circuits 920 are used.

[0160] FIG. 14 is a circuit diagram a structure of an impedance matching circuit 1420 operating as a high pass filter, according to an embodiment.

[0161] According to the embodiment of FIG. 14, the impedance matching circuit 1420 may operate as a high-pass filter. In this case, impedance of an ultrasound probe 1410 is smaller than impedance of a body **1430**. In order for the impedance matching circuit **1420** to operate as a high-pass filter, a capacitor **1423** is connected to the ultrasound probe **1410**, and an inductor **1421** is connected to the body **1430**. In this case, a element value of the inductor **1421** may be calculated using Equation 11, and a element value of the capacitor **1423** may be calculated using Equation 12.

[0162] According to an embodiment, the impedance of the ultrasound probe **1410** is equal to Equation 23, and the impedance of the body **1430** is equal to Equation 24. In unique frequency characteristics of a transducer element of the ultrasound probe **1410**, a central frequency is 47.5 MHz, and a bandwidth is 24 MHz (35 MHz to 59 MHz).

[0163] When Equation 23 and Equation 24 are substituted into Equation 11 and Equation 12, the element value of the inductor **1421** and the element value of the capacitor **1423** may be calculated.

$$C_S=702.303\text{ pF},\ L_P=94.119\text{ nH}$$

[0164] Characteristics of a high-pass filter with respect to a variation in the inductance of the inductor **1421** from a calculated element value, and characteristics of a high-pass filter with respect to a variation in the capacitance of the capacitor **1423** from a calculated element value will now be described.

[0165] FIG. **15** is a graph showing the characteristics of the impedance matching circuit **1420** respectively corresponding to capacitance values when the impedance matching circuit **1420** operates as a high-pass filter.

[0166] According to the embodiment of FIG. **15**, characteristics of a high-pass filter vary according to a variation in the element value of the capacitor **1423** of the impedance matching circuit **1420**. In detail, when the capacitance of the capacitor **1423** increases, a cutoff frequency of the impedance matching circuit **1420** operating as a high-pass filter decreases. When the capacitance of the capacitor **1423** decreases, the cutoff frequency of the impedance matching circuit **1420** operating as a high-pass filter increases.

[0167] Thus, when the cutoff frequency of the impedance matching circuit **1420** is desired to be changed, the controller **1431** of FIG. **14** may change the capacitance of the capacitor **1423** calculated using Equation 12. In detail, when it is desired to decrease the cutoff frequency of the impedance matching circuit **1420**, the controller **1431** may include in the impedance matching circuit **1420** a capacitor having a larger capacitance than the capacitance of the capacitor **1423** calculated using Equation 12. On the other hand, when it is desired to increase the cutoff frequency of the impedance matching circuit **1420**, the controller **1431** may control the impedance matching circuit **1420** to include therein a capacitor having a smaller capacitance than the capacitance of the capacitor **1423** calculated using Equation 12.

[0168] FIG. **16** is a graph showing the characteristics of the impedance matching circuit **1420** respectively corresponding to inductance values when the impedance matching circuit **1420** operates as a high-pass filter.

[0169] According to the embodiment of FIG. **16**, characteristics of a high-pass filter vary according to a variation in the element value of the inductor **1421** of the impedance matching circuit **1420**. In detail, when the inductance of the inductor **1421** increases, a cutoff frequency of the impedance matching circuit **1420** operating as a high-pass filter decreases. When the inductance of the inductor **1421** decreases, the cutoff frequency of the impedance matching circuit **1420** operating as a high-pass filter increases.

[0170] Thus, when the cutoff frequency of the impedance matching circuit **1420** is desired to be changed, the controller **1431** of FIG. **14** may change the inductance of the inductor **1421** calculated using Equation 11. In detail, when it is desired to decrease the cutoff frequency of the impedance matching circuit **1420**, the controller **1431** may include in the impedance matching circuit **1420** an inductor having a larger inductance than the inductance of the inductor **1421** calculated using Equation 11. On the other hand, when it is desired to increase the cutoff frequency of the impedance matching circuit **1420**, the controller **1431** may include in the impedance matching circuit **1420** an inductor having a smaller inductance than the inductance of the inductor **1421** calculated using Equation 11.

[0171] Referring to FIGS. **15** and **16**, when the impedance matching circuit **1420** operates as a high-pass filter, a change in the cutoff frequency of the impedance matching circuit **1420** according to the variation in the inductance value of the inductor **1421**, which is connected to the body **1430**, is larger than a change in the cutoff frequency of the impedance matching circuit **1420** according to the variation in the capacitance value of the capacitor **1423**, which is connected to the ultrasound probe **1410**. Thus, when the controller **1431** selects circuit elements included in the impedance matching circuit **1420**, the controller **1431** may select the inductor **1421** first and then may select the capacitor **1423**. When the controller **1431** changes the cutoff frequency of the impedance matching circuit **1420**, the controller **1431** may change the inductor **1421** included in the impedance matching circuit **1420** in preference to the capacitor **1423** included in the impedance matching circuit **1420**.

[0172] FIG. **17** is a graph showing the characteristics of the impedance matching circuit **1420** respectively corresponding to cutoff frequencies when the impedance matching circuit **1420** operates as a high-pass filter.

[0173] When the impedance matching circuit **1420** is constructed within a unique bandwidth range (central frequency is 47.5 MHz and bandwidth is 24 MHz) of a transducer included in an ultrasound probe, the impedance matching circuit **1420** has cutoff frequencies and characteristics of a high-pass filter shown in FIG. **17**. Thus, the controller **1431** may select circuit elements included in the impedance matching circuit **1420**, based on the cutoff frequencies and the characteristic of the impedance matching circuit **1420** operating as a high-pass filter, which are shown in FIG. **17**.

[0174] FIG. **18** is a graph showing a result of impedance matching performed by using the impedance matching circuit **1420** operating as a high pass filter.

[0175] FIG. **18** shows effects obtained by matching the impedance the ultrasound probe **1410** with the impedance of the body **1430** by using the impedance matching circuit **1420** operating as a high-pass filter. The graph of FIG. **18** shows characteristics of a reception signal when the impedance matching circuit **1420** exists within the unique bandwidth range (central frequency is 47.5 MHz and bandwidth is 24 MHz) of a transducer included in an ultrasound probe and characteristics of the reception signal when no impedance matching circuits exist.

[0176] When impedance matching is performed using the impedance matching circuit **1420**, a central frequency of a reception signal input to the body **1430** is 46.8 MHz, a bandwidth thereof is 47.5 MHz, an output impedance Zout thereof is 46.8Ω, and an impedance phase thereof is −8.9°. On the other hand, when no impedance matching circuits **1420** exist, a central frequency of the reception signal input to the body **1430** is 47.5 MHz, a bandwidth thereof is 23.5 MHz, an output impedance Zout thereof is 21.6.Ω, and an impedance phase thereof is −55.5 °.

[0177] When the impedance matching circuit **1420** exists, the bandwidth increased, the output impedance Zout increased, and the impedance phase decreased. As the magnitude of the output impedance Zout and the impedance magnitude of the body **1430** are similar to each other, electrical energy loss of the reception signal input to the body **1430** decreases. Thus, the reception signal input to the body **1430** is less lost when the impedance matching circuit **1420** exists than when no impedance matching circuits **1420** exist.

[0178] In addition, a signal response of a 25 MHz to 50 MHz band is better when the impedance matching circuit **1420** is used than when the impedance matching circuit **1420** is not used. Thus, loss of the reception signal input to the body **1430** is reduced within a unique bandwidth of a transducer included in the ultrasound probe **1410** when the impedance matching circuit **1420** is used, compared to when no impedance matching circuits **1420** are used.

[0179] FIG. **19** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit **1920** including a plurality of circuit elements of an identical type having different values, according to an embodiment.

[0180] According to the embodiment of FIG. **19**, the impedance matching circuit **1920** may include the plurality of circuit elements of an identical type having different values. Although the plurality of circuit elements are a serial inductor **1921** and a parallel capacitor **1926** in FIG. **19**, embodiments are not limited thereto. The impedance matching circuit **1920** may include a serial capacitor and a parallel inductor. Although an impedance magnitude of an ultrasound probe **1910** is smaller than that of a body **1930** in FIG. **19**, embodiments are not limited thereto.

[0181] According to the embodiment of FIG. **19**, the inductance value of serial inductors **1921***a*, **1921***b*, **1921***c*, and **1921***d* may be 82 nH, 100 nH, 120 nH, and 150 nH, respectively, and the capacitance values of parallel capacitors **1926***a*, **1926***b*, **1926***c*, and **1926***d* may be 82 pF, 100 pF, 120 pF, and 150 pF, respectively. A controller **1931** may select one from the plurality of serial inductors **1921***a*, **1921***b*, **1921***c*, and **1921***d* and one from the parallel capacitors **1926***a*, **1926***b*, **1926***c*, and **1926***d*, by using element values determined according to impedance of the ultrasound probe **1910**, impedance of the body **1930**, and relevant frequency characteristics of a reception signal. The controller **1931** may control the impedance matching circuit **1920** to operate as a filter by using the selected serial inductor and the selected parallel capacitor.

[0182] FIG. **20** is a circuit diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit **2020** including a plurality of circuit element banks, according to an embodiment.

[0183] According to the embodiment of FIG. **20**, the impedance matching circuit **2020** may include a plurality of circuit element banks **2021***a*, **2021***b*, **2021***c*, **2021***d*, **2026***a*, **2027***b*, **2028***c*, and **2029***d*. Each of the plurality of circuit element banks **2021***a*, **2021***b*, **2021***c*, **2021***d*, **2026***a*, **2027***b*, **2028***c*, and **2029***d* may include a plurality of circuit elements of different types having different values. The plurality of circuit elements may be variable elements of which element values are variable. The circuit elements included in each of the plurality of circuit element banks may be circuit elements of different types. For example, a plurality of circuit elements (for example, serial inductors) included in a first circuit element bank **2021***a*may be of different types from a plurality of circuit elements (for example, parallel capacitors) included in a second circuit element bank **2026***a*.

[0184] According to an embodiment, the circuit element bank **2021***a*from among the plurality of circuit element banks may include serial inductors having different values. The circuit element bank **2026***a* from among the plurality of circuit element banks may include parallel capacitors having different values. The circuit element bank **2021***b* from among the plurality of circuit element banks may include serial capacitors having different values. The circuit element bank **2021***c* from among the plurality of circuit element banks may include parallel inductors having different values. The circuit element bank **2021***d* from among the plurality of circuit element banks may include parallel capacitors having different values. The circuit element bank **2026***b* from among the plurality of circuit element banks may include parallel inductors having different values. The circuit element bank **2026***c* from among the plurality of circuit element banks may include serial inductors having different values. The circuit element bank **2026***d* from among the plurality of circuit element banks may include serial capacitors having different values.

[0185] To select impedance of an ultrasound probe **2010** with impedance of a body **2030**, a controller **2031** may select one from the plurality of circuit element banks included in the impedance matching circuit **2020** and may select one from the plurality of circuit elements included in the selected circuit element bank.

[0186] The controller **2031** may control the impedance matching circuit **2020** to match the impedance of the ultrasound probe **2010** with the impedance of the body **2030** by using the selected circuit element. The controller **2031** may control switches included in the impedance matching circuit **2020** to connect the impedance matching circuit **2020** to the selected circuit element.

[0187] FIG. **21** is a block diagram of a structure of an ultrasound diagnosis apparatus including an impedance matching circuit **2120** to which a plurality of ultrasound probes is connected, according to an embodiment.

[0188] According to the embodiment of FIG. **21**, the ultrasound diagnosis apparatus **100** may include a plurality of ultrasound probes **2110***a*, **2110***b*, and **2110***c*, one of which may be connected to a body **2130**. The plurality of ultrasound probes **2110***a*, **2110***b*, and **2110***c* may be ultrasound probes of an identical type or may be ultrasound probes of different types.

[0189] A controller **2131** may detect an ultrasound probe currently-being-used by a user from among the plurality of ultrasound probes **2110***a*, **2110***b*, and **2110***c*. The controller **2131** may control the impedance matching circuit **2120**, based on the type and application of the ultrasound probe currently-being-used by the user.

[0190] According to an embodiment, at least one of the first ultrasound probe **2110***a* including a single transducer element and having a smaller impedance magnitude than the body **2130**, a second ultrasound probe **2110***b* including a transducer array of a plurality of transducer elements and having a larger impedance magnitude than the body **2130**, and a third ultrasound probe **2110***c* including a single transducer element and having a larger impedance magnitude than the body **2130** may be connected to the body **2130**.

[0191] According to an embodiment, when a user uses the first ultrasound probe **2110***a*, the controller **2131** may detect the first ultrasound probe **2110***a* from the at least one ultrasound probe connected to the body **2130**. The controller **2131** may select circuit elements that are included in the impedance matching circuit **2120** to correspond to the detected first ultrasound probe **2110***a*. In this case, the controller **2131** may select a serial inductor **2121** and a parallel capacitor **2129**.

[0192] According to an embodiment, when the user uses the second ultrasound probe **2110***b*, the controller **2131** may detect the second ultrasound probe **2110***b* from the at least one ultrasound probe connected to the body **2130** and may select circuit elements of the impedance matching circuit **2120** corresponding to the detected second ultrasound probe **2110***b*. In this case, the controller **2131** may select a parallel capacitor **2124** and a serial inductor **2126**.

[0193] According to an embodiment, a storage may store identification information for identifying the types of ultrasound probes. The controller **2131** may use the identification information stored in the storage, to identify the type of ultrasound probe connected to the body **2130**. The controller **2131** may extract identification information for identifying the type of ultrasound probe, from the ultrasound probe connected to the body **2130**. The controller **2131** may compare the identification information stored in the storage with the identification information extracted from the ultrasound probe. The controller **2131** may select circuit elements of the impedance matching circuit **2120** by using a result of the comparison of the identification information, and may control the impedance matching circuit **2120** to match impedance of the ultrasound probe connected to the body **2130** with impedance of the body **2130** by using the selected circuit elements. In this case, the storage may store identification information, information about a circuit element corresponding to the identification information, information about circuit elements respectively corresponding to a plurality of cutoff frequencies, information about a circuit element corresponding to relevant frequency characteristics, and information about relevant frequency characteristics respectively corresponding to a plurality of applications. The storage may arrange the stored various pieces of information into a table and store the table. The controller **2131** may construct the impedance matching circuit **2120** by using the various pieces of information stored in the storage. The controller **2131** may update the various pieces of information stored in the storage.

[0194] According to an embodiment, the storage may store information about the types of ultrasound probes. A user input interface may receive a user input of selecting one from the types of ultrasound probes stored in the storage. The controller **2131** may detect, from the storage, information about circuit elements of the impedance matching circuit **2120** corresponding to the ultrasound probe selected based on the user input. The controller **2131** may control the impedance matching circuit **2120** to be constructed using the information about the circuit elements detected from the storage, and may control the impedance of ultrasound probes **2110***a*, **2110***b*, and **2110***c* with the impedance of the body **2130**.

[0195] According to an embodiment, when identification information detected from the ultrasound probes **2110***a*, **2110***b*, and **2110***c* is different from the identification information stored in the storage, the controller **2131** may control measurement of the impedance of the ultrasound probe **21**s **2110***a*, **2110***b*, and **2110***c* **10**. The controller **2131** may control measurement of the impedance of the body **2130**. The controller **2131** may select circuit elements that are included in the impedance matching circuit **2120** so that the impedance of the ultrasound probes **2110***a*, **2110***b*, and **2110***c* is matched with the impedance of the body **2130** by using the measured impedance of the ultrasound probes **2110***a*, **2110***b*, and **2110***c*. The controller **2131** may control the impedance matching circuit **2120** to match the impedance of the ultrasound probes **2110***a*, **2110***b*, and **2110***c* with the impedance of the body **2130** by using the selected circuit elements.

[0196] FIG. **22** is a flowchart of a method of controlling the ultrasound diagnosis apparatus **100**, according to an embodiment.

[0197] According to the embodiment of FIG. **22**, the ultrasound diagnosis apparatus **100** may transmit an ultrasound signal to an object and receive an ultrasound echo signal from the object to thereby form a reception signal, in operation **S2210**. The impedance matching circuit **320** may operate as at least one filter, in operation **S2220**. The ultrasound diagnosis apparatus **100** may process a reception signal that has passed through the impedance matching circuit **320**, in operation **S2230**.

[0198] In detail, in operation **S2210**, the ultrasound diagnosis apparatus **100** may transmit an ultrasound signal to an object by using the ultrasound probe **310** and receive an ultrasound echo signal from the object to thereby form a reception signal. In this case, the ultrasound diagnosis apparatus **100** may differently set the frequencies of ultrasound signals transmitted to different objects, according to the type of ultrasound probe **310**, an application of the ultrasound probe **310**, and the type of object that is to be diagnosed.

[0199] In operation **S2220**, the impedance matching circuit **320** may operate as a filter that stops or passes a specific frequency of the reception signal. This operation has already described above in detail.

[0200] In operation **S2220**, the impedance matching circuit **320** may operate as a filter so that the reception signal that has passed through the impedance matching circuit **320** includes changed relevant frequency characteristics based on a received user input.

[0201] In operation **S2230**, the ultrasound diagnosis apparatus **100** processes the reception signal that has passed through the impedance matching circuit **320**. According to an embodiment, the ultrasound diagnosis apparatus **100** may generate an ultrasound image by using the reception signal and display the ultrasound image. The ultrasound diagnosis apparatus **100** may use a well-known method of processing an ultrasound reception signal.

[0202] According to an embodiment, the ultrasound diagnosis apparatus **100** may receive a user input of changing relevant frequency characteristics. In this case, the user input of changing relevant frequency characteristics may include an input of changing the application of the ultrasound probe, an input of selecting an application, an input of changing the cutoff frequency of a filter, and an input of selecting one from a plurality of ultrasound probes connected to a body.

[0203] FIG. **23** is a flowchart of a method of controlling the ultrasound diagnosis apparatus **100**, according to an embodiment.

[0204] According to the embodiment of FIG. **23**, the ultrasound diagnosis apparatus **100** may sense whether the ultrasound probe **310** has been connected to the ultrasound diagnosis apparatus **100**, in operation S**2310**. In operation S**2320**, to detect the application and the type of the connected ultrasound probe **310**, the ultrasound diagnosis apparatus **100** may compare first identification information stored in the storage **150** with second identification information extracted from the sensed ultrasound probe **310**. In operation S**2330**, when the first identification information is the same as the second identification information, the impedance matching circuit **320** may operate as a filter corresponding to the first identification information. In operation S**2331**, when the first identification information is not the same as the second identification information, the ultrasound diagnosis apparatus **100** may measure impedance of the ultrasound probe **310**. In operation S**2336**, the impedance matching circuit **320** that matches the measured impedance with the impedance of the body **330** may operate as a filter. In operation S**2340**, when impedance matching circuit **320** operates as a filter, the ultrasound diagnosis apparatus **100** may process a reception signal that has passed through the impedance matching circuit **320**.

[0205] In operation S**2330**, the ultrasound diagnosis apparatus **100** may select circuit elements of the impedance matching circuit **320** by using information about elements of the impedance matching circuit **320** corresponding to the first identification information stored in the storage **150**. The storage **150** may store identification information, information about a circuit element corresponding to the identification information, information about circuit elements respectively corresponding to a plurality of cutoff frequencies, information about a circuit element corresponding to relevant frequency characteristics, and information about relevant frequency characteristics respectively corresponding to a plurality of applications. The storage **150** may arrange the stored various pieces of information into a table and store the table. The information about elements of the impedance matching circuit **320** corresponding to the first identification information may include the types of circuit elements, element values of the circuit elements, and a method of connecting the circuit elements.

[0206] In operation S**2331**, the ultrasound diagnosis apparatus **100** may receive a user input regarding the application and type of an ultrasound probe. The ultrasound diagnosis apparatus **100** may determine the application and type of an ultrasound probe, based on the received user input. The ultrasound diagnosis apparatus **100** may control the impedance matching circuit **320** to operate as a filter corresponding to the determined application and type of the ultrasound probe.

[0207] The above-described embodiments of the present inventive concept may be embodied in form of a computer-readable recording medium for storing computer executable command languages and data. The command languages may be stored in form of program codes and, when executed by a processor, may perform a certain operation by generating a certain program module. Also, when executed by a processor, the command languages may perform certain operations of the disclosed embodiments.

What is claimed is:

1. An ultrasound diagnosis apparatus comprising:

an ultrasound probe configured to transmit an ultrasound signal to an object and receive an ultrasound echo signal from the object to form a reception signal;

a body configured to receive the reception signal from the ultrasound probe and process the reception signal;

an impedance matching circuit configured to match an impedance of the ultrasound probe with an impedance of the body; and

a controller configured to control the impedance matching circuit to operate as at least one filter that passes or rejects a signal of a specific frequency band, based on the impedance of the ultrasound probe, the impedance of the body, and relevant frequency characteristics of the reception signal,

wherein the at least one filter is controlled to match the impedance of the ultrasound probe with the impedance of the body and is controlled so that the reception signal has the relevant frequency characteristics.

2. The ultrasound diagnosis apparatus of claim **1**, wherein the controller is configured to control the impedance matching circuit to operate as a multi-stage filter.

3. The ultrasound diagnosis apparatus of claim **1**, wherein

the impedance matching circuit comprises a plurality of circuit elements of an identical type having different values, and

the controller is configured to control the impedance matching circuit to match the impedance of the ultrasound probe with the impedance of the body by using at least one of the plurality of circuit elements.

4. The ultrasound diagnosis apparatus of claim **1**, wherein

the impedance matching circuit comprises a plurality of circuit elements of different types, and

the controller is configured to control the impedance matching circuit to match the impedance of the ultrasound probe with the impedance of the body by using at least one of the plurality of circuit elements.

5. The ultrasound diagnosis apparatus of claim **1**, wherein

the impedance matching circuit comprises a plurality of circuit element banks of different types,

each of the plurality of circuit element banks comprises a plurality of circuit elements of an identical type having different values, and

the controller is configured to control the impedance matching circuit to match the impedance of the ultrasound probe with the impedance of the body by using at least one of the plurality of circuit elements.

6. The ultrasound diagnosis apparatus of claim **1**, wherein

the impedance matching circuit comprises a plurality of circuit elements of different types,

the plurality of circuit elements are variable elements of which values are variable, and

the controller is configured to control a value of at least one of the plurality of circuit elements, based on the impedance of the ultrasound probe and the impedance of the body.

7. The ultrasound diagnosis apparatus of claim **1**, further comprising an input interface configured to receive from a user an input for changing the relevant frequency characteristics,

wherein the controller is configured to control the impedance matching circuit to operate as a filter corresponding to changed relevant frequency characteristics.

8. The ultrasound diagnosis apparatus of claim **1**, wherein

a plurality of ultrasound probes are included, and are connected to the body, and

the controller is configured to detect a first probe that receives the ultrasound echo signal, from among the plurality of ultrasound probes, and to control the impedance matching circuit to match impedance of the first probe with the impedance of the body.

9. The ultrasound diagnosis apparatus of claim **1**, further comprising:

a storage configured to store a plurality of applications used for ultrasound diagnosis; and

an input interface configured to receive, from a user, an input for selecting one from the plurality of stored applications,

wherein the controller is configured to run the selected application in response to the input received by the input interface, and to control the impedance matching circuit so that the reception signal has the relevant frequency characteristics corresponding to the selected application.

10. The ultrasound diagnosis apparatus of claim **1**, further comprising:

a storage configured to store information about a type of the ultrasound probe; and

an input interface configured to receive, from a user, an input for selecting one from the stored information about the type of the ultrasound probe,

wherein the controller is configured to control the impedance matching circuit to operate as a filter corresponding to the selected information about the type of the ultrasound probe.

11. The ultrasound diagnosis apparatus of claim **1**, further comprising a storage configured to store first identification information for identifying a type of the ultrasound probe,

wherein the controller is configured to detect second identification information from the ultrasound probe connected to the body, to compare the first identification information with second identification information, and to control the impedance matching circuit according to a result of the comparing of the first identification information with the second identification information.

12. The ultrasound diagnosis apparatus of claim **11**, wherein, when the first identification information is the same as the second identification information, the controller is configured to control the impedance matching circuit to operate as a filter corresponding to the first identification information.

13. The ultrasound diagnosis apparatus of claim **11**, wherein, when the first identification information is not the same as the second identification information, the controller is configured to control measurements of the impedance of the ultrasound probe and the impedance of the body and to control the impedance matching circuit to match the measured impedance of the ultrasound probe with the measured impedance of the body.

14. A method of controlling an ultrasound diagnosis apparatus comprising an ultrasound probe and a body for processing a reception signal received from the ultrasound probe, the method comprising:

transmitting an ultrasound signal to an object and receiving an ultrasound echo signal from the object to form the reception signal;

controlling an impedance matching circuit for matching an impedance of the ultrasound probe with an impedance of the body to operate as at least one filter that passes or rejects a signal of a specific frequency band, based on the impedance of the ultrasound probe, the impedance of the body, and relevant frequency characteristics of the reception signal; and

processing a reception signal that has passed through the impedance matching circuit,

wherein the reception signal that has passed through the impedance matching circuit has the relevant frequency characteristics.

15. The method of claim **14**, further comprising sensing the ultrasound probe connected to the body,

wherein the controlling of the impedance matching circuit to operate as the at least one filter that passes or rejects the signal of the specific frequency band comprises controlling the impedance matching circuit to operate as a filter corresponding to a type of the sensed ultrasound probe.

16. The method of claim **15**, wherein the sensing of the ultrasound probe connected to the body comprises:

comparing first identification information stored in a storage with second identification information of the ultrasound probe; and

determining the type of the sensed ultrasound probe based on a result of the comparing of the first identification information with the second identification information.

17. The method of claim **16**, wherein, when the first identification information is the same as the second identification information, the controlling of the impedance matching circuit to operate as the filter corresponding to the type of the sensed ultrasound probe comprises controlling the impedance matching circuit to operate as a filter corresponding to the identification information.

18. The method of claim **15**, wherein, when the first identification information is not the same as the second identification information, the controlling of the impedance matching circuit to operate as the at least one filter that passes or rejects the signal of the specific frequency band comprises:

measuring the impedance of the ultrasound probe; and

controlling the impedance matching circuit to operate as a filter so that the measured impedance of the ultrasound probe is matched with the impedance of the body.

19. The method of claim **14**, further comprising receiving from a user an input for changing the relevant frequency characteristics,

wherein the controlling of the impedance matching circuit to operate as the at least one filter that passes or rejects the signal of the specific frequency band comprises controlling the impedance matching circuit to operate as a filter so that the reception signal that has passed through the impedance matching circuit has the changed relevant frequency characteristics.

20. The method of claim **19**, wherein the input for changing the relevant frequency characteristics comprises at least one of an input for changing an application of the ultrasound probe, an input for selecting an application, an input for changing a cutoff frequency of the at least one filter, and an input for selecting one from a plurality of ultrasound probes connected to the body.

* * * * *

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摘要(译)

提供了一种超声诊断设备及其控制方法。超声波诊断装置包括超声波探头，该超声波探头被配置为将超声波信号发送到物体并从物体接收超声波回波信号以形成接收信号;主体，被配置为从超声探头接收接收信号并处理接收信号;阻抗匹配电路，被配置为使超声波探头的阻抗与身体的阻抗相匹配;控制器，被配置为基于超声探头的阻抗，主体的阻抗以及主体的相关频率特性，控制阻抗匹配电路作为至少一个滤波器，该滤波器通过或拒绝特定频带的信号。接收信号。控制所述至少一个滤波器以使超声波探头的阻抗与身体的阻抗相匹配，并且控制所述至少一个滤波器使得接收信号具有相关的频率特性。