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(54) ULTRASONIC PROBE AND ULTRASONIC DIAGNOSTIC APPARATUS

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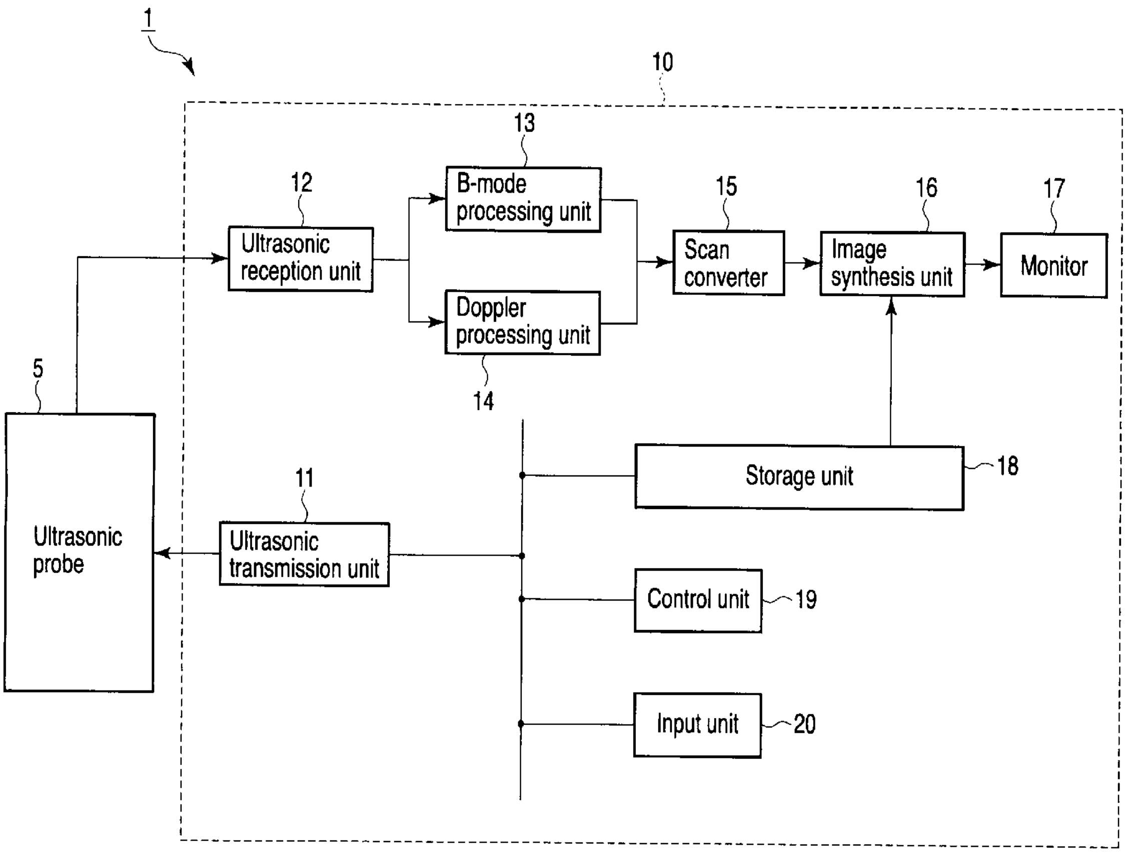
(57) **ABSTRACT**

An ultrasonic probe has a plurality of modules joined at least along the elevation direction. The module has a plurality of first piezoelectric transducers having a first width with respect to the elevation direction. The module has at least one second piezoelectric transducer having a second width narrower than the first width with respect to the elevation direction. The second piezoelectric transducer is arranged at the module ends with respect to the elevation direction. The module is arranged in such a manner that the second piezoelectric transducer faces the second piezoelectric transducer of the adjacent module.



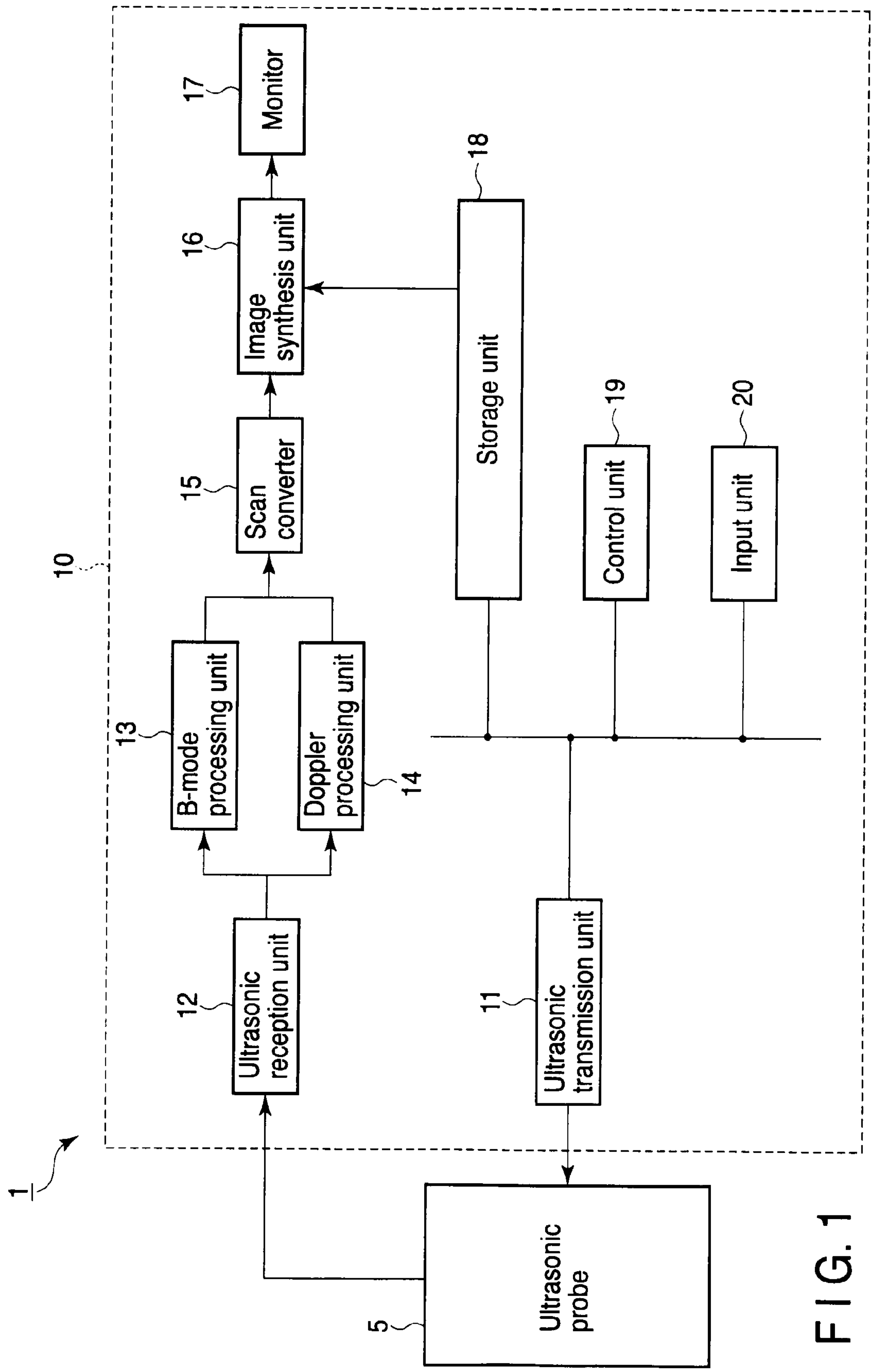

1
10
Monitor
17
Image synthesis unit
16
Scan converter
15
Storage unit
18
B-mode processing unit
13
Doppler processing unit
14
Control unit
19
Input unit
20
Ultrasonic reception unit
12
Ultrasonic transmission unit
11
Ultrasonic probe
5

FIG. 1

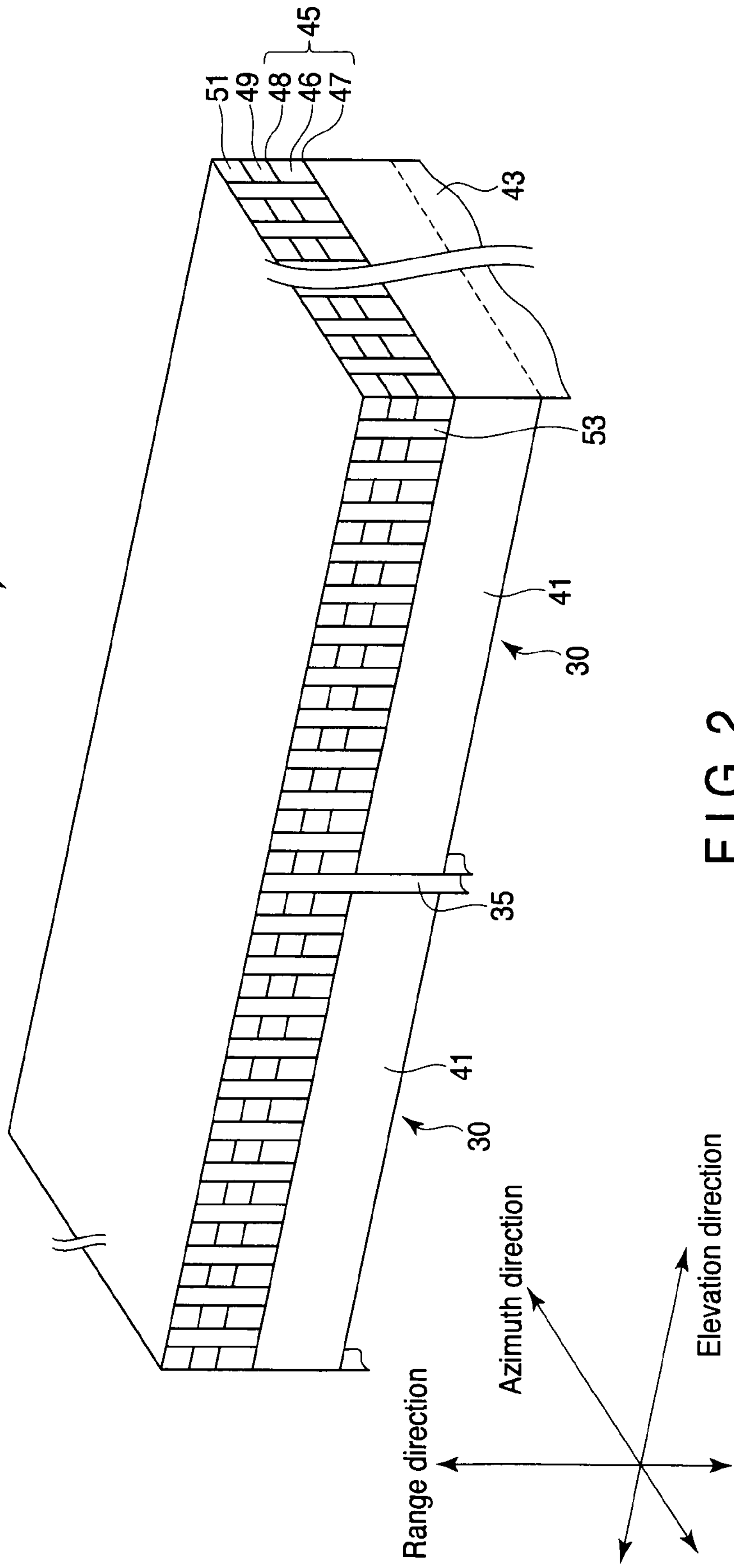

45
51
49
48
46
47
43
53
5
41
30
35
41
30
Range direction
Azimuth direction
Elevation direction

FIG. 2

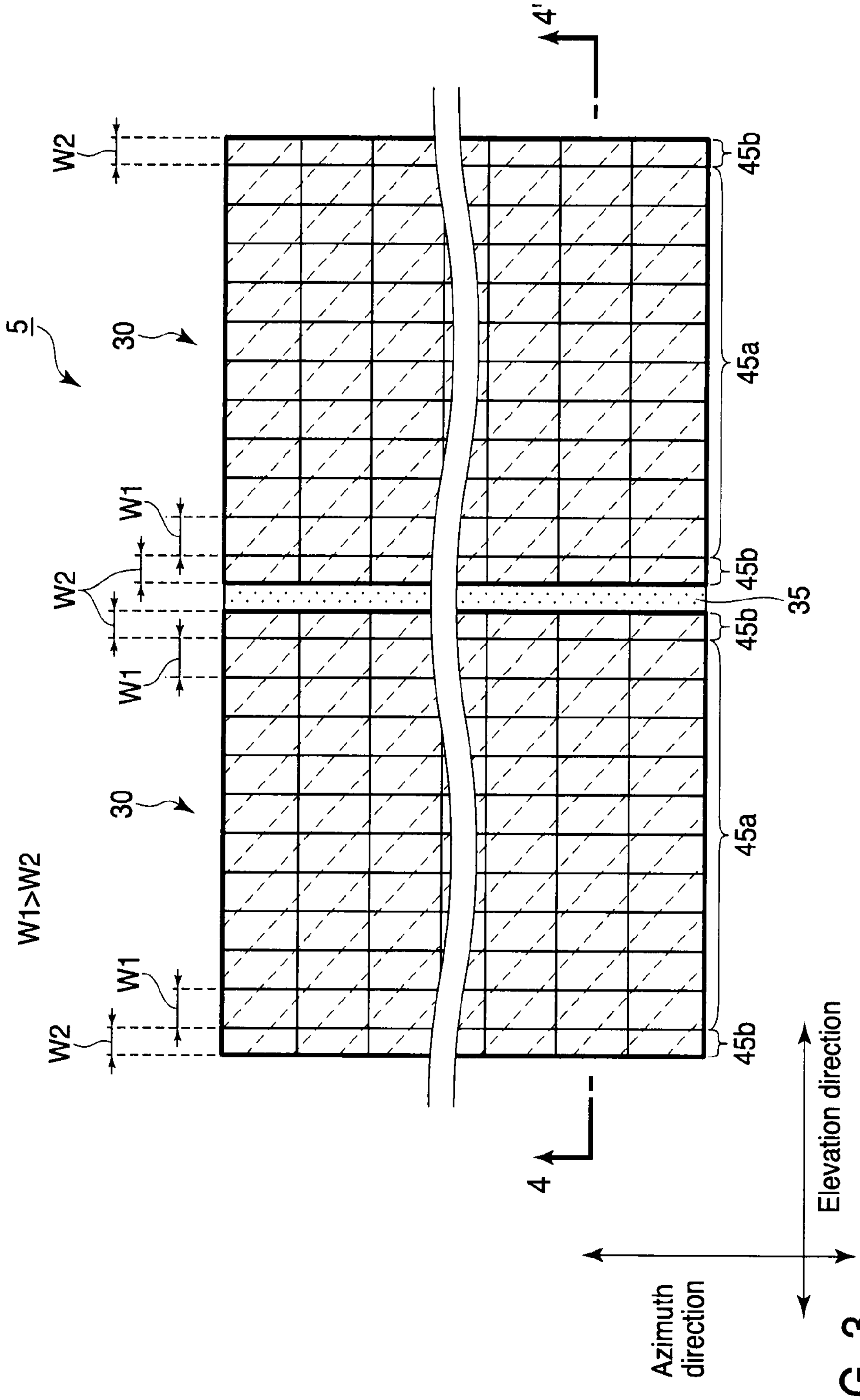

4'
4
5
30
30
W1>W2
W1
W2
35
45a
45b
Elevation direction
Azimuth direction

FIG. 3

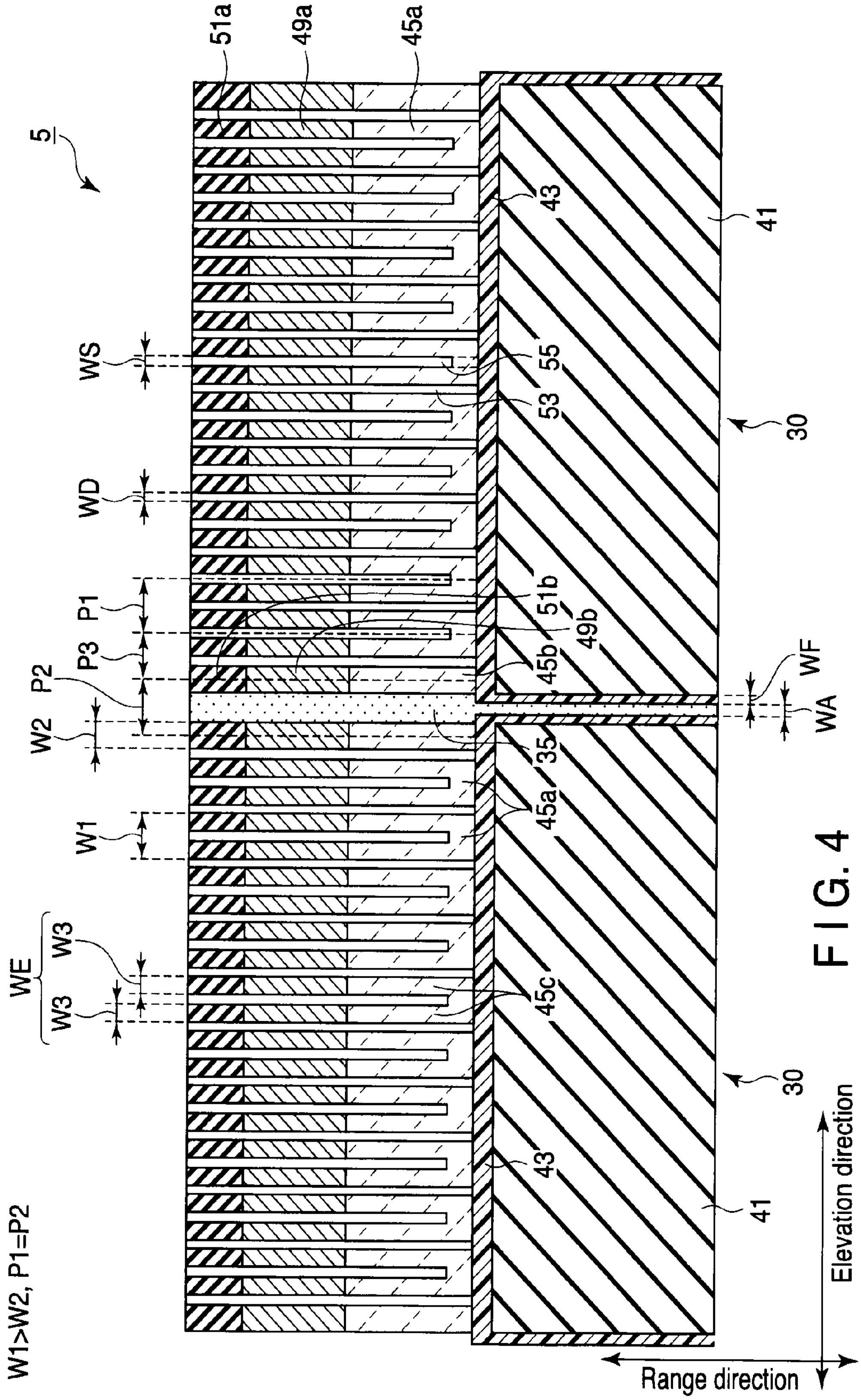
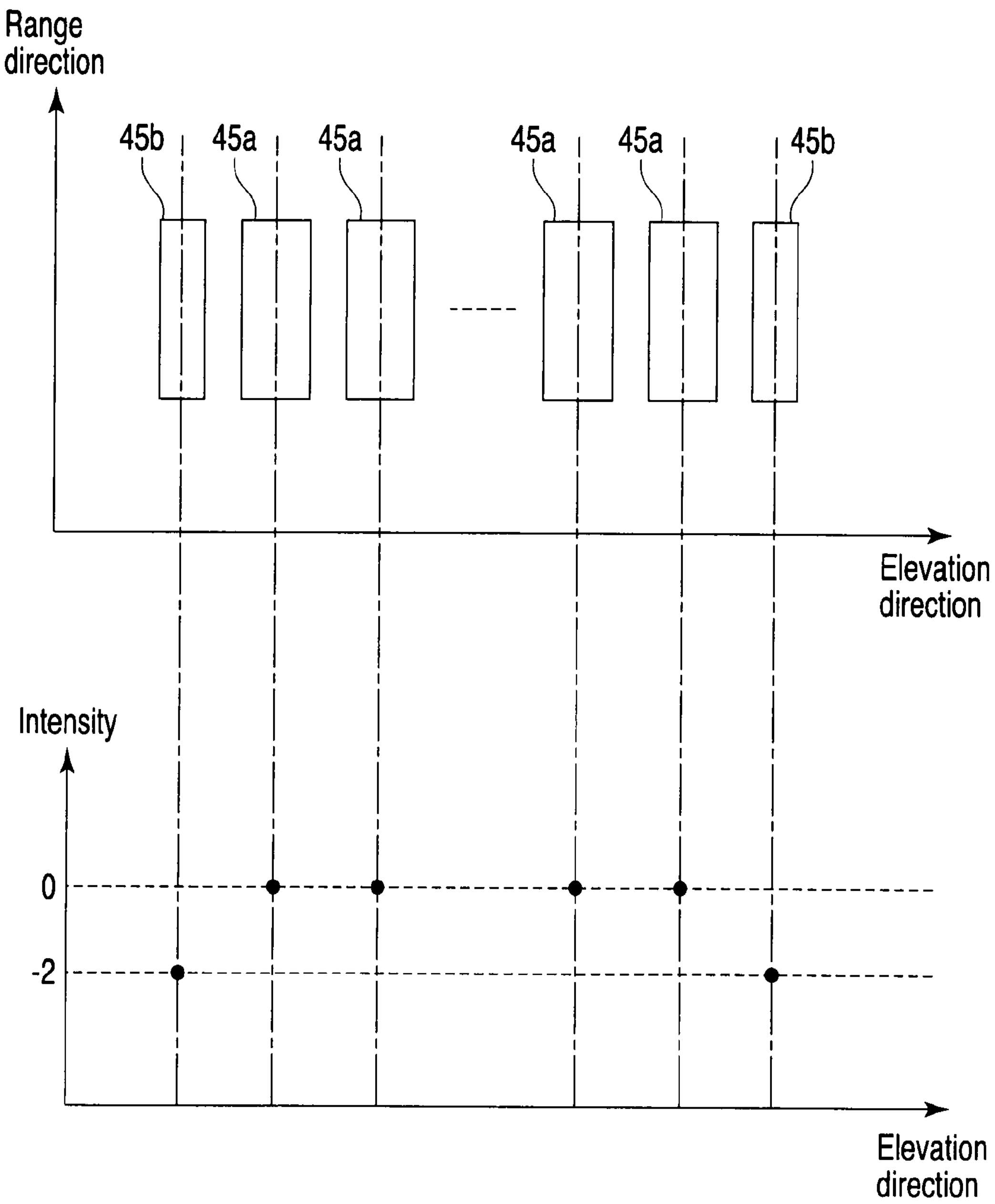
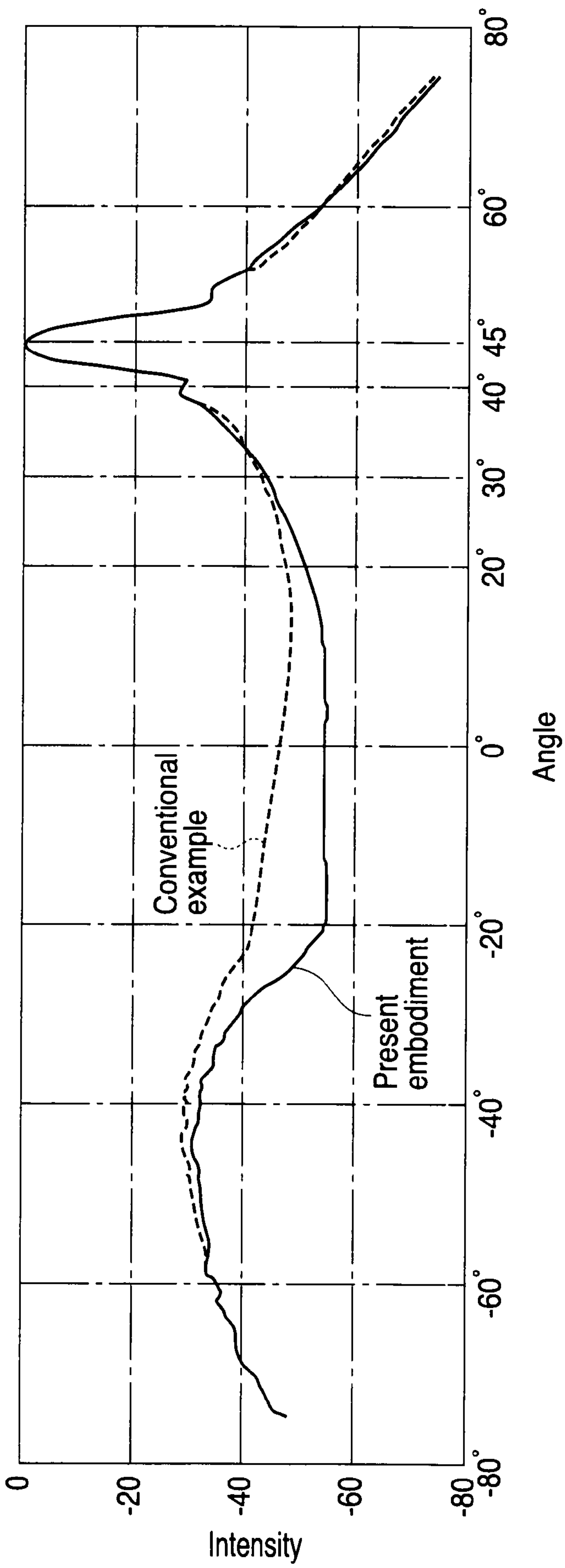

5
51a
49a
45a
43
41
WS
55
53
30
WD
P1
51b
P3
49b
45b
P2
WF
WA
W2
35
W1
45a
WE
W3
W3
45c
30
43
41
Elevation direction
Range direction
W1>W2, P1=P2

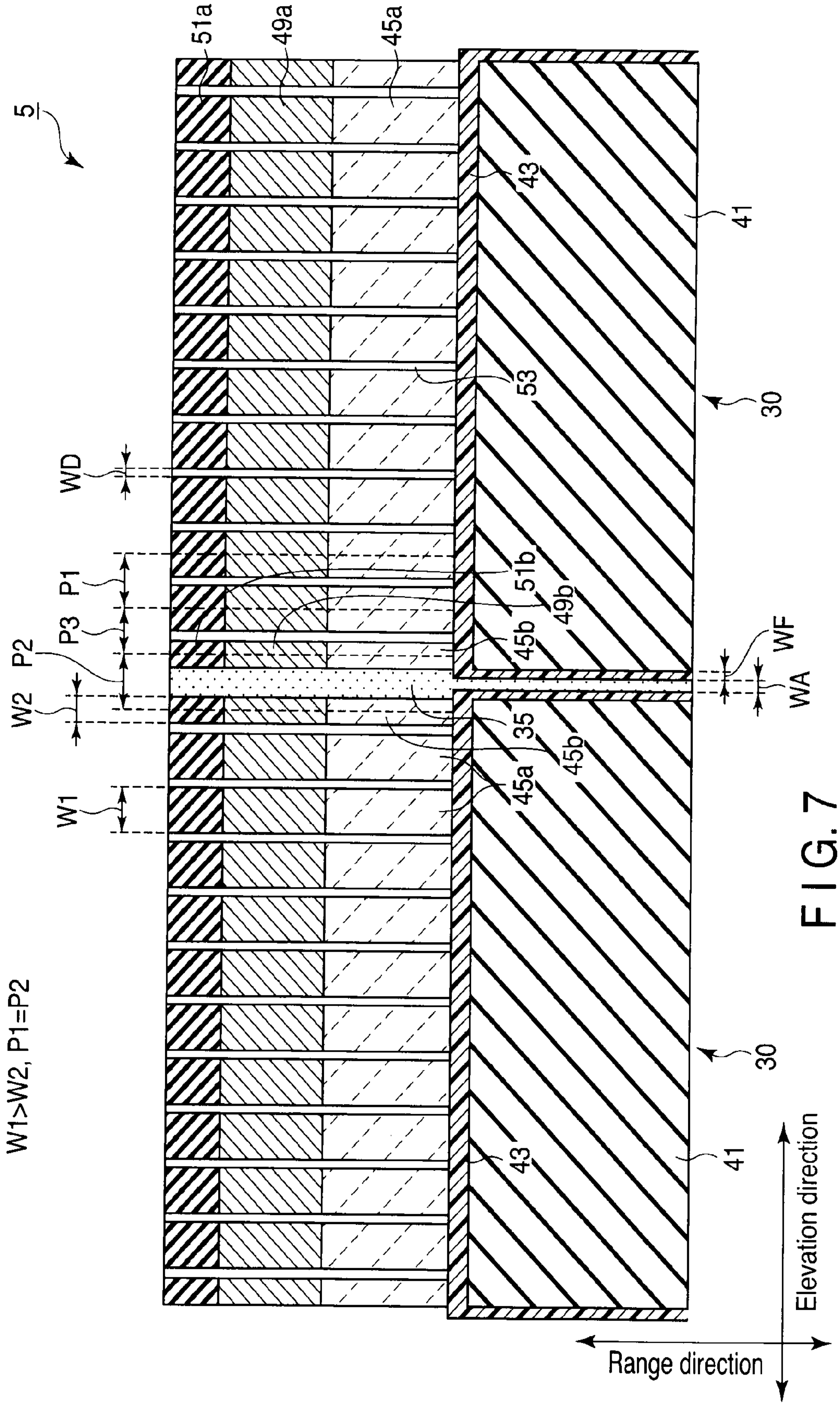
FIG. 4


Range direction
45b
45a
45a
45a
45a
45b
Elevation direction
Intensity
0
-2
Elevation direction

F I G. 5


0
-20
-40
-60
-80
Intensity
-80°
-60°
-40°
-20°
0°
20°
30°
40°
45°
60°
80°
Angle
Conventional example
Present embodiment

F I G. 6



5
51a
49a
45a
43
41
53
30
WD
P1
51b
P3
49b
P2
45b
WF
W2
WA
35
45b
45a
W1
W1>W2, P1=P2
30
43
41
Elevation direction
Range direction

F I G. 7

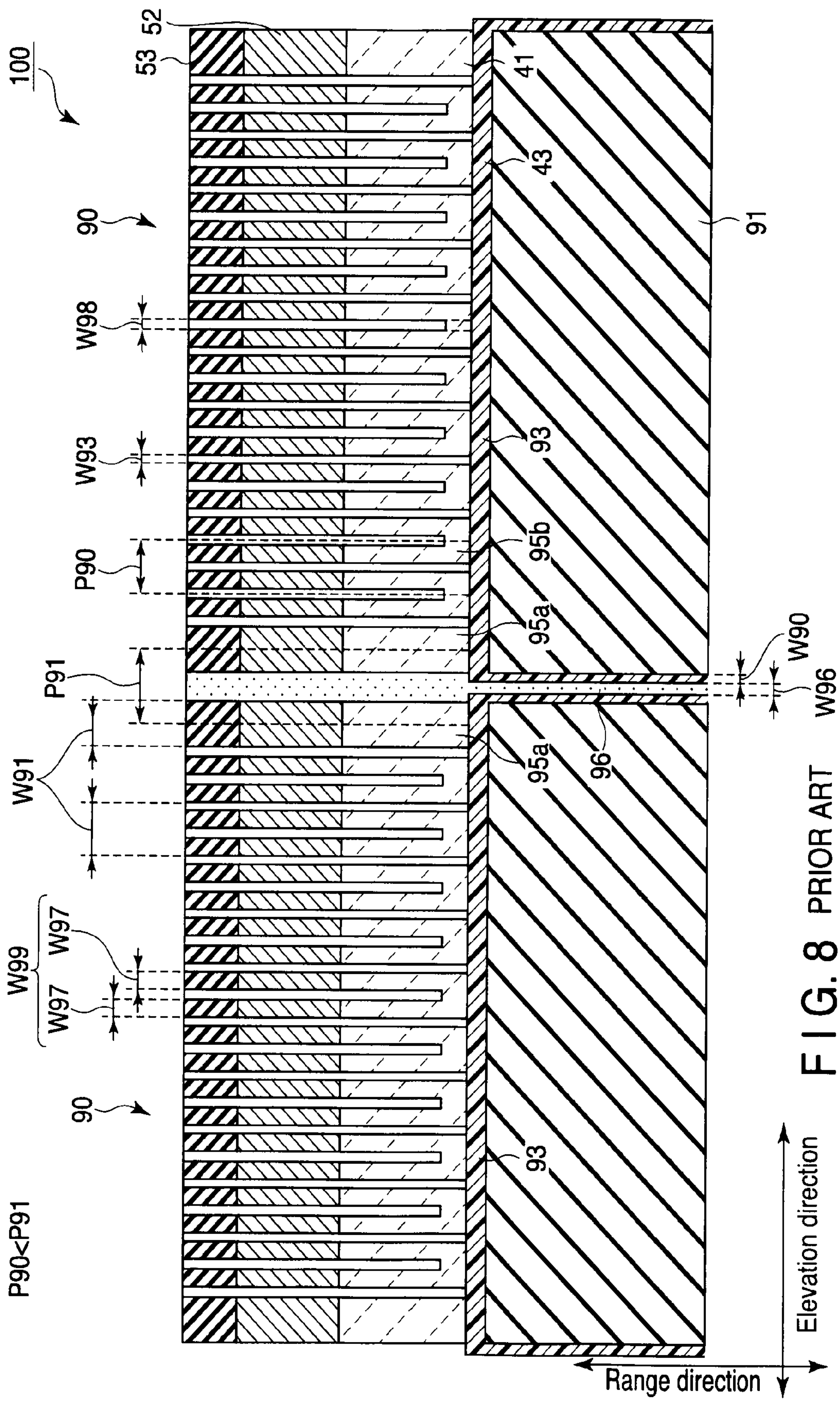


FIG. 8 PRIOR ART

ULTRASONIC PROBE AND ULTRASONIC DIAGNOSTIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2007-260320, filed Oct. 3, 2007, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an ultrasonic probe having a plurality of modules, and an ultrasonic diagnostic apparatus.

[0004] 2. Description of the Related Art

[0005] There is an ultrasonic probe which has a plurality of piezoelectric transducers. As applied examples of this ultrasonic probe, there is an ultrasonic probe with two or more modules connected in at least one direction (see, for example, Jpn. Pat. Appln. KOKAI Publication No. 2004-41730).

[0006] FIG. **8** shows a transverse cross sectional view of an ultrasonic probe **100** including a plurality of modules **90**. The ultrasonic probe **100** has two modules **90**. The module **90** has a backing material **91**. To the upper of the backing material **91**, a plurality of piezoelectric transducers **95** are disposed via a flexible PC board (FPC) **93** having a thickness of W**90** (typically 50 μm). The module **90** has 12 piezoelectric transducers **95** along a first direction. Typically, the width W**91** along the first direction of the piezoelectric transducer **95** is 250 μm. In addition, the width W**93** of a groove between the piezoelectric transducers **95** by dicing is typically 50 μm. Consequently, the center-to-center distance p**90** of two adjacent piezoelectric transducers **95***b* inside the module **90** is 300 μm.

[0007] The modules **90** are connected in the first direction by silicone adhesives, etc. and the thickness W**96** of an adhesive layer **96** is typically 50 μm. In order to connect the modules **90**, or in order to allow the FPC **93** to pass through between surfaces to be connected, the center-to-center distance p**91** of two piezoelectric transducers **95***a* to be connected becomes 400 μm. That is, the distance p**91** is wider than the distance p**90**. As a result, side lobes rise.

[0008] In a module of this kind of configuration, sub-dicing is sometimes performed for piezoelectric transducers in order to suppress unrequired vibrations. In this event, assume that part of the piezoelectric transducer **95***b* which is divided by sub-dicing and has the width W**97** is called a piezoelectric transducer piece **95***c*. The width W**98** of a groove generated by sub-dicing is typically 50 μm. Consequently, the width W**97** of the piezoelectric transducer piece **95***c* is 100 μm, and therefore, the effective width W**99** (W99=2×W97) of the piezoelectric transducer piece **95***c* inside the module **90** becomes 200 μm.

[0009] As shown in FIG. **8**, even if sub-dicing is performed on the piezoelectric transducer **95***b*, only the piezoelectric transducer **95***a* at an ends of the module **90** is not sub-diced in order to secure mechanical strength. However, in such event, the width W**91** of the piezoelectric transducer **95***a* is 50 μm wider than the effective width W**99** of the piezoelectric transducer **95***b*. Consequently, applying the same drive voltage to the piezoelectric transducer **95***a* and the piezoelectric transducer **95***b* increases the intensity of ultrasonic wave generated from the piezoelectric transducer **95***a* by about 2 dB from the intensity of ultrasonic wave generated from the piezoelectric transducer **95***b*. This results in inverse-weighting acoustic distribution and increases side lobes further.

BRIEF SUMMARY OF THE INVENTION

[0010] It is an object of the present invention to enable reduction of side lobe increase in an ultrasonic probe including a plurality of modules and an ultrasonic diagnostic apparatus.

[0011] According to a first aspect of the present invention, there is provided an ultrasonic probe comprising: a plurality of modules joined along at least in one direction, wherein each of said modules includes: a plurality of first transducers having a first width with respect to the first direction; and at least one second transducer having a second width narrower than the first width with respect to the first direction, and arranged at both ends or one end of the modules with respect to the first direction.

[0012] According to a second aspect of the present invention, there is provided an ultrasonic probe comprising: a plurality of first transducers having a first width with respect to a first direction and arranged two-dimensionally along the first direction as well as along a second direction that intersects with the first direction; and a plurality of second transducers having a second width narrower than the first width with respect to the first direction and arranged two-dimensionally along the first direction as well as along the second direction, wherein said plurality of first transducers and said plurality of second transducers are alternately arranged at least along the first direction.

[0013] According to a third aspect of the present invention, there is provided an ultrasonic diagnostic apparatus comprising: an ultrasonic probe having a plurality of modules joined at least along a first direction, wherein each of said modules includes: a plurality of first transducers having a first width with respect to the first direction; and at least one second transducer having a second width narrower than the first width with respect to the first direction, and arranged at both ends or one end of the modules with respect to the first direction.

[0014] Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0015] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0016] FIG. **1** is a block diagram showing a configuration of an ultrasonic diagnostic apparatus according to an embodiment of the present invention;

[0017] FIG. **2** is a perspective view briefly showing the structure of an ultrasonic probe of FIG. **1**;

[0018] FIG. **3** is a plan view briefly showing the structure of the ultrasonic probe of FIG. **2**;

[0019] FIG. **4** is a cross-sectional view taken on line **4-4'** of FIG. **3**;

[0020] FIG. **5** is a diagram showing difference in ultrasonic intensity generated from each piezoelectric transducer of FIG. **3**;

[0021] FIG. **6** is a diagram showing difference in ultrasonic characteristics between the ultrasonic probe in the embodiment and a conventional ultrasonic probe;

[0022] FIG. **7** is a transverse cross-sectional view of an ultrasonic probe according to the embodiment, which is not sub-diced; and

[0023] FIG. **8** is a transverse cross-sectional view of a conventional type ultrasonic probe.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Referring now to the drawings, embodiments of the present invention will be described in detail as follows.

[0025] FIG. **1** is a block diagram showing configuration of an ultrasonic probe and an ultrasonic diagnostic apparatus according to the present embodiment. As shown in FIG. **1**, the ultrasonic diagnostic apparatus **1** includes an ultrasonic probe **5** and an ultrasonic diagnostic apparatus body **10**.

[0026] The ultrasonic probe **5** is connected to the ultrasonic diagnostic apparatus body **10**. The ultrasonic probe **5** receives ultrasonic drive pulses from the ultrasonic diagnostic apparatus body **10** and generates ultrasonic waves, and receives ultrasonic waves reflected by a patient. The ultrasonic probe **5** converts the received ultrasonic waves into echo signals and transmits them to the ultrasonic diagnostic apparatus body **10**. The ultrasonic probe **5** has a structure unique to the present embodiment. This unique structure will be discussed later.

[0027] The ultrasonic diagnostic apparatus body **10** is provided with an ultrasonic transmission unit **11**, an ultrasonic reception unit **12**, a B-mode processing unit **13**, a Doppler processing unit **14**, a scan converter **15**, an image synthesis unit **16**, a monitor **17**, a storage unit **18**, a control unit **19**, and an input unit **20**. Functions of individual constituent elements will be explained hereinafter.

[0028] The ultrasonic transmission unit **11** has a rate pulse generation circuit, a delay circuit, a drive pulse generation circuit, etc. which are not illustrated. The rate pulse generation circuit repeatedly generates rate pulses at a predetermined rate frequency fr Hz (cycle: 1/fr-sec). The delay circuit gives delay time to each rate pulse necessary to focus ultrasonic waves in a form of beams for each channel as well as to determine transmission directional characteristics. The drive pulse generation circuit generates ultrasonic drive pulses at a timing based on each delayed rate pulse. A plurality of piezoelectric transducers of the ultrasonic probe **5** which have received ultrasonic drive pulses generate ultrasonic waves.

[0029] The ultrasonic reception unit **12** has an amplifier circuit, an analog-to-digital converter, an adder, etc. which are not illustrated. The amplifier circuit amplifies echo signals for each channel. The analog-to-digital converter converts the amplified echo signals from analog signals to digital signals by sampling and quantization. The delay circuit gives each echo signal converted into a digital signal the delay time necessary to focus echo signals in a form of beams and to successively change the reception directional characteristics. The adder adds echo signals to which the delay time is given. The echo signals which have undergone addition-processing are supplied to the B-mode processing unit **13** and the Doppler processing unit **14**.

[0030] The B-mode processing unit **13** logarithmically amplifies the echo signals supplied from the ultrasonic reception unit **12**. Then the B-mode processing unit **13** performs the envelope detection on the logarithmically amplified echo signals. By the envelope detection, the B-mode processing unit **13** generates brightness data in which the echo signal intensity is expressed by brightness. The B-mode processing unit **13** supplies this brightness data to the scan converter **15**. The brightness data supplied is displayed on the monitor **17** as a B-mode image.

[0031] The Doppler processing unit **14** computes Doppler signals of blood current, etc. derived from Doppler effects by frequency-analyzing the echo signals supplied from the ultrasonic reception unit **12**. The Doppler processing unit **14** computes data such as average speed of blood current, etc., speed dispersion, blood information represented by power of Doppler signals, etc., at a large number of points on the basis of the Doppler signals of blood current, etc. The Doppler processing unit **14** transmits the computed blood information and other data to the scan converter **15**. The blood current information and other data transmitted are displayed on the monitor **17** as average speed images, dispersion images, power images or combined images of those.

[0032] The scan converter **15** converts ultrasonic scan line signal columns of the received brightness data, blood information data, and other data into scan line signal columns of general video formats used to TV, generates video signals, and transmits the signals to the image synthesis unit **16**.

[0033] The image synthesis unit **16** receives video signals from the scan converter **15** and the storage unit **18**, synthesizes the video signals with character information and scales, etc. of various parameters and outputs them to the monitor **17**.

[0034] The monitor **17** displays morphological information within the living body and blood information as images on the basis of the video signals from the image synthesis unit **16**.

[0035] The storage unit **18** stores control programs for implementing image generation and display processing, various kinds of image data, etc.

[0036] The system control unit **19** controls each constituent element to realize operation as the ultrasonic diagnostic apparatus body **10**.

[0037] The input unit **20** has various kinds of switches, buttons, a track ball, a mouse, a keyboard, and others to import instructions from an operator into the ultrasonic diagnostic apparatus body **10**.

[0038] Now, discussion will be made on the structure unique to the ultrasonic probe **5** according to the present embodiment. FIG. **2** is a perspective view showing the configuration of the ultrasonic probe **5**. As shown in FIG. **2**, the ultrasonic probe **5** has two modules **30** connected along the elevation (side surface) direction. The adjacent modules **30** are joined by, for example, silicone, etc. Note that, "two modules" is one example, and three, four, or more modules **30** may be joined. Now, let the azimuth direction be the electronic scanning direction of the ultrasonic probe **5**, the elevation direction the direction perpendicular to the electronic scanning surface, and the range direction the direction perpendicular to the azimuth direction and the elevation direction.

[0039] The module **30** has a backing material **41** as a sound absorbing material. The backing material **41** is formed in a rectangular block shape. At the upper side of the backing material **41**, a plurality of piezoelectric transducers **45** are joined via a flexible PC board (FPC) **43**.

[0040] The plurality of piezoelectric transducers **45** are arranged with predetermined intervals provided in the elevation direction and in the azimuth direction. In this way, the plurality of piezoelectric transducers **45** form a two-dimensional array structure. For example, a total of 480 pieces of piezoelectric transducers **45** are arranged, with 12 columns along the elevation direction and 40 columns along the azimuth direction. Needless to say, the piezoelectric transducers **45** of the quantity other than this may be arranged.

[0041] Each piezoelectric transducer **45** has a piezoelectric element **46**, a signal electrode **47** formed at the lower side of the piezoelectric element **46**, and an earth electrode **48** formed at the upper side of the piezoelectric element **46**. The detail on the arrangement of the piezoelectric transducer **45** will be described later.

[0042] The piezoelectric element **46** is formed of two-component system or three-component system piezoelectric ceramics or piezoelectric monocrystal.

[0043] The signal electrode **47** is formed of copper foil or other metal foils. A plurality of signal electrodes **47** are electrically connected to a plurality of wirings disposed on the FPC **43**, one by one. This connection relation can apply drive signals to the plurality of piezoelectric transducers **45** separately.

[0044] The FPC **43** is disposed between the backing material **41** and the piezoelectric transducer **45** as described above. The FPC **43** is configured of a plurality of wirings for supplying electric power to a plurality of signal electrodes **47**, a flexible substrate, and others. The signal electrode **47** and wiring are electrically connected. Via this wiring, a predetermined voltage is applied to the signal electrode **47** from the ultrasonic transmission unit **11**. The FPC **43** is bent substantially **90** degrees along both side surfaces concerning the elevation direction of the backing material **41**.

[0045] The earth electrode **48** is formed of copper foil or other metal foils. The earth electrode **48** is taken out by a earth lead-out electrode (not illustrated) connected to both side surfaces along the elevation direction of the ultrasonic probe **5**. The earth lead-out electrode is an electrode to connect the earth electrode **48** to the ground. Though not illustrated, the earth lead-out electrode is connected to the FPC **43** in both side surfaces of the ultrasonic probe **5** and integrated into one.

[0046] At the upper side of each piezoelectric transducer **45**, a first acoustic matching layer **49** is disposed via the earth electrode **48**. The first acoustic matching layer **49** is formed of a conductive material. The upper side of the first acoustic matching layer **49** is joined to a second acoustic matching layer **51**. The second acoustic matching layer **51** is formed of an insulating material. The first acoustic matching layer **49** and the second acoustic matching layer **51** are disposed to change the acoustic impedance stepwise from the piezoelectric transducer **45** to a patient. The upper side of the second acoustic matching layer **51** has an acoustic lens (not illustrated) disposed so as to cover all the upper side of the second acoustic matching layer **51**. Note that, the ultrasonic probe **5** according to the present embodiment has a configuration to have the first acoustic matching layer **49** and the second acoustic matching layer **51**, but may have a configuration to have the first acoustic matching layer **49** only.

[0047] The piezoelectric transducer **45**, the first acoustic matching layer **49**, and the second acoustic matching layer **51** are divided by a clearance **53** along the elevation direction and azimuth direction. In each clearance **53**, typically, resin material such as epoxy resin, or packing material with a filler material mixed in resin material such as epoxy resin is packed.

[0048] FIG. **3** is a simplified plan view of the ultrasonic probe **5** of FIG. **2**. As shown in FIG. **3**, two modules **30** (thick frames of FIG. **3**) are connected via an adhesive layer **35** formed of silicone. To one module **30**, a total of 480 pieces of piezoelectric transducers **45**, with 12 columns along the elevation direction and 40 columns along the azimuth direction, are arranged. The piezoelectric transducer **45** is divided into a first piezoelectric transducer **45***a* and a second piezoelectric transducer **45***b* in accordance with the width related to the elevation direction. The first piezoelectric transducer **45***a* has the width **W1** along the elevation direction. The first piezoelectric transducer **45***a* is disposed in the inside along the elevation direction of the module **30**. In FIG. **3**, 10 pieces each of the first piezoelectric transducers **45***a* are disposed along the elevation direction. The second piezoelectric transducer **45***b* has the width **W2** along the elevation direction. The second piezoelectric transducer **45***b* is disposed at the edge along the elevation direction of the module **30**. In order to achieve reduction of side lobe increase, the width **W1** is designed to be larger than the width **W2**.

[0049] To see the module **30** not independently but as a whole ultrasonic probe **5**, to the ultrasonic probe **5**, a total of 960 pieces of piezoelectric transducers **45** are disposed, with 24 columns in the elevation direction and 40 columns in the azimuth direction. On both edges of the ultrasonic probes **5** along the elevation direction, the second piezoelectric transducers **45***b* are disposed. Furthermore, at the boundary portion of adjacent modules **30** along the elevation direction, second piezoelectric transducers **45***b* are disposed. In the remainder portion, the first piezoelectric transducers **45***a* are disposed.

[0050] FIG. **4** is a cross-sectional view taken on line **4-4'** of FIG. **3**. As shown in FIG. **4**, the module **30** has a backing material **41**. The upper side of the backing material **41** is joined to a plurality of piezoelectric transducers **45** via the FPC **43** which has a thickness WF. The thickness WF is typically 50 μm. The FPC **43** is bent substantially 90 degrees at both side surfaces of the backing material **41**. The module **30** is joined in the elevation direction by silicone adhesives, etc. To explain more in detail, the module **30** is joined in such a manner that the second piezoelectric transducer **45***b* faces the second piezoelectric transducer **45***b* of the adjoining module **30** with the adhesive layer **35** therebetween. The thickness WA of the adhesive layer **35** by silicone (distance between two FPCs **43** pasted together) is typically 50 μm.

[0051] As shown in FIG. **4**, dicing grooves **53** are disposed between adjacent first piezoelectric transducers **45***a*, between adjacent second piezoelectric transducers **45***b*, and between adjacent first piezoelectric transducer **45***a* and second piezoelectric transducer **45***b*. The dicing groove **53** has the width WD along the elevation direction. This width DS is determined in accordance with the thickness of a dicing blade. Typically, the width DS is 50 μm.

[0052] The width **W1** of the first piezoelectric transducer **45***a* along the elevation direction is designed to be typically 250 μm. The first piezoelectric transducer **45***a* has a sub-dicing groove **55** formed by being sub-diced by a dicing blade. The sub-dicing groove **55** has the width WS along the elevation direction. The width WS is determined in accordance with the thickness of the dicing blade. Typically, the width WS is equal to the width WD and is 50 μm. Now, assume that each portion of the first piezoelectric transducer **45**a cut into two by sub-dicing is called a first piezoelectric transducer piece **45**c. The first piezoelectric transducer piece **45** has width W**3** along the elevation direction. The width W**3** is 100 μm. Consequently, effective width WE (WE=2×W3=W1−WS) of the first piezoelectric transducer **45**b is 200 μm. In addition, the center-to-center distance (pitch between first piezoelectric transducers) p**1** of adjacent two first piezoelectric transducers **45**a is 300 μm.

[0053] As shown in FIG. **4**, the second piezoelectric transducer **45**b disposed at the edge part of the module **30** is not sub-diced for reinforcing the mechanical strength. Width W**2** is determined in such a manner that the center-to-center distance (pitch between second piezoelectric transducers) p**2** of the two second piezoelectric transducers **45**b joined is equal to the pitch p**1** between the first piezoelectric transducers. That is, the width W**2** is 150 μm. In addition, the distance between the center of the first piezoelectric transducer and the center of the second piezoelectric transducer (pitch between the first and second piezoelectric transducers) p**3** is 250 μm.

[0054] The effects of the ultrasonic probe **5** which has the configuration described above will be explained as follows.

[0055] (1) According to the configuration of a conventional type ultrasonic probe **100** shown in FIG. **8**, the center-to-center distance p**91** of two piezoelectric transducers **95**a which are adjacent to each other via an adhesive layer is larger than the center-to-center distance p**90** of two piezoelectric transducers **95**b which are adjacent to each other inside the module. On the other hand, according to the configuration of the ultrasonic probe **5** according to the present embodiment shown in FIG. **4**, the width W**2** of the piezoelectric transducer **45**b at the end part of the module **30** is narrower than the width W**1** of the first piezoelectric transducer **45**a in the inside of the module **30**. Consequently, it is possible to make the pitch p**2** between the second piezoelectric transducers substantially equal to the pitch p**1** between the first piezoelectric transducers. As a result, the ultrasonic probe **5** has the side lobe increase reduced as compared to the conventional type ultrasonic probe **100**.

[0056] (2) In the case of being sub-diced, according to the configuration of the conventional ultrasonic probe **100** shown in FIG. **8**, the width W**91** of the piezoelectric transducer **95**a at the module end part is 250 μm and the effective width W**99** of the piezoelectric transducer **95**b inside the module is 200 μm. Consequently, when the same drive voltage is applied to the piezoelectric transducer **95**a and the piezoelectric transducer **95**b, the intensity of the ultrasonic wave generated from the piezoelectric transducer **95**a is about 2 dB higher than the intensity of the ultrasonic wave generated from the piezoelectric transducer **95**b. On the other hand, according to the configuration of the ultrasonic probe **5** according to the present embodiment shown in FIG. **4**, making the width W**2** of the second piezoelectric transducer **45**b narrower than the width W**1** of the first piezoelectric transducer **45**a narrows the width W**2** of the second piezoelectric transducer **45**b from the effective width WE of the first piezoelectric transducer **45**a. In the example of FIG. **4**, the width W**3** is 150 μm and the width WE is 200 μm, and therefore, when the same drive voltage is applied to the piezoelectric transducer **45**a and the piezoelectric transducer **45**b, the intensity of the ultrasonic wave generated from the second piezoelectric transducer **45**b is about 2 dB smaller than the intensity of ultrasonic wave generated from the first piezoelectric transducer **45**a as shown in FIG. **5**. As a result, the acoustic field of the ultrasonic wave generated from the ultrasonic probe **5** is not inverse-weighting. That is, the side lobe increase is reduced as compared to the conventional ultrasonic probe **100**.

[0057] Referring now to simulation results shown in FIG. **6**, characteristics of the ultrasonic wave generated from the ultrasonic probe **5** are discussed. FIG. **6** shows the relationship between the acoustic field intensity of the ultrasonic wave and the angle of the ultrasonic beam when the same drive voltage is applied to 3-MHz driven piezoelectric transducers and the ultrasonic beam is deviated by 45 degrees relative to the center axis. The solid line shows the data by the ultrasonic probe **5** in the present embodiment and the broken line shows the data by the conventional ultrasonic probe **100** of FIG. **8**. In both data, the acoustic field intensity at **45** degrees is set to zero. As shown in FIG. **6**, the ultrasonic probe **5** in the present embodiment has side lobes reduced in a wide range from −40 degrees to +30 degrees as compared to the conventional ultrasonic probe **100**.

[0058] Note that, in the above-mentioned configuration, it is assumed that the first piezoelectric vibrator **45**a is sub-diced. However, the first piezoelectric vibrator **45**a may not always be sub-diced. FIG. **7** shows a transverse cross-sectional view of an ultrasonic probe which is not sub-diced. As shown in FIG. **7**, since the effective width W**1** of the first piezoelectric transducer **45**a is 250 μm, the intensity of the ultrasonic wave generated from the second piezoelectric transducer **45**b is 4 dB lower than the intensity of the ultrasonic wave generated from the first piezoelectric transducer **45**a. Consequently, the acoustic field does not become inverse-weighting and as a result, as compared to the non-sub-diced conventional ultrasonic probe, the ultrasonic probe shown in FIG. **7** has the side-lobe increase reduced.

[0059] In addition, in the above-mentioned configuration, the elevation direction only is considered for the pasting direction of the module **30**. However, the module **30** can be joined not only in the elevation direction but also in the azimuth direction. That is, the module **30** can be joined in the two-dimensional manner. In such event, the azimuth-direction center-to-center distance of the two piezoelectric transducers connected in the azimuth direction is made equal to the azimuth-direction center-to-center distance of the piezoelectric transducers inside the module in the azimuth direction. For this purpose, the width concerning the azimuth direction of the piezoelectric transducers connected in the azimuth direction is made narrower than the width concerning the azimuth direction of the piezoelectric transducers inside the module.

[0060] In addition, in the above-mentioned configuration, piezoelectric transducers are arranged in the two-dimensional manner. However, the invention shall not be limited to this, but piezoelectric transducers may be arranged in the one-dimensional manner along the elevation direction or the azimuth direction.

[0061] Furthermore, in the above-mentioned configuration, the place where the second piezoelectric transducer **45**b having the width W**3** is disposed is both ends of the module **30**. However, to the portion which is the end of the module **30** and which is not joined to the adjacent module **30**, the first piezoelectric transducer **45**a having the width W**1** may be disposed.

[0062] In this way, according to the present embodiment, reduction of side lobe increase is enabled in the ultrasonic probe **5** with a plurality of modules **30** and the ultrasonic diagnostic apparatus **1**. In addition, the ultrasonic diagnostic apparatus **1** having the ultrasonic probe **5** can provide highly accurate ultrasonic images such as B-mode images, Doppler images, etc.

[0063] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An ultrasonic probe comprising:

a plurality of modules joined along at least in one direction, wherein each of said modules includes:

a plurality of first transducers having a first width with respect to the first direction; and

at least one second transducer having a second width narrower than the first width with respect to the first direction, and arranged at both ends or one end of the modules with respect to the first direction.

2. The ultrasonic probe according to claim **1**, wherein each of said modules has the second transducers joined to the second transducers of adjacent modules in such a manner that they face each other.

3. The ultrasonic probe according to claim **2**, wherein a center-to-center distance of the two second transducers joined in the first direction is substantially equal to a center-to-center distance of the two adjacent first transducers along the first direction.

4. The ultrasonic probe according to claim **1**, wherein said first transducers are arranged not only along the first direction but also along the second direction that intersects with the first direction.

5. The ultrasonic probe according to claim **1**, wherein said modules are joined not only along the first direction but also along the second direction that intersects with the first direction.

6. The ultrasonic probe according to claim **1**, wherein the first transducer has a groove.

7. An ultrasonic probe comprising:

a plurality of first transducers having a first width with respect to a first direction and arranged two-dimensionally along the first direction as well as along a second direction that intersects with the first direction; and

a plurality of second transducers having a second width narrower than the first width with respect to the first direction and arranged two-dimensionally along the first direction as well as along the second direction,

wherein said plurality of first transducers and said plurality of second transducers are alternately arranged at least along the first direction.

8. An ultrasonic diagnostic apparatus comprising:

an ultrasonic probe having a plurality of modules joined at least along a first direction,

wherein each of said modules includes:

a plurality of first transducers having a first width with respect to the first direction; and

at least one second transducer having a second width narrower than the first width with respect to the first direction, and arranged at both ends or one end of the modules with respect to the first direction.

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摘要(译)

超声波探头具有至少沿仰角方向连接的多个模块。该模块具有多个第一压电换能器，其具有相对于仰角方向的第一宽度。该模块具有至少一个第二压电传感器，该第二压电传感器具有相对于仰角方向比第一宽度窄的第二宽度。第二压电传感器相对于仰角方向布置在模块端部。模块以这样的方式布置，使得第二压电传感器面对相邻模块的第二压电传感器。