US 20200060651A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2020/0060651 A1
(43) Pub. Date: Feb. 27, 2020
MORIMOTO et al.

(54) ARRAY-TYPE ULTRASONIC VIBRATOR, ULTRASONIC PROBE, ULTRASONIC CATHETER, HAND-HELD SURGICAL INSTRUMENT, AND MEDICAL APPARATUS

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(21) Appl. No.: **16/462,818**

(22) PCT Filed: **Oct. 13, 2017**

(86) PCT No.: **PCT/JP2017/037211**

§ 371 (c)(1),
(2) Date: **May 21, 2019**

(30) **Foreign Application Priority Data**

Dec. 20, 2016 (JP) 2016-246688

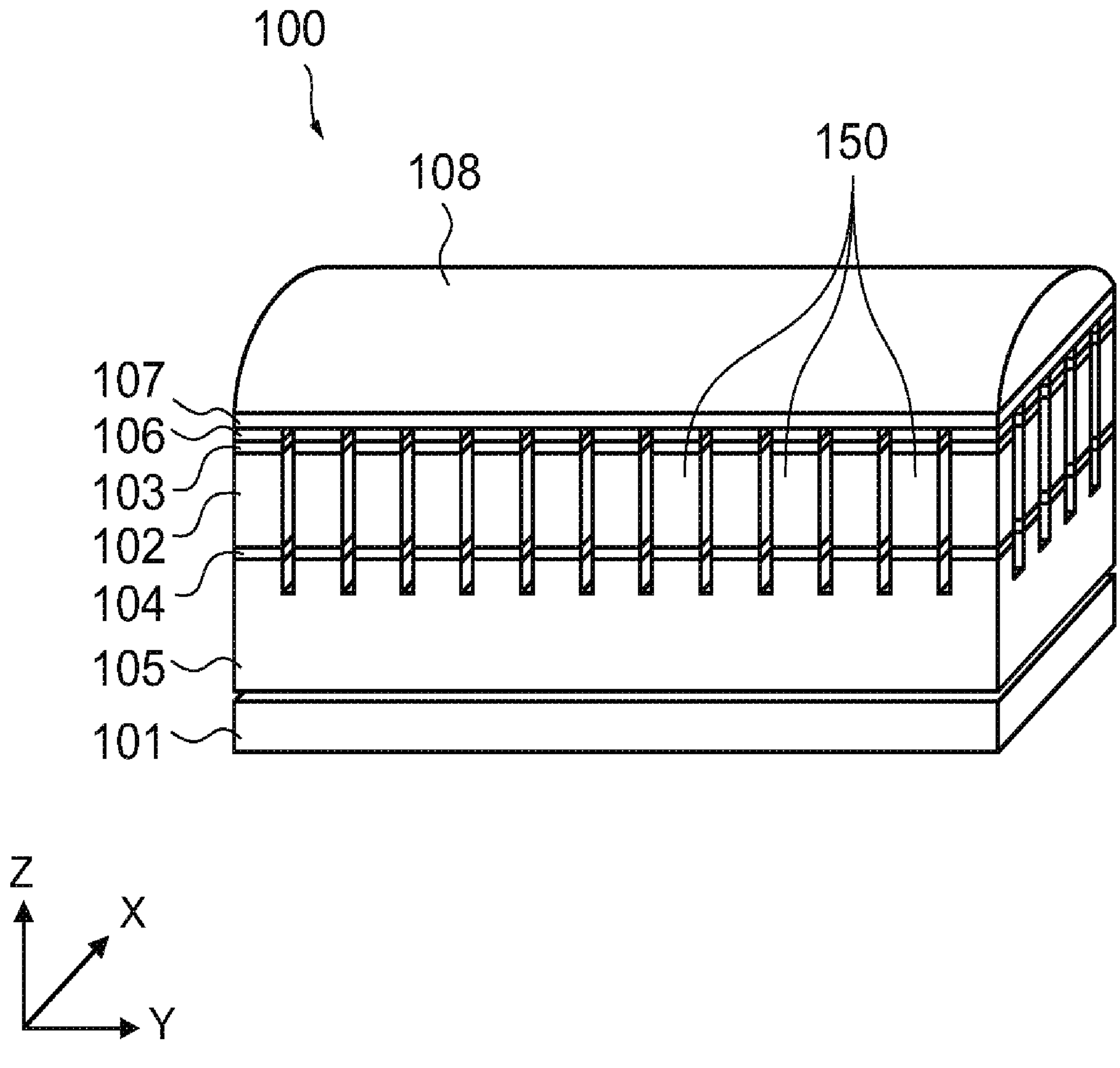
Publication Classification

(51) **Int. Cl.**
A61B 8/00 (2006.01)
A61B 8/12 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 8/4488*** (2013.01); ***A61B 8/445*** (2013.01); ***A61B 8/12*** (2013.01)

(57) **ABSTRACT**

[Object] To provide an array-type ultrasonic vibrator, which is excellent in productivity and practicability and has a two-dimensional array structure capable of improving a focusing property of an ultrasonic beam in a slice direction, an ultrasonic probe, an ultrasonic catheter, a hand-held surgical instrument, and a medical apparatus. [Solving Means] An array-type ultrasonic vibrator according to an embodiment of the present technology includes a vibrator array and a resistor. The vibrator array is a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction. The resistor is electrically connected between a pair of arbitrary ultrasonic vibrator elements in the element row.



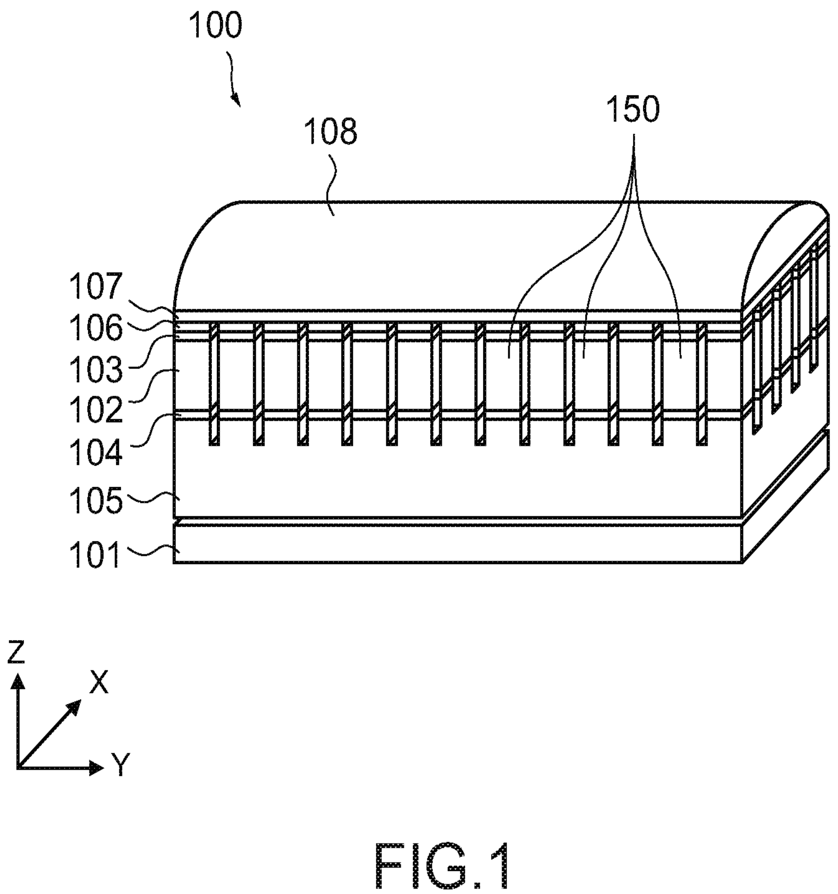


FIG.1

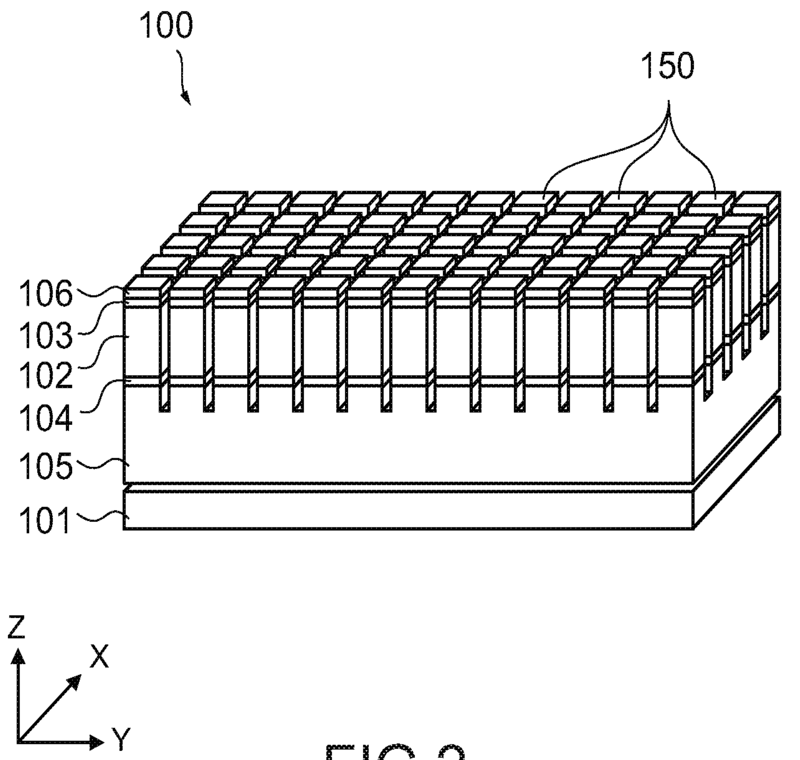


FIG.2

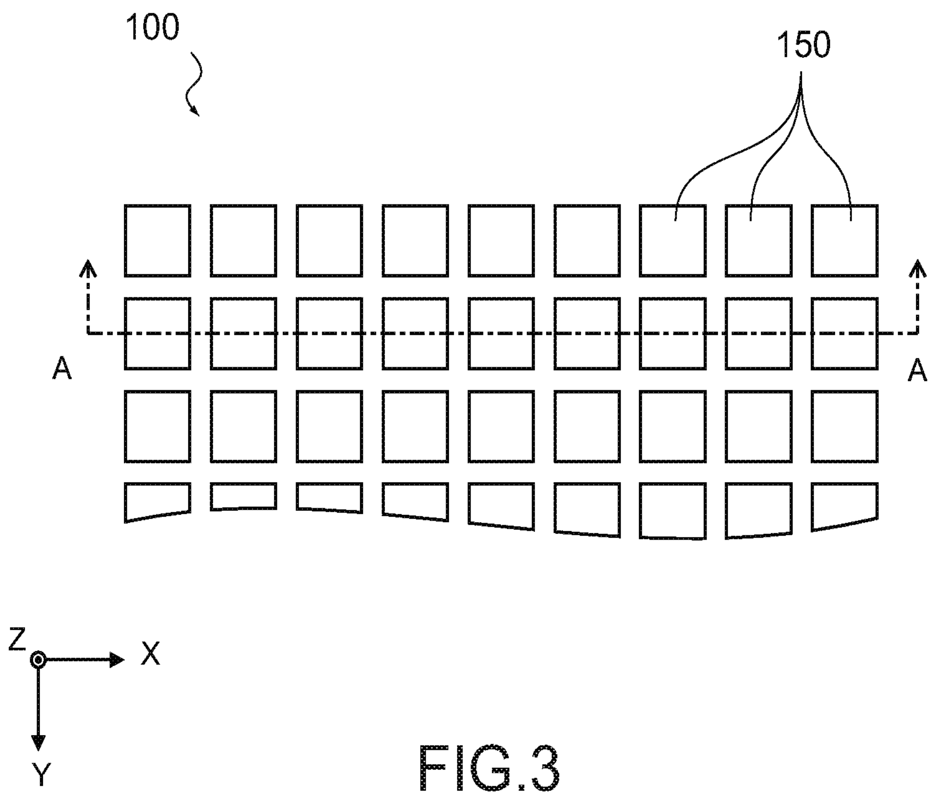


FIG.3

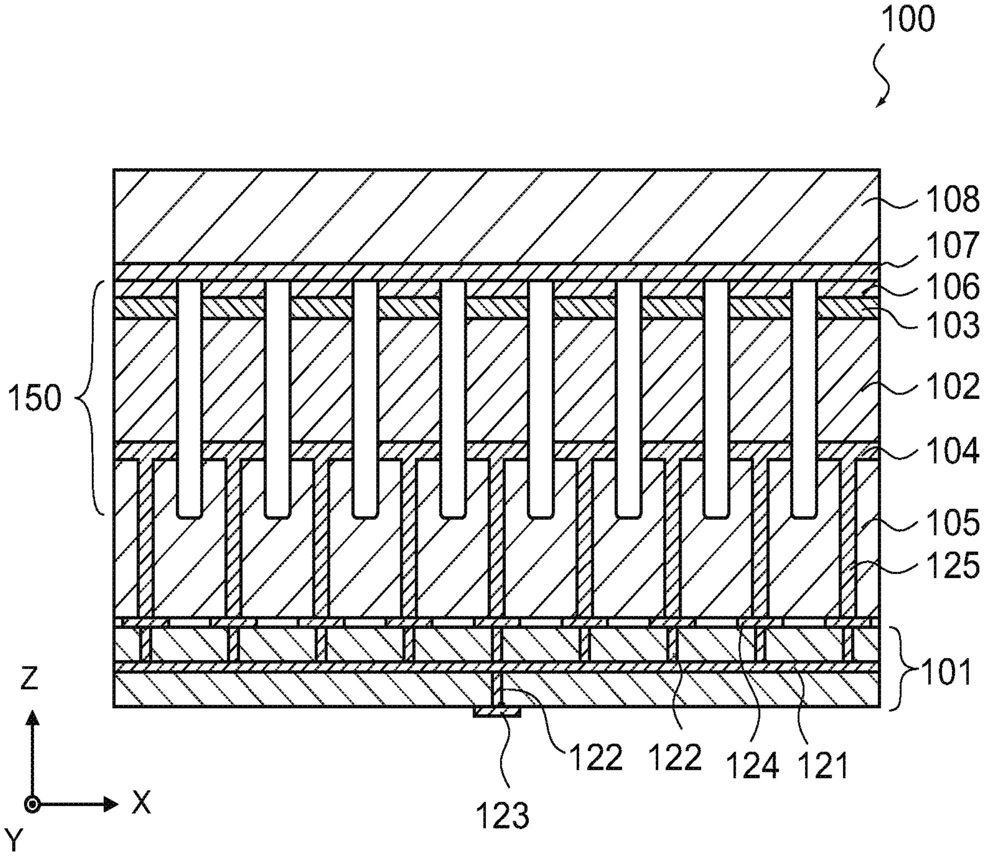

100
108
107
106
103
150
102
104
105
125
101
Z
X
Y
122
122
124
121
123

FIG.4

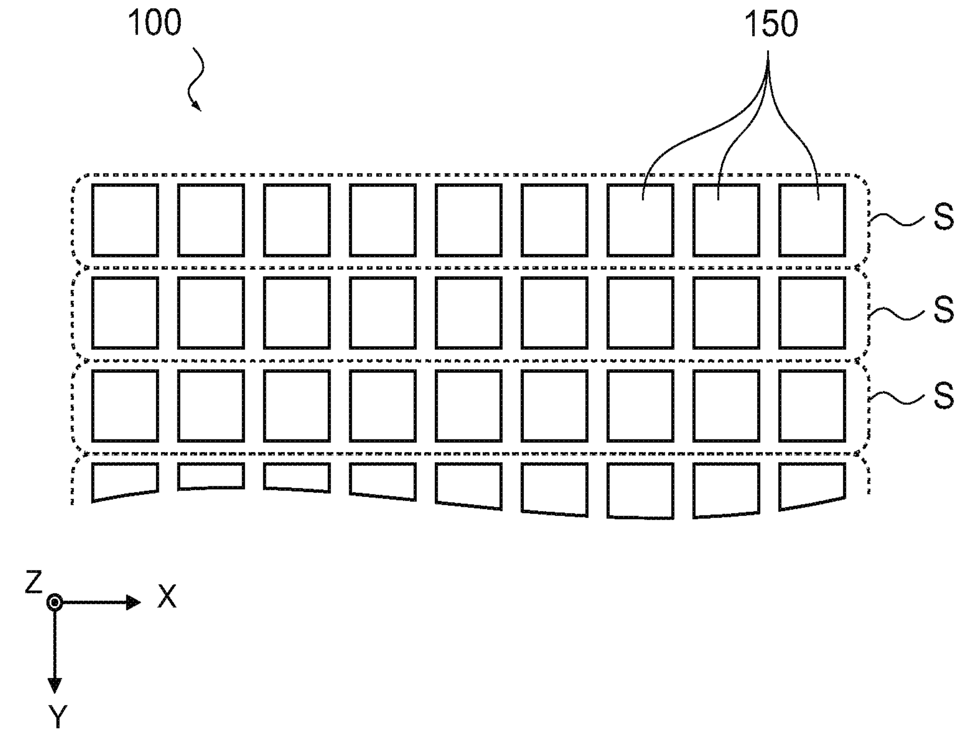

100
150
S
S
S
Z
X
Y

FIG.5

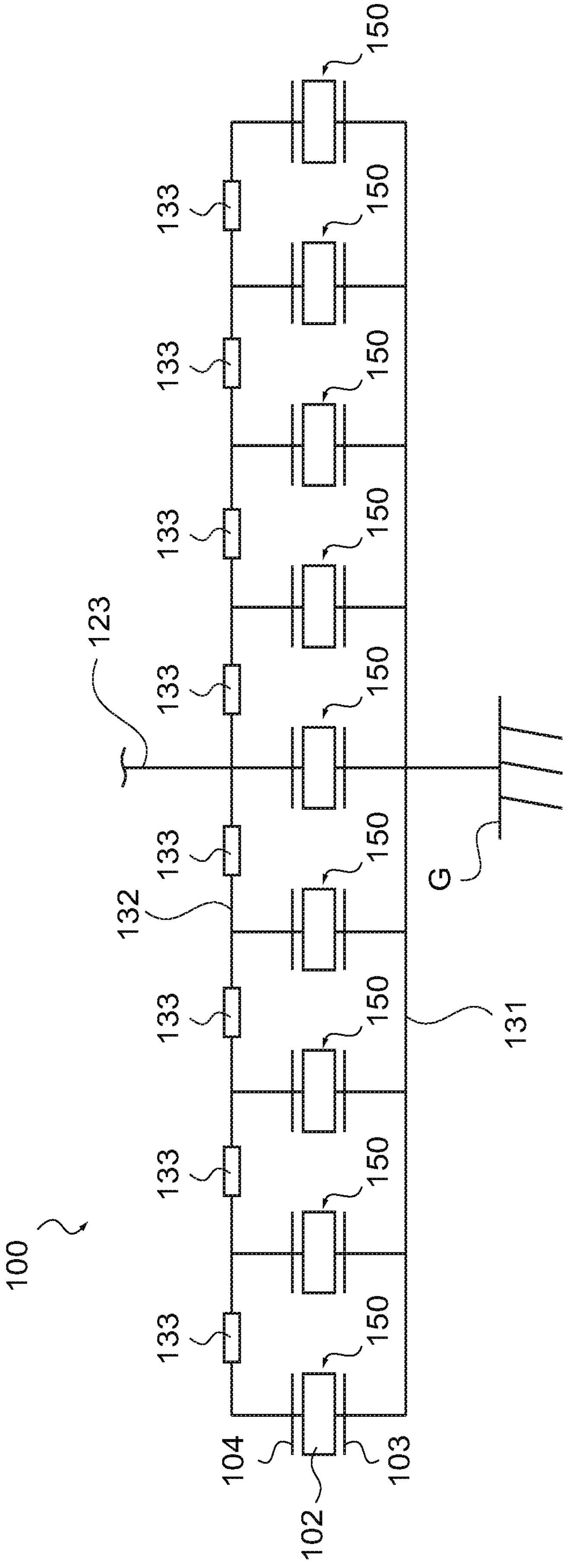


FIG.6

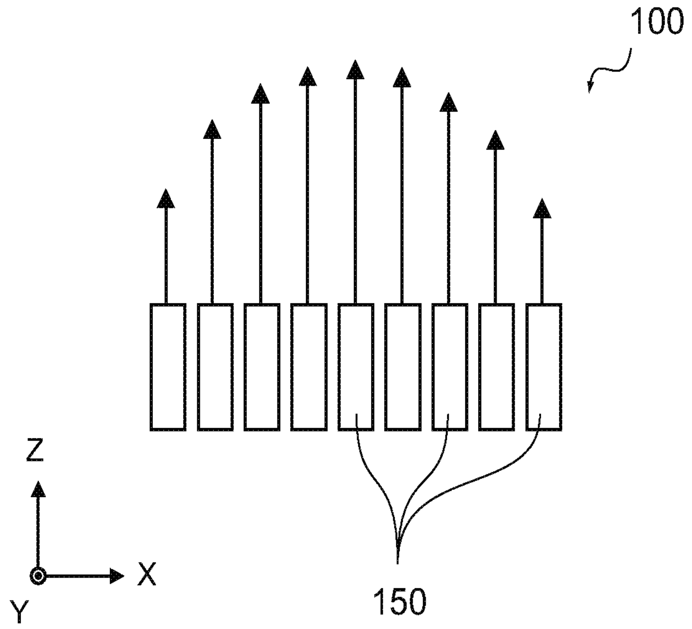


FIG.7

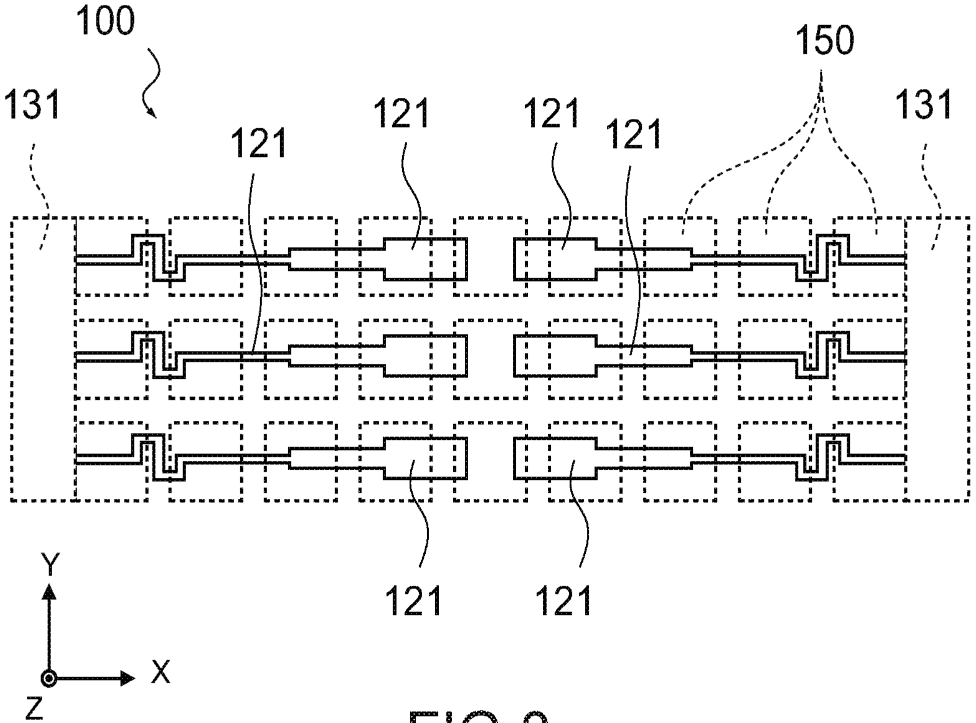


FIG.8

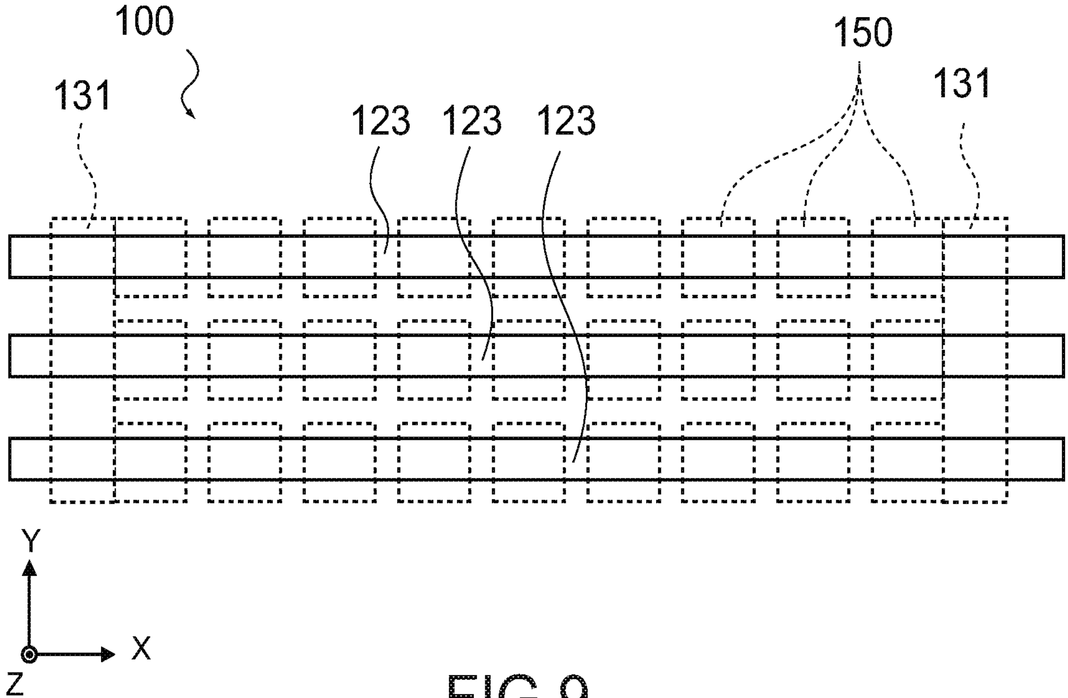


FIG.9

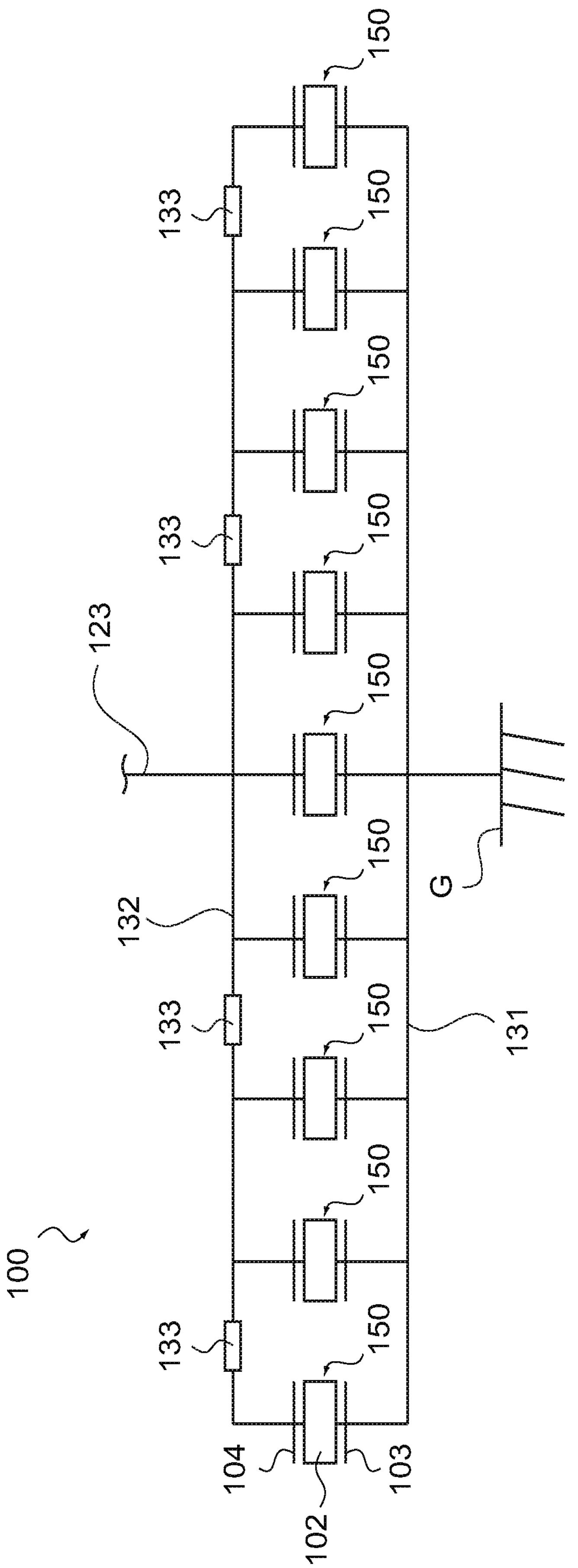


FIG.10

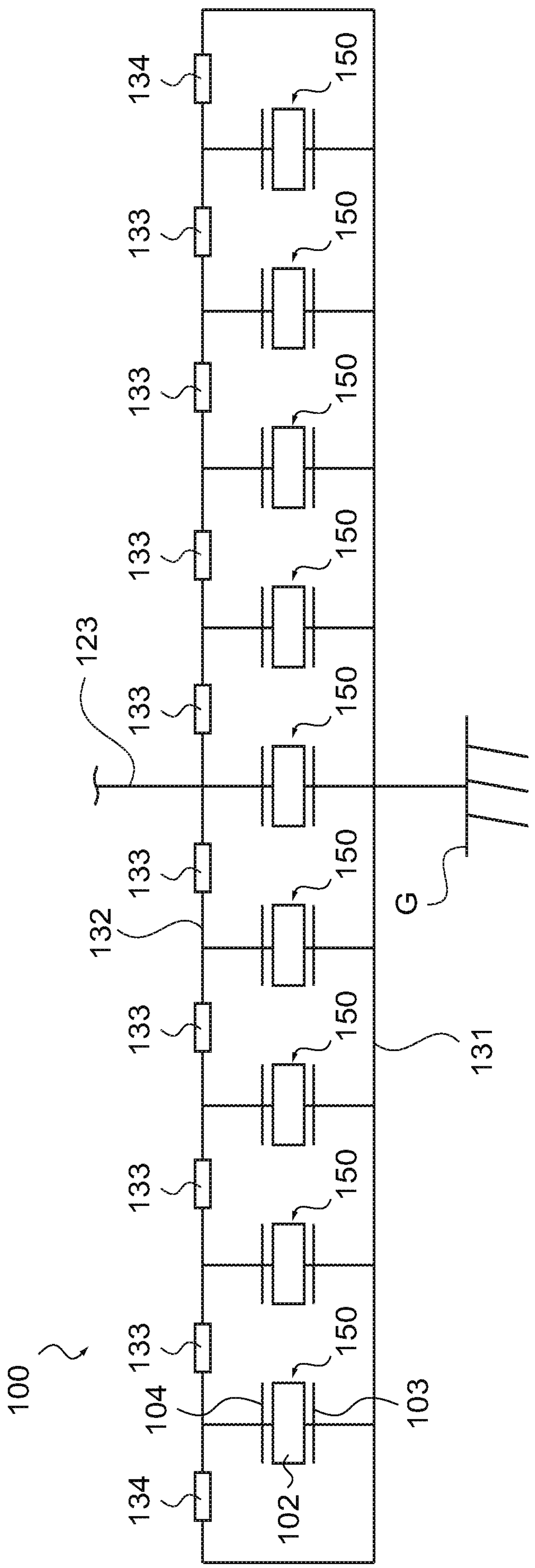

134
133
133
133
133
133
133
133
134
150
150
150
150
150
150
150
150
150
123
132
131
G
100
104
103
102

FIG.11

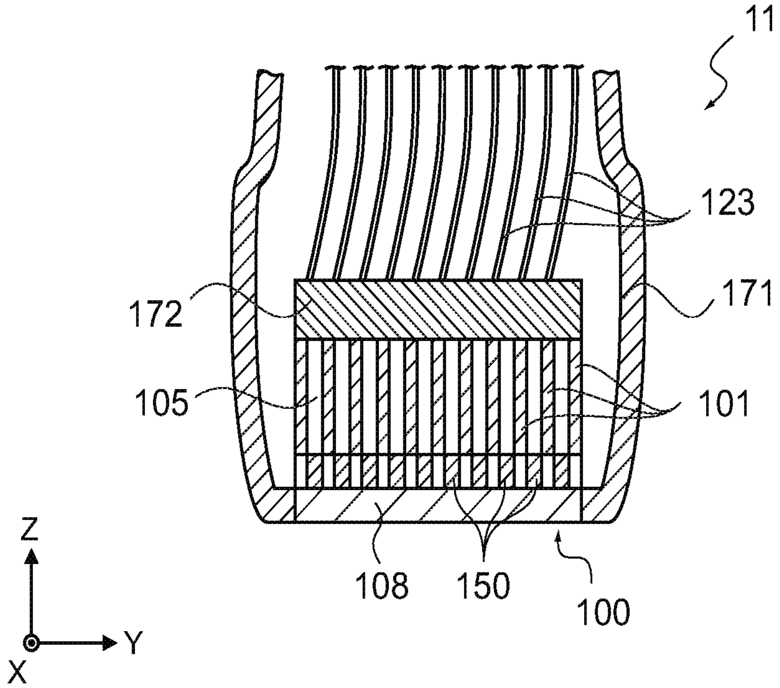

11
123
171
172
105
101
108
150
100
Z
Y
X

FIG.12

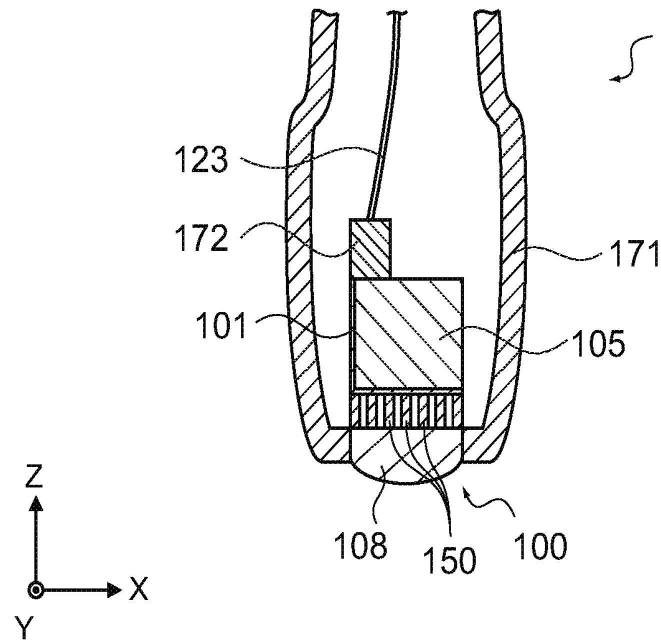
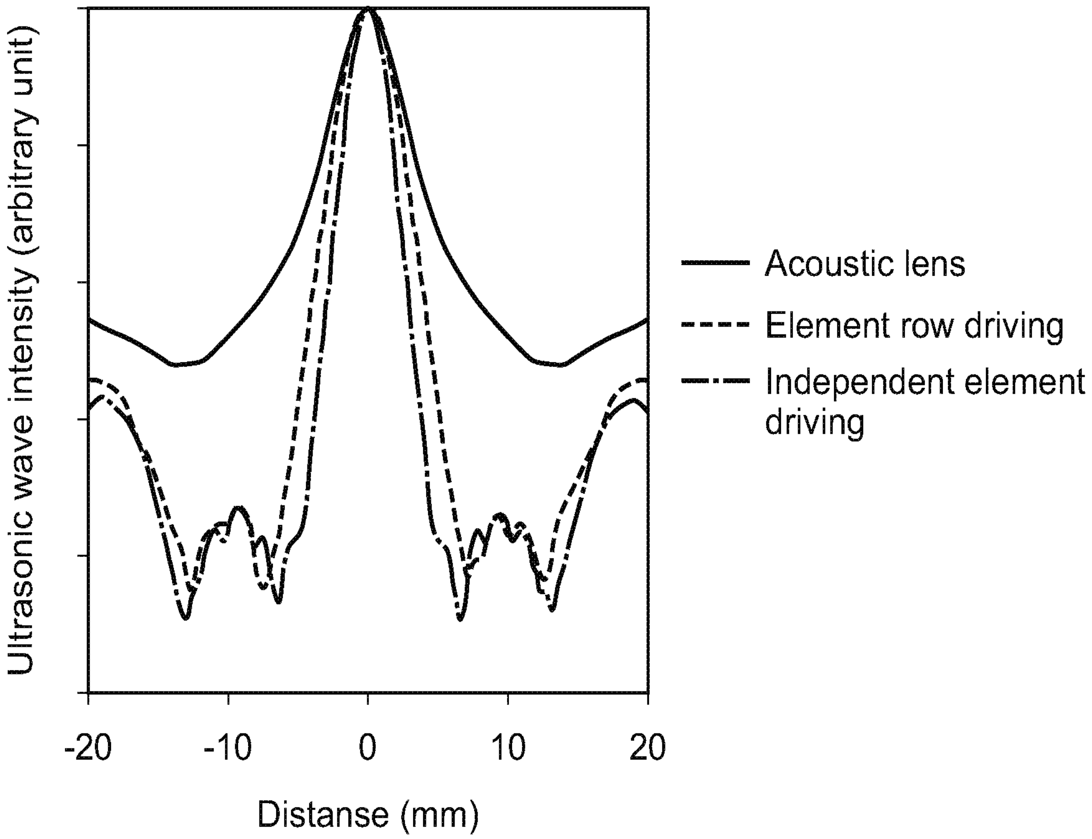

11
123
172
171
101
105
108
150
100
Z
X
Y

FIG.13



Ultrasonic wave intensity (arbitrary unit)
-20
-10
0
10
20
Distanse (mm)
Acoustic lens
Element row driving
Independent element driving

FIG.14

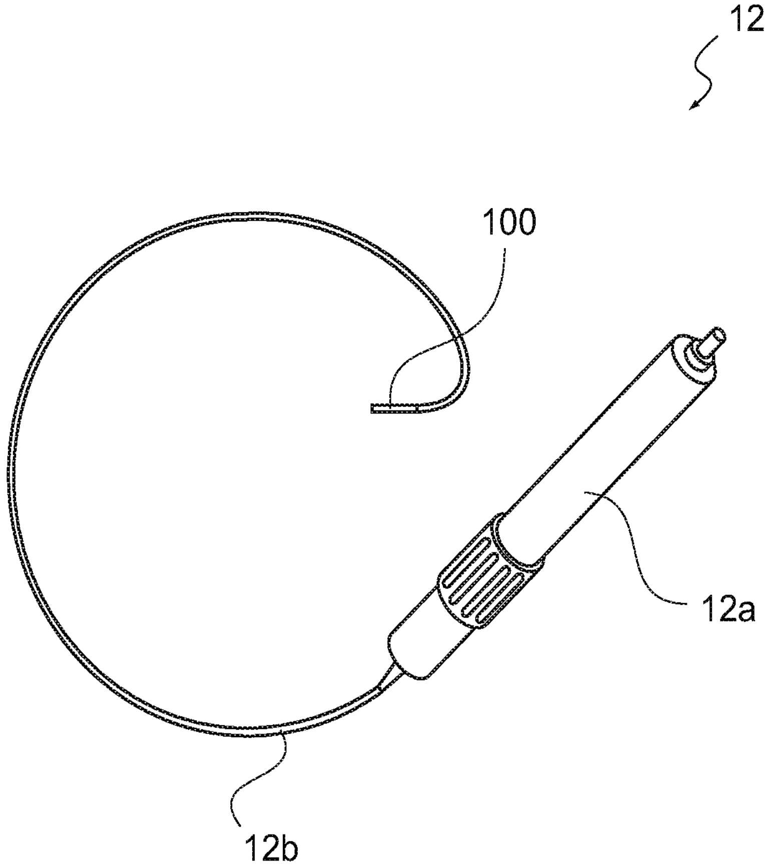


FIG.15

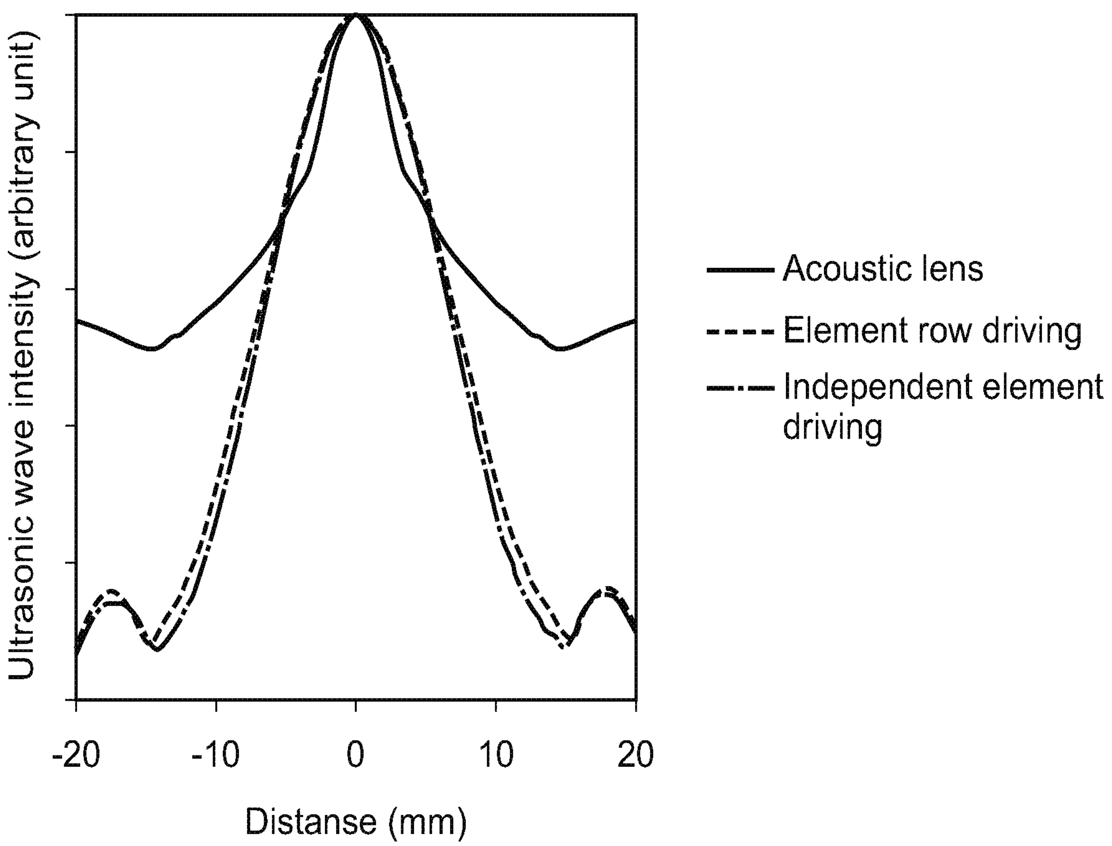

Ultrasonic wave intensity (arbitrary unit)
-20
-10
0
10
20
Distanse (mm)
Acoustic lens
Element row driving
Independent element driving

FIG.16

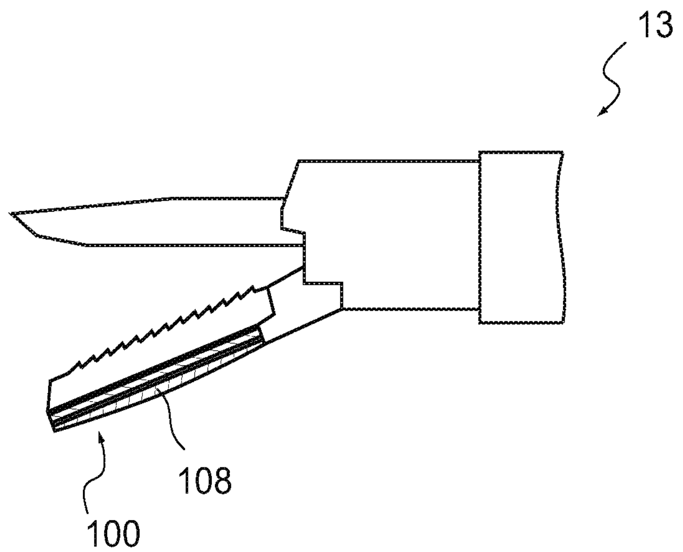

13
108
100

FIG.17

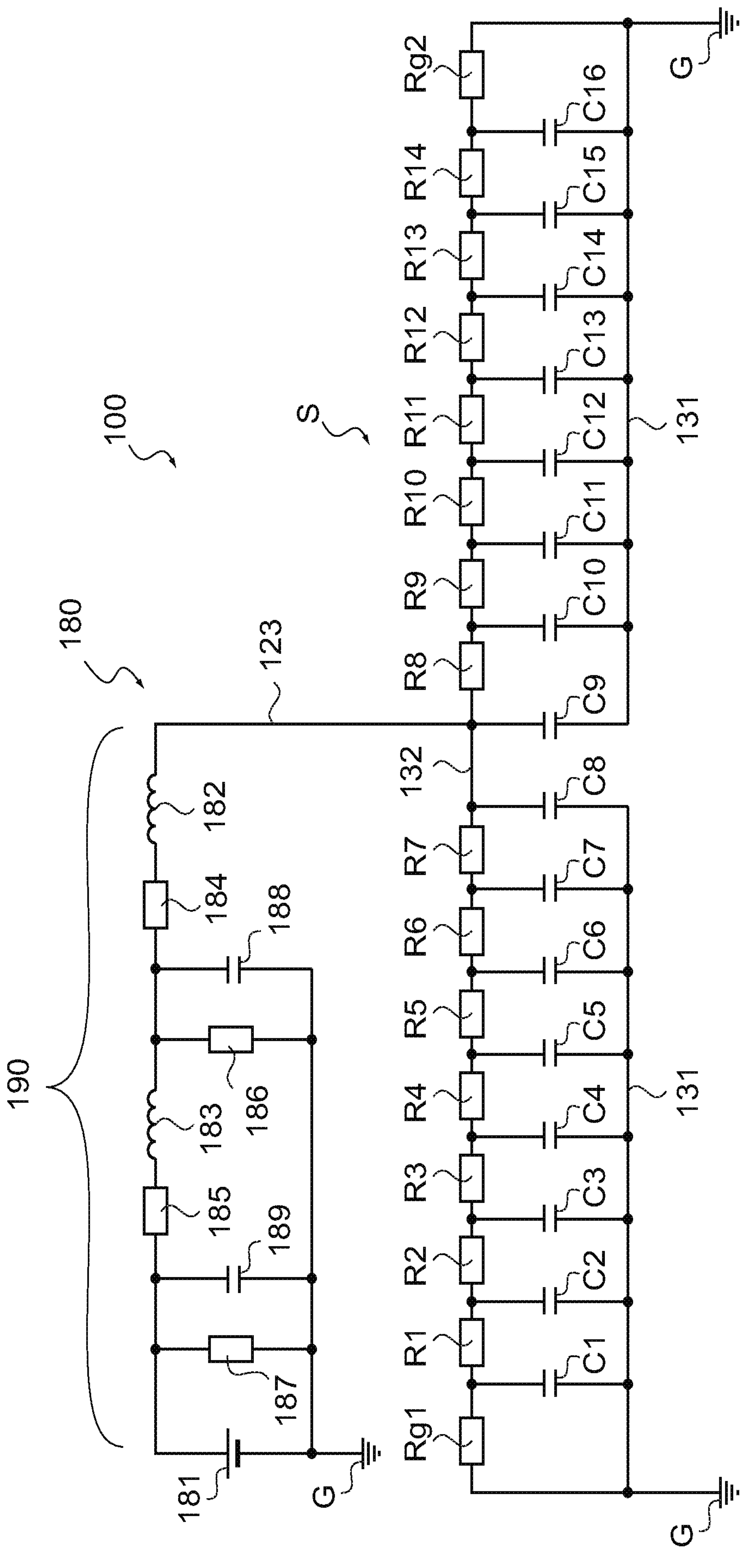

100
S
180
123
190
181
182
183
184
185
186
187
188
189
G
Rg1
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
Rg2
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
131
132

FIG. 18

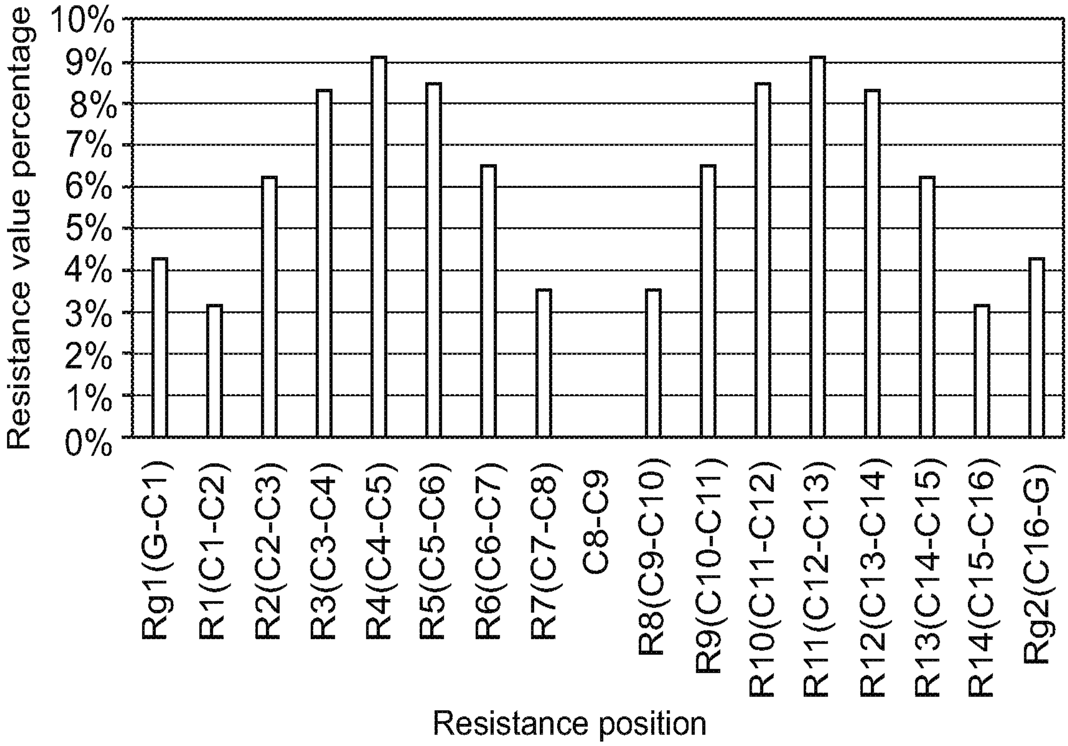

Resistance value percentage
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Rg1(G-C1)
R1(C1-C2)
R2(C2-C3)
R3(C3-C4)
R4(C4-C5)
R5(C5-C6)
R6(C6-C7)
R7(C7-C8)
C8-C9
R8(C9-C10)
R9(C10-C11)
R10(C11-C12)
R11(C12-C13)
R12(C13-C14)
R13(C14-C15)
R14(C15-C16)
Rg2(C16-G)
Resistance position

FIG.19

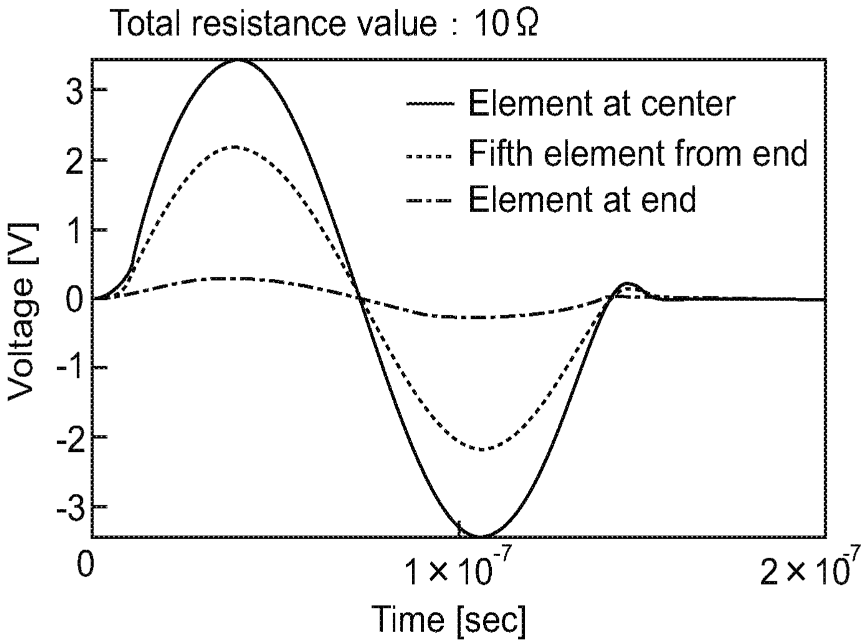

Total resistance value : 10Ω
Element at center
Fifth element from end
Element at end
Voltage [V]
3
2
1
0
-1
-2
-3
0
1×10^-7
2×10^-7
Time [sec]

FIG.20

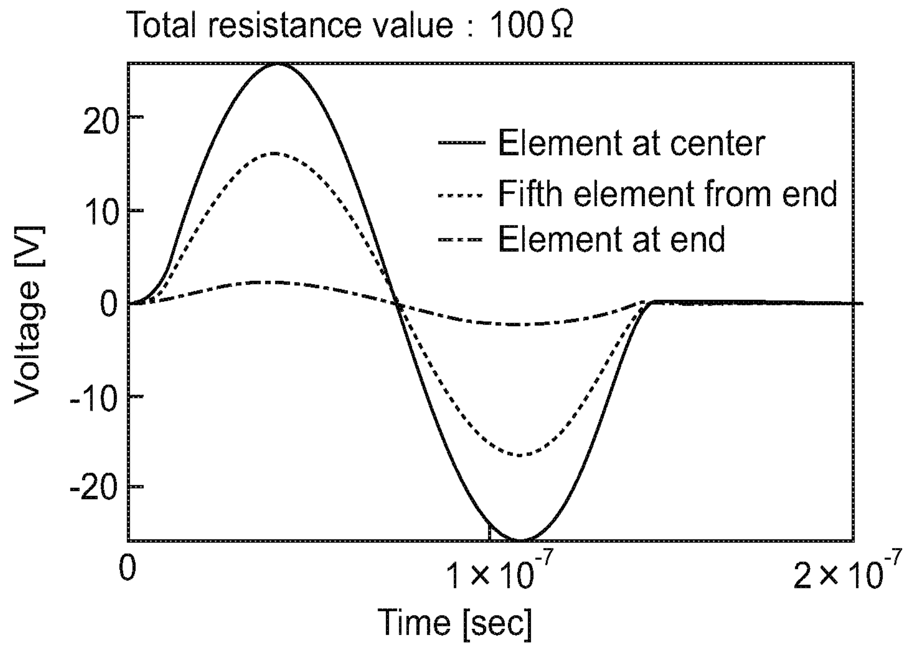

Total resistance value : 100Ω
Element at center
Fifth element from end
Element at end
Voltage [V]
20
10
0
-10
-20
0
1×10^-7
2×10^-7
Time [sec]

FIG.21

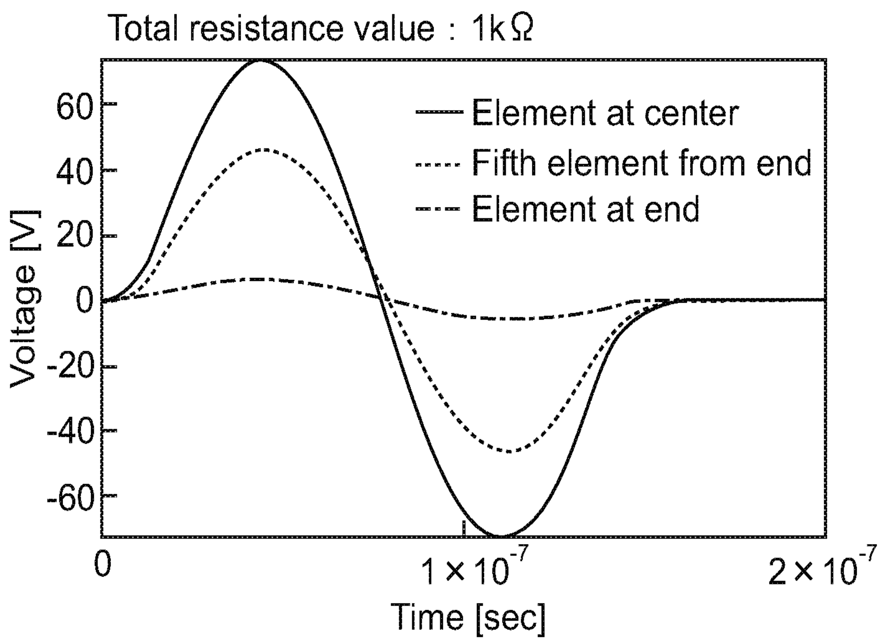

Total resistance value : 1kΩ
Element at center
Fifth element from end
Element at end
Voltage [V]
60
40
20
0
-20
-40
-60
0
1×10^-7
2×10^-7
Time [sec]

FIG.22

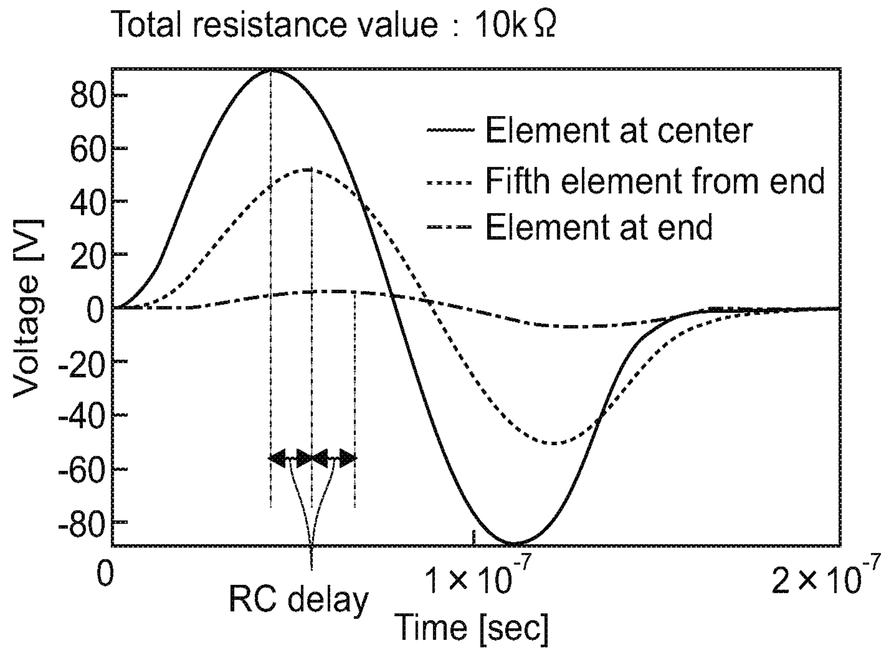

Total resistance value : 10kΩ
80
60
40
20
0
-20
-40
-60
-80
Voltage [V]
Element at center
Fifth element from end
Element at end
0
1×10^-7
2×10^-7
RC delay
Time [sec]

FIG.23

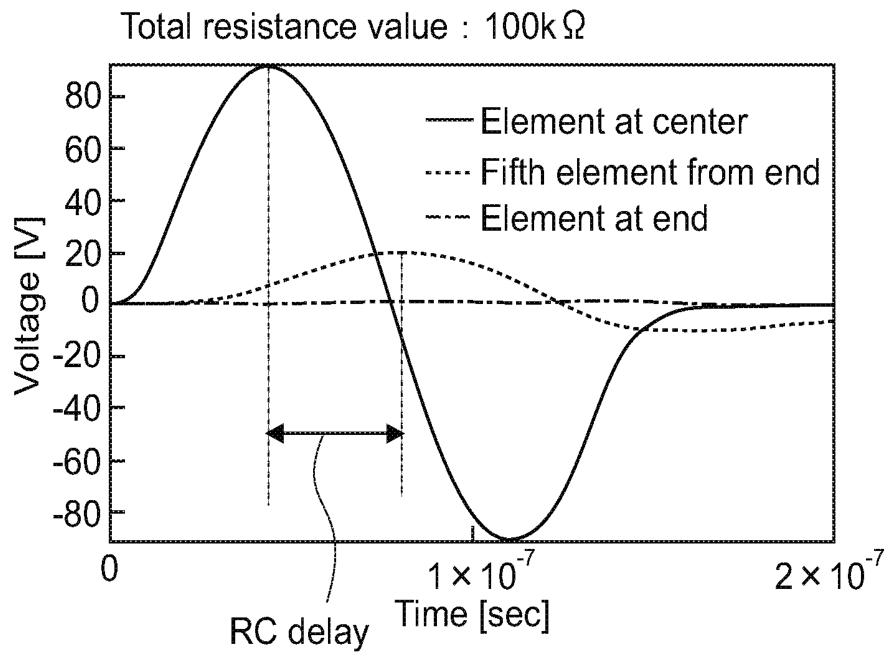
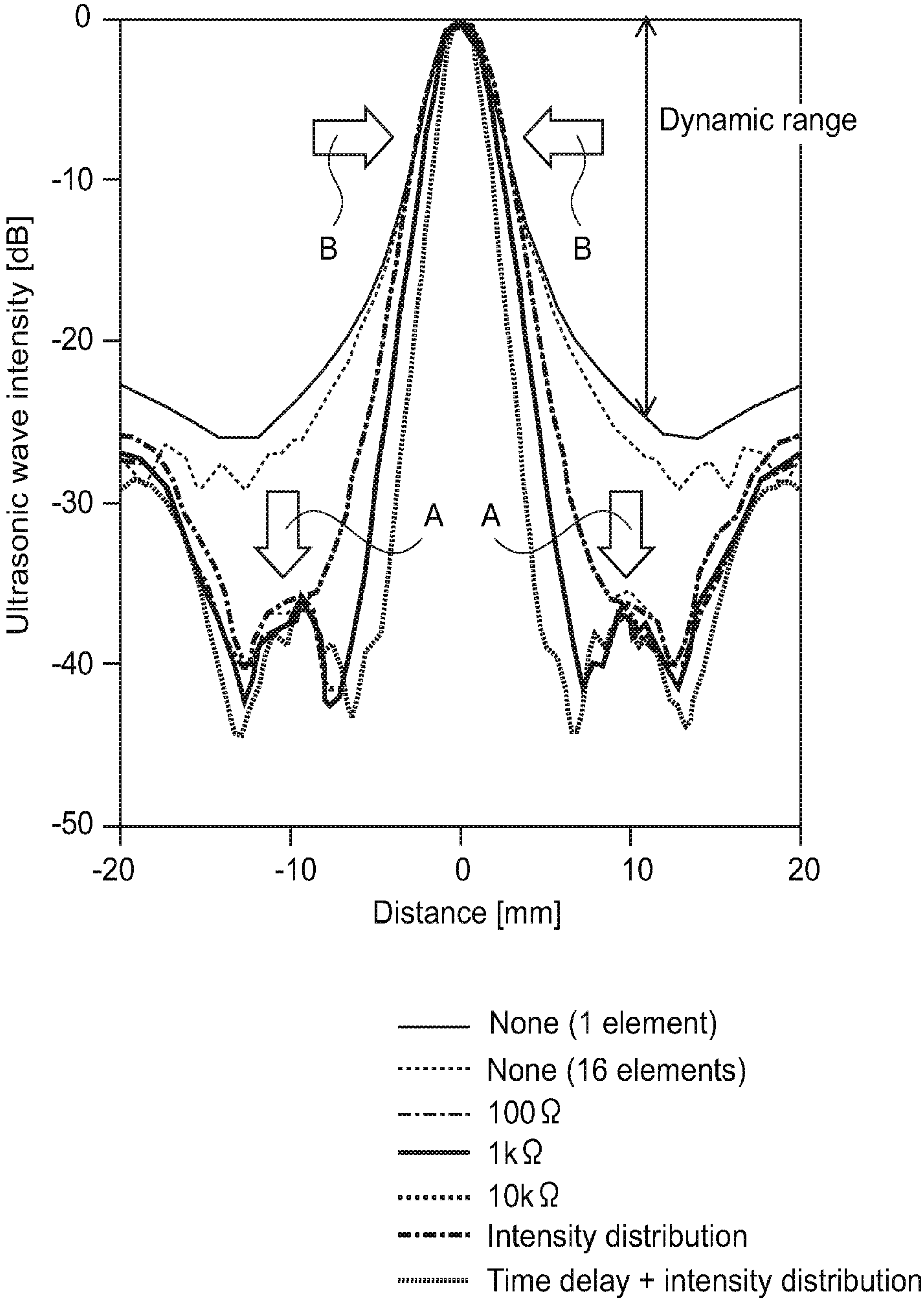

Total resistance value : 100kΩ
80
60
40
20
0
-20
-40
-60
-80
Voltage [V]
Element at center
Fifth element from end
Element at end
0
1×10^-7
2×10^-7
RC delay
Time [sec]

FIG.24



0
-10
-20
-30
-40
-50
Ultrasonic wave intensity [dB]
-20
-10
0
10
20
Distance [mm]
Dynamic range
B
B
A
A
None (1 element)
None (16 elements)
100Ω
1kΩ
10kΩ
Intensity distribution
Time delay + intensity distribution

FIG.25

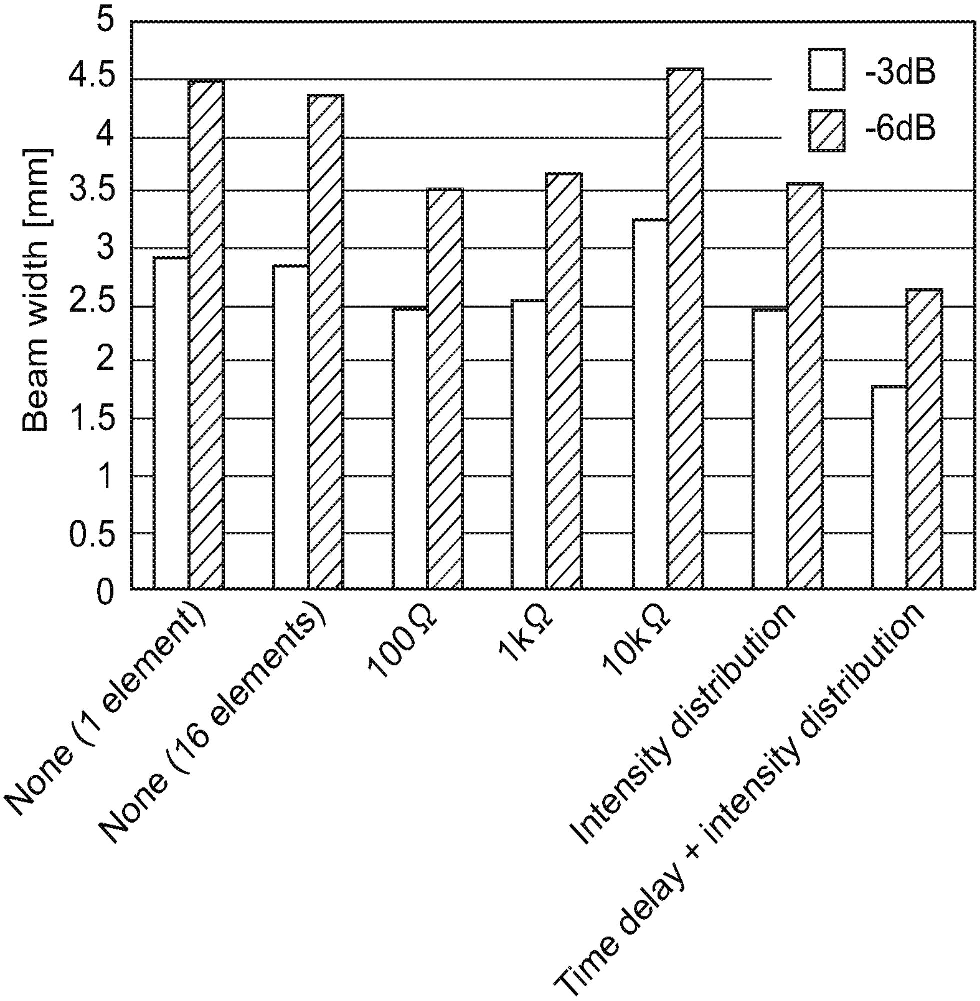
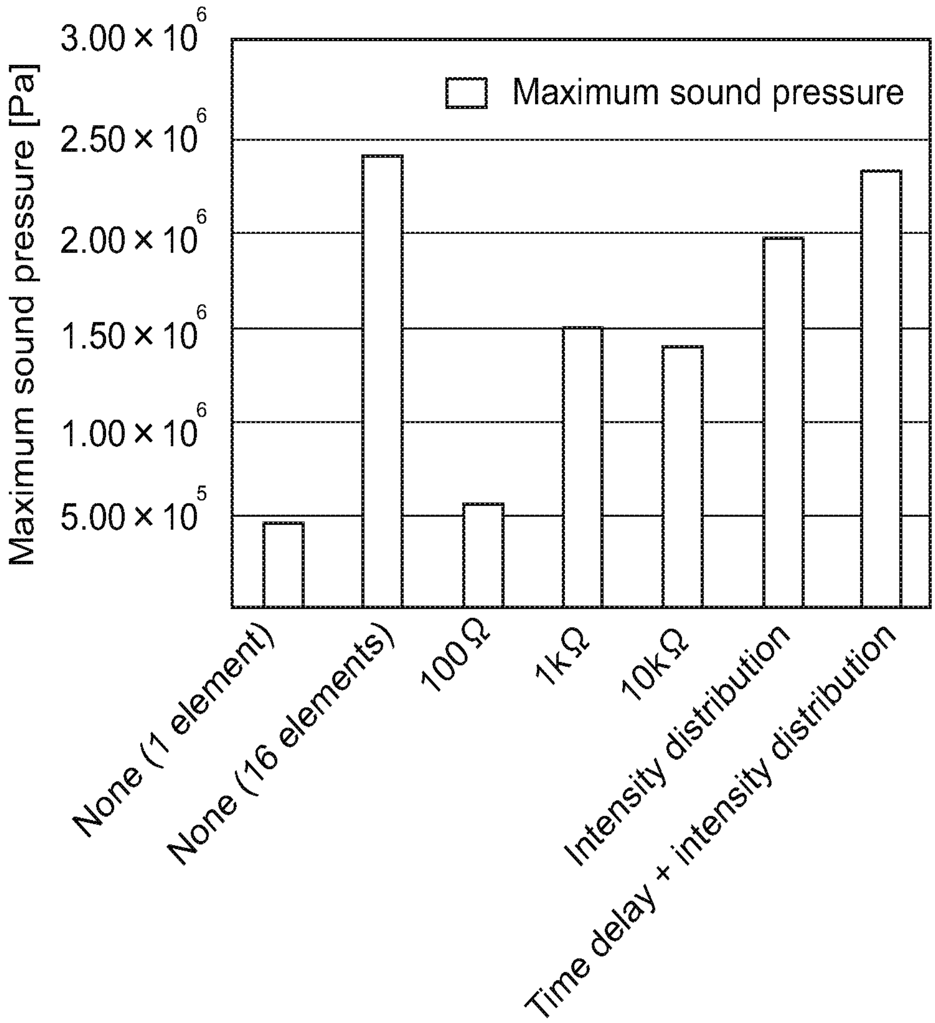

5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Beam width [mm]
-3dB
-6dB
None (1 element)
None (16 elements)
100Ω
1kΩ
10kΩ
Intensity distribution
Time delay + intensity distribution

FIG.26



Maximum sound pressure [Pa]
3.00×10^6
2.50×10^6
2.00×10^6
1.50×10^6
1.00×10^6
5.00×10^5
Maximum sound pressure
None (1 element)
None (16 elements)
100Ω
1kΩ
10kΩ
Intensity distribution
Time delay + intensity distribution

FIG.27

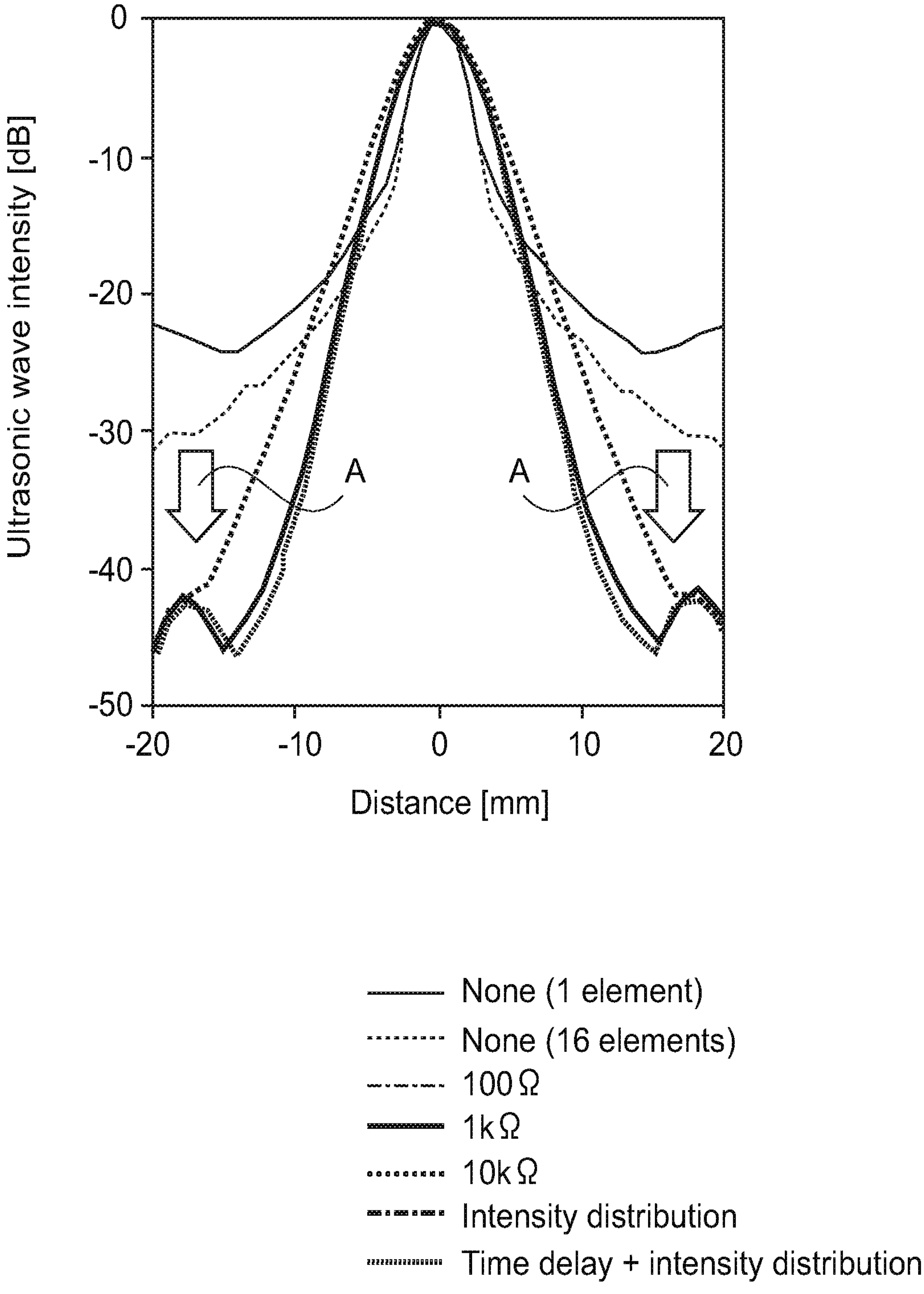
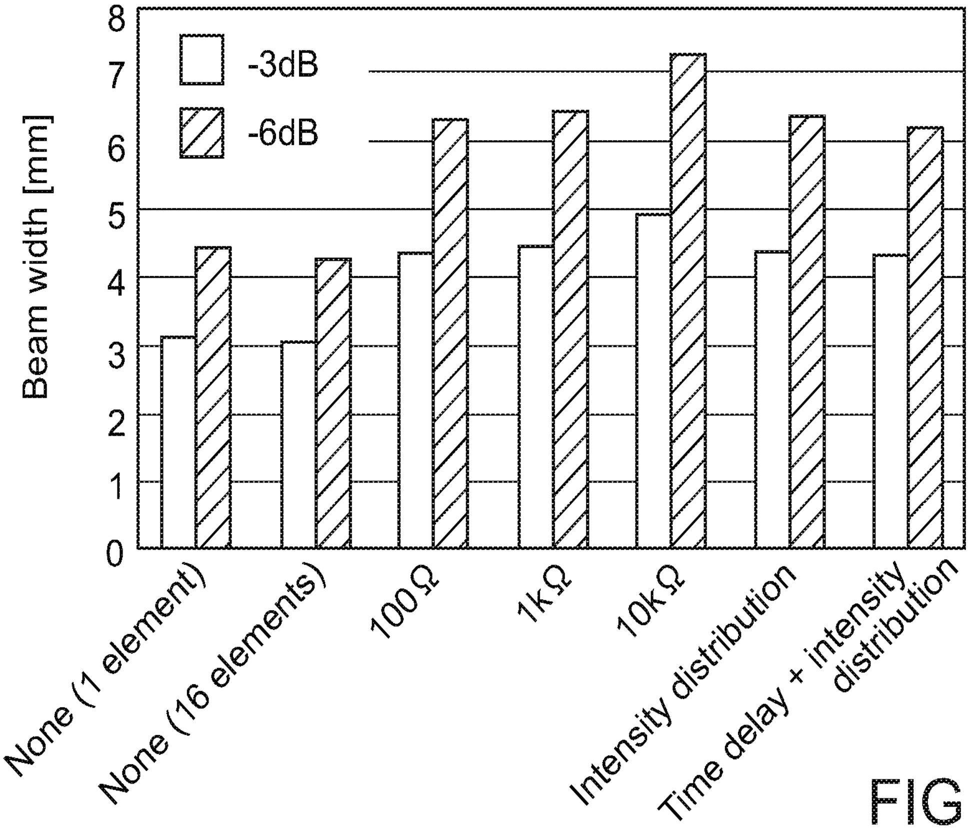
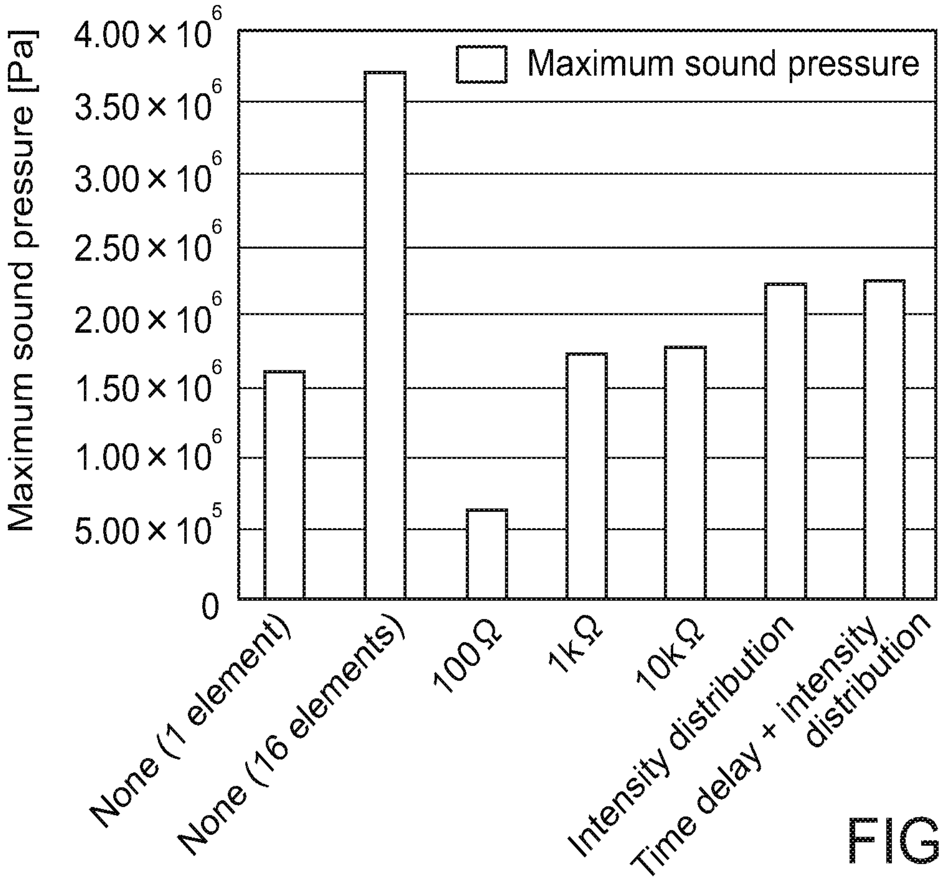

0
-10
-20
-30
-40
-50
-20
-10
0
10
20
A
A
Ultrasonic wave intensity [dB]
Distance [mm]
None (1 element)
None (16 elements)
100 Ω
1k Ω
10k Ω
Intensity distribution
Time delay + intensity distribution

FIG.28



Beam width [mm]
-3dB
-6dB
0
1
2
3
4
5
6
7
8
None (1 element)
None (16 elements)
100Ω
1kΩ
10kΩ
Intensity distribution
Time delay + intensity distribution

FIG.29



Maximum sound pressure [Pa]
Maximum sound pressure
0
5.00×10^5
1.00×10^6
1.50×10^6
2.00×10^6
2.50×10^6
3.00×10^6
3.50×10^6
4.00×10^6
None (1 element)
None (16 elements)
100Ω
1kΩ
10kΩ
Intensity distribution
Time delay + intensity distribution

FIG.30

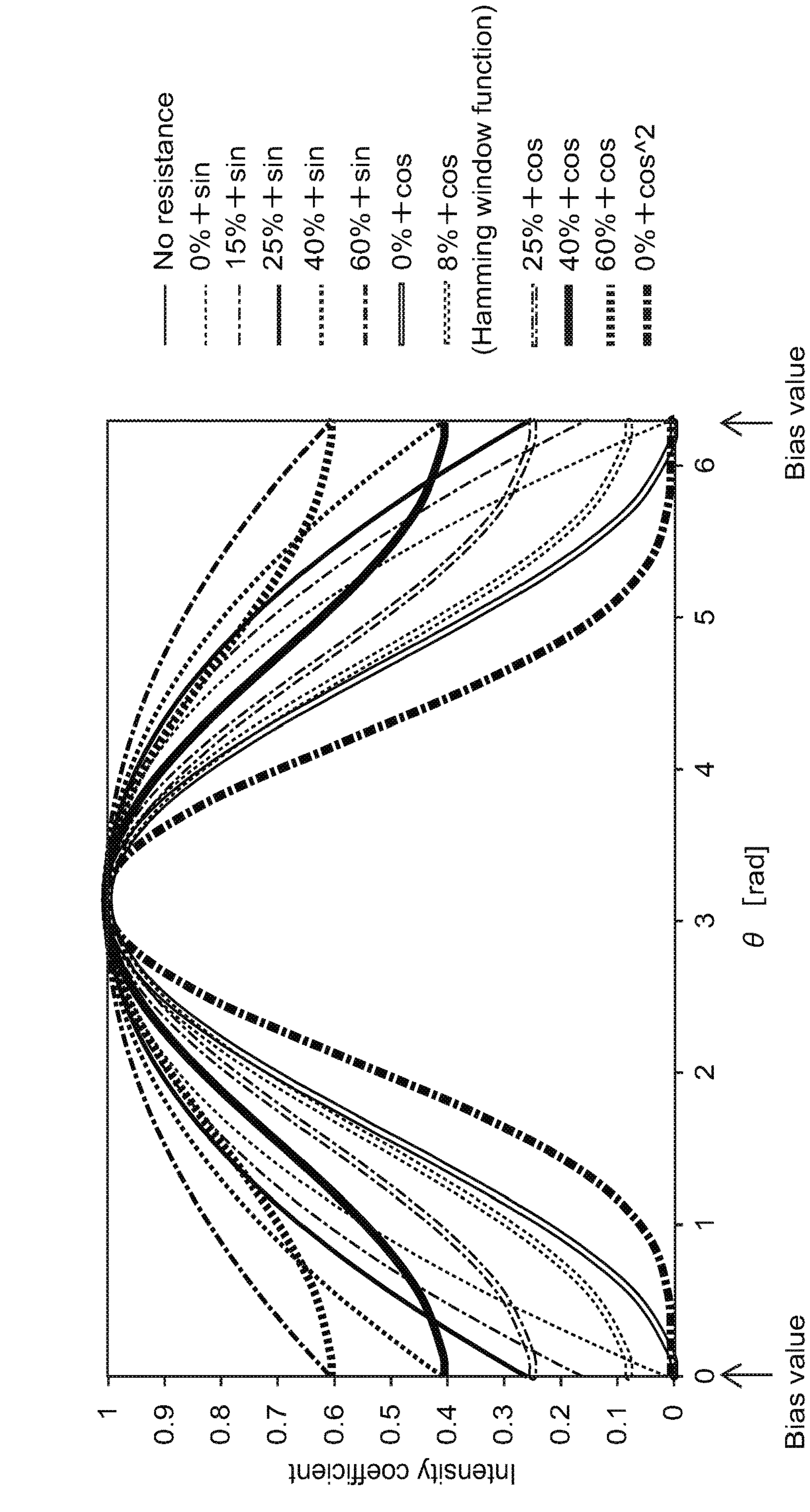

Intensity coefficient
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
θ [rad]
Bias value
Bias value
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
(Hamming window function)
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.31

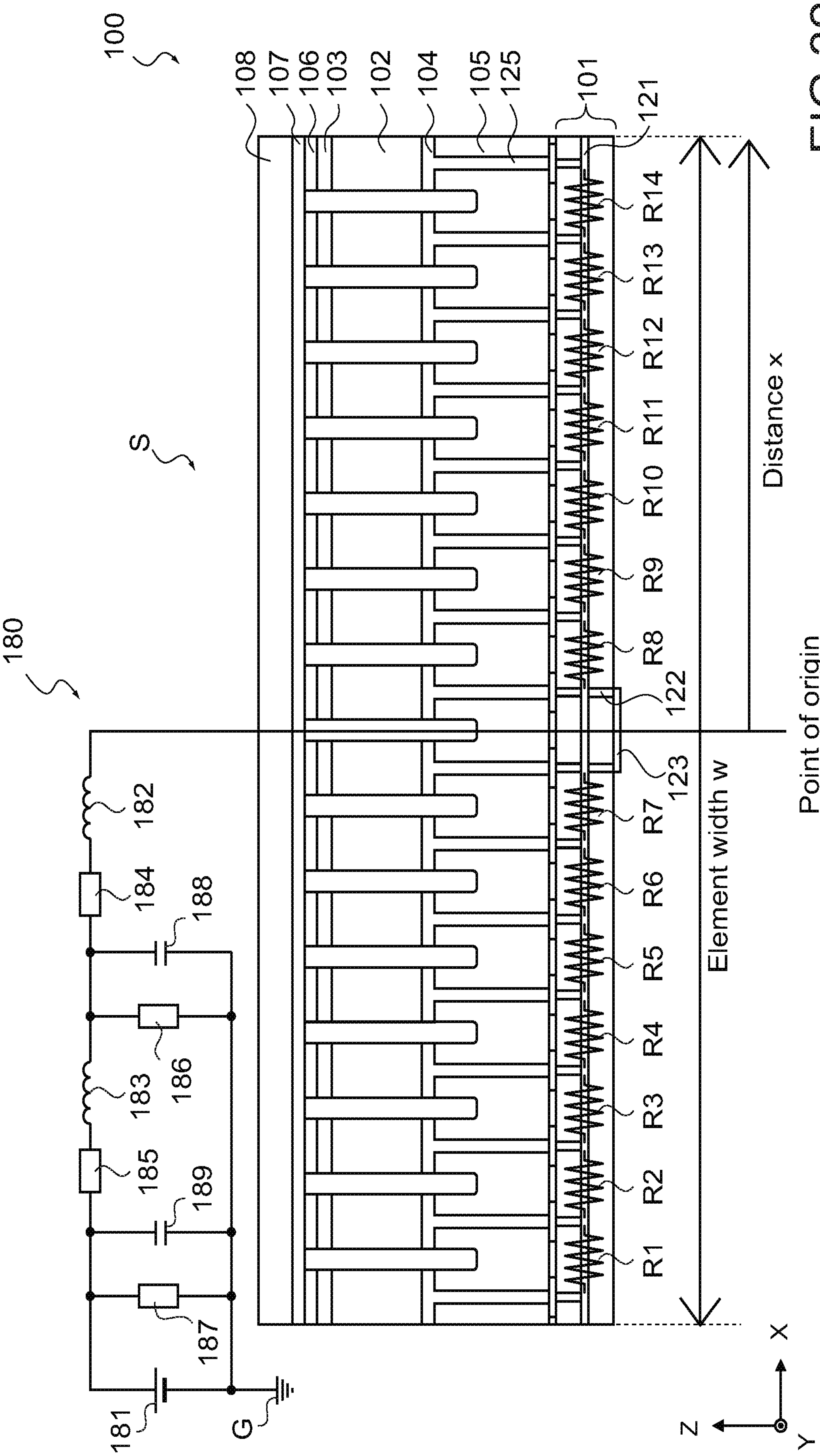

100
S
180
108
107
106
103
102
104
105
125
101
121
122
123
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
181
182
183
184
185
186
187
188
189
G
Element width w
Distance x
Point of origin
X
Y
Z

FIG.32

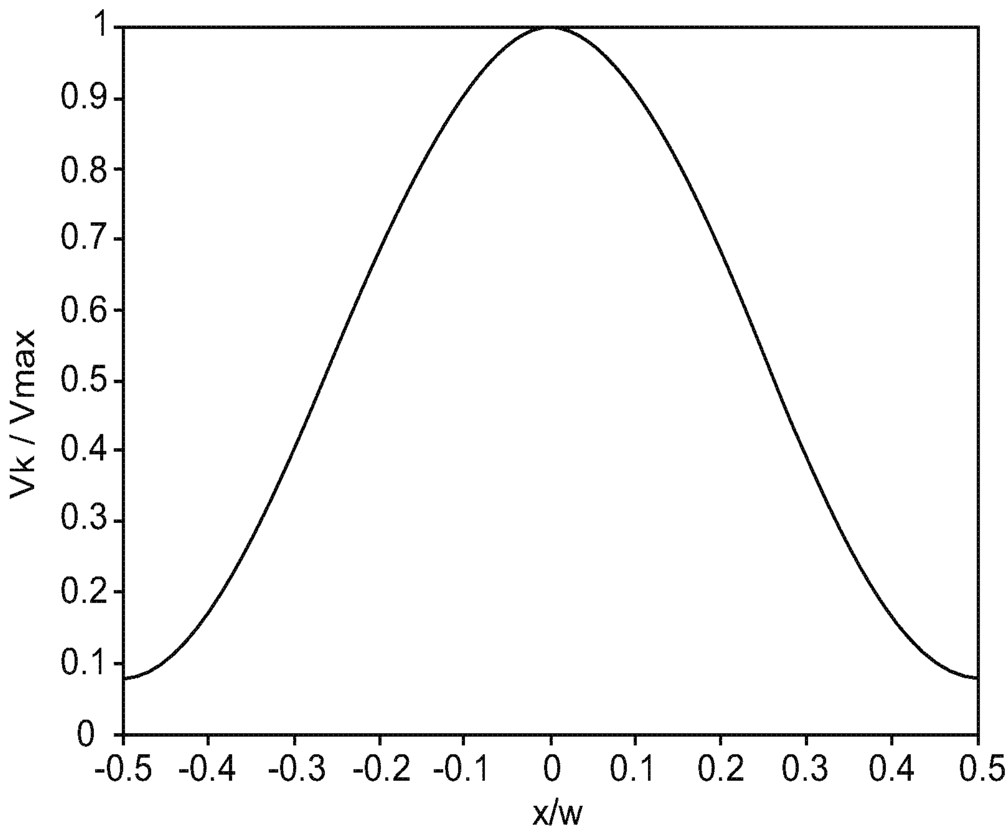
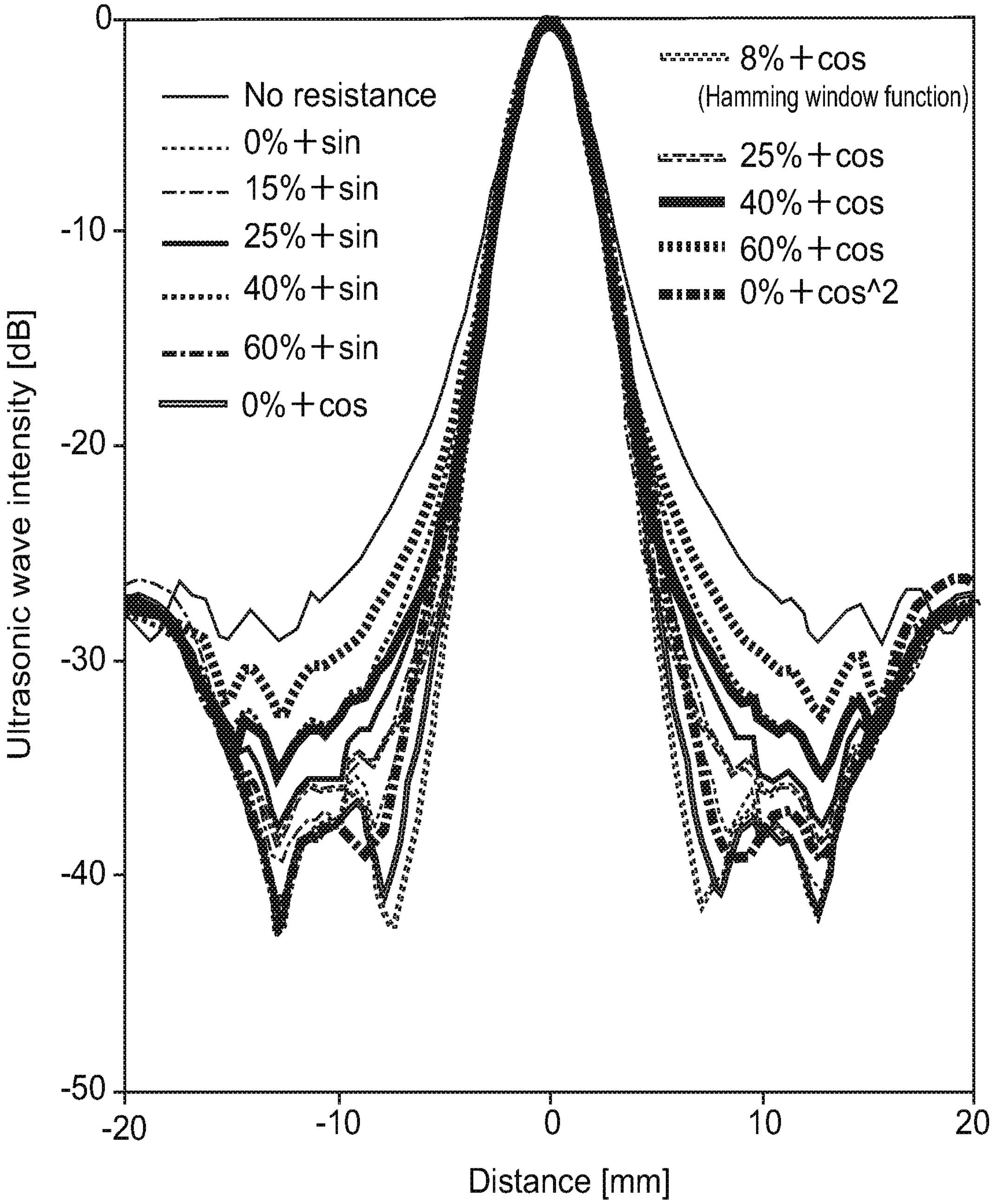


FIG.33



0
-10
-20
-30
-40
-50
Ultrasonic wave intensity [dB]
-20
-10
0
10
20
Distance [mm]
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
(Hamming window function)
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.34

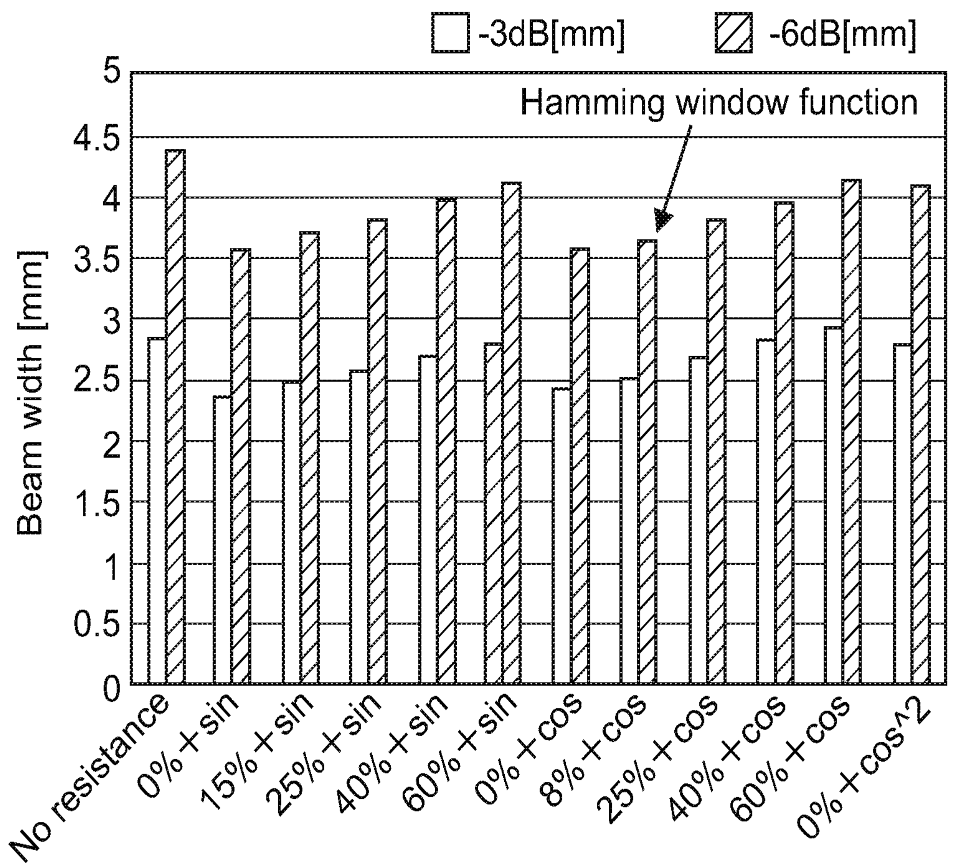

-3dB[mm]
-6dB[mm]
Hamming window function
Beam width [mm]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.35

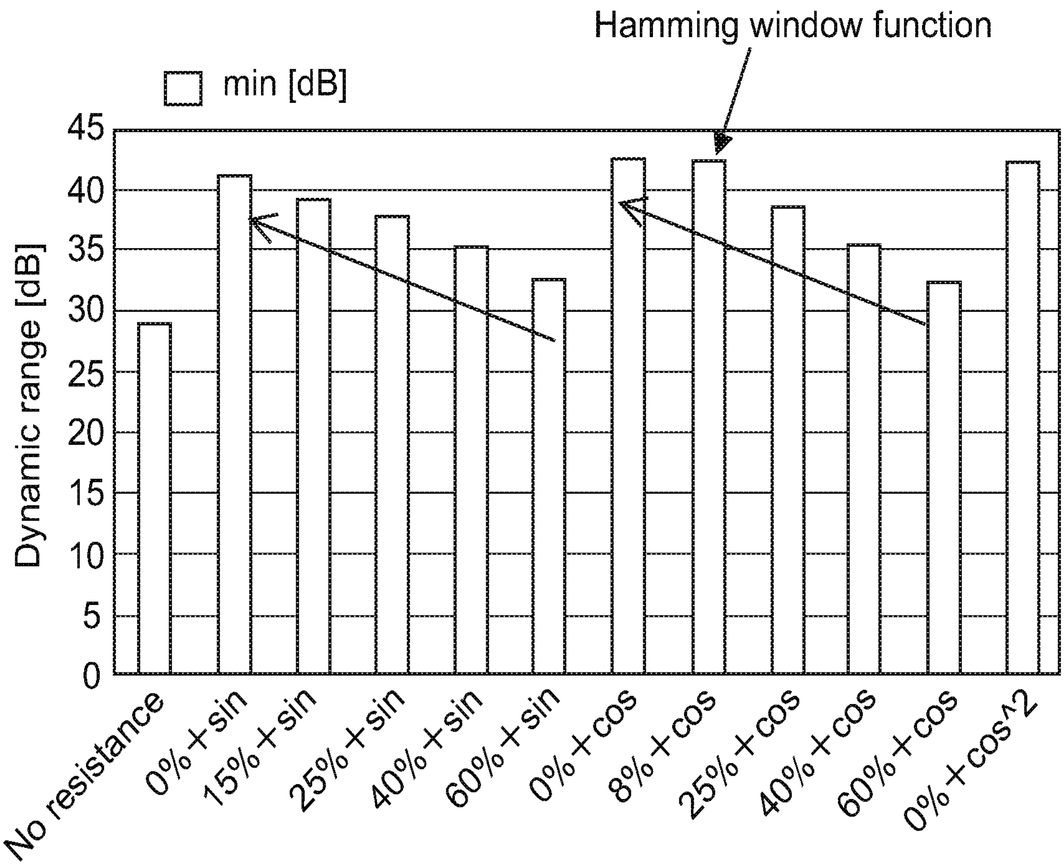
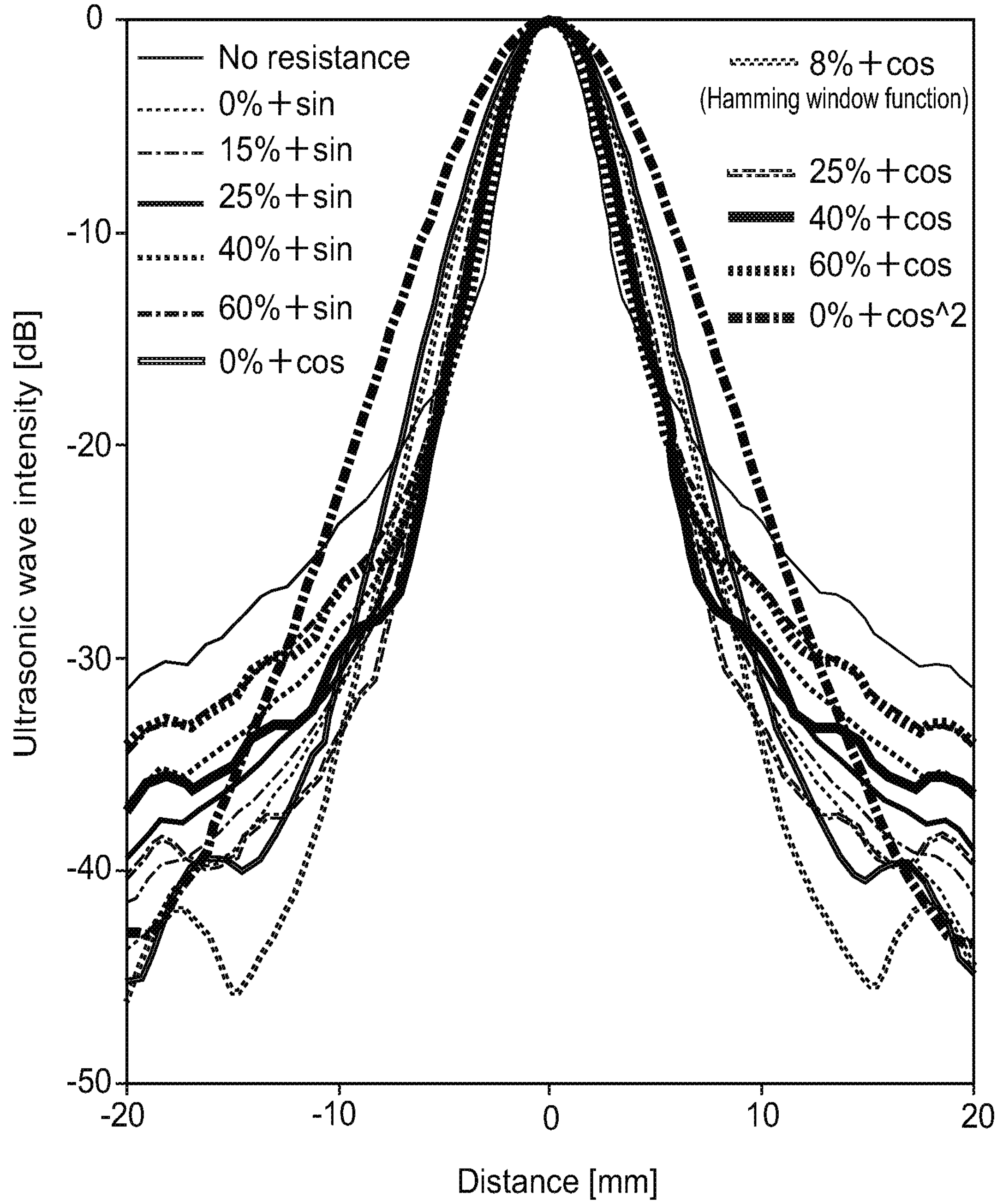

Hamming window function
min [dB]
Dynamic range [dB]
45
40
35
30
25
20
15
10
5
0
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.36



0
-10
-20
-30
-40
-50
-20
-10
0
10
20
Ultrasonic wave intensity [dB]
Distance [mm]
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
(Hamming window function)
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.37

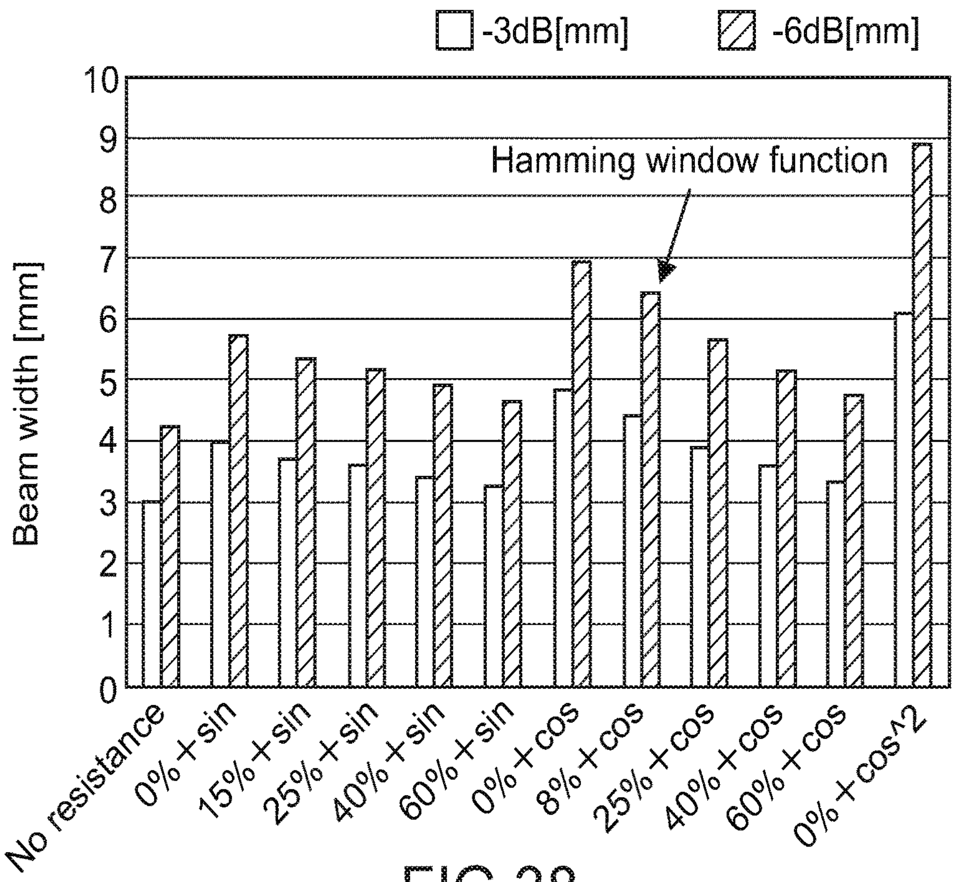

-3dB[mm]
-6dB[mm]
Hamming window function
Beam width [mm]
0
1
2
3
4
5
6
7
8
9
10
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.38

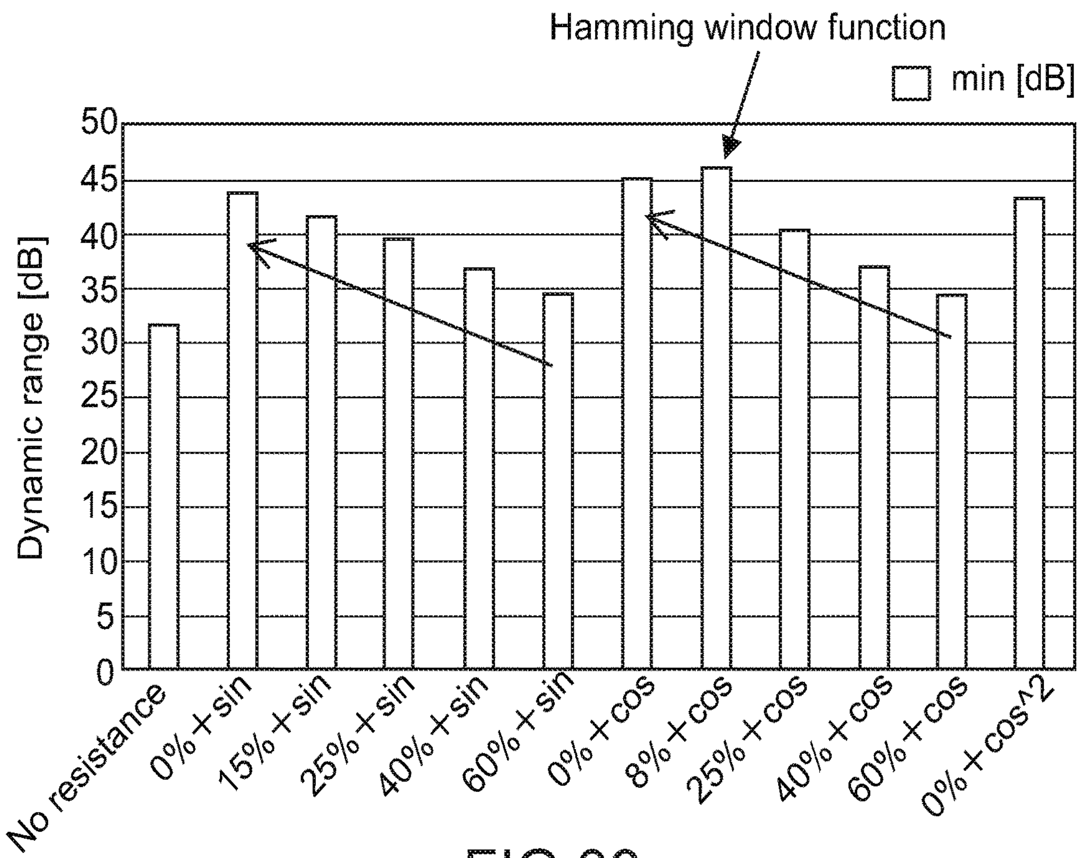

Hamming window function
min [dB]
Dynamic range [dB]
0
5
10
15
20
25
30
35
40
45
50
No resistance
0%+sin
15%+sin
25%+sin
40%+sin
60%+sin
0%+cos
8%+cos
25%+cos
40%+cos
60%+cos
0%+cos^2

FIG.39

ARRAY-TYPE ULTRASONIC VIBRATOR, ULTRASONIC PROBE, ULTRASONIC CATHETER, HAND-HELD SURGICAL INSTRUMENT, AND MEDICAL APPARATUS

TECHNICAL FIELD

[0001] The present technology relates to an array-type ultrasonic vibrator, an ultrasonic probe, an ultrasonic catheter, a hand-held surgical instrument, and a medical apparatus, which can be used for generating an ultrasonic diagnosis image.

BACKGROUND ART

[0002] In ultrasonic imaging for the use in the medical field and the like, an ultrasonic probe including an ultrasonic vibrator array radiates an ultrasonic wave to an object to be observed. The ultrasonic probe detects a reflected wave thereof. An ultrasonic image of the object to be observed is thus generated. The ultrasonic imaging makes a biological tissue visible from outside. The ultrasonic imaging is suitable for grasping a blood stream and the position and shape of a tumor or finding a nerve associated with a blood vessel, for example.

[0003] An ultrasonic beam width in a slice direction (depth direction of the ultrasonic image) in the ultrasonic imaging acts on slice resolution and contrast. Therefore, in recent years, reduction of this beam width has been developed. For example, in a one-dimensional array in which ultrasonic vibrators are arranged in one row, the beam width in the slice direction can be made narrower by focusing an ultrasonic beam through an acoustic lens.

[0004] On the other hand, in a two-dimensional array in which the ultrasonic vibrators are arranged in a flat state, technologies such as apodization and phase adjustment are used for improving a focusing property of the ultrasonic beam in the slice direction. The apodization is a technology of reducing the outputs of the vibrators at the ends of the two-dimensional array. In the apodization, the focusing property of the beam is improved by reducing components of side lobes (ultrasonic waves travelling in a direction deviated from a main radiation direction). Further, in the phase adjustment, the focusing property of the beam is improved by voluntarily adjusting a phase difference between the vibrators (e.g., Patent Literature 1).

[0005] In addition, there is also well known a structure called Hanafy lens. In this structure, the focusing property of the beam is improved by making the thickness of the vibrators different to thereby form the entire two-dimensional array in the lens-like shape.

CITATION LIST

Patent Literature

[0006] Patent Literature 1: Japanese Patent Application Laid-open No. 2014-097157

DISCLOSURE OF INVENTION

Technical Problem

[0007] However, in order to realize the above-mentioned apodization and phase adjustment, it is necessary to individually control the output of each of the ultrasonic vibrators, and the number of wirings to be connected to the respective vibrator increases. Therefore, the manufacture complication and the manufacture cost increase. Further, it becomes necessary to introduce a multiplexer and the like into the ultrasonic probe, and the structure of the ultrasonic probe is complicated.

[0008] Also in a case where the Hanafy lens structure is formed, it becomes necessary to machine the vibrators. In particular, in a case where the vibrators are thin, it is difficult to make the thickness of the vibrators different and it is not easy to cause the vibrators to have a higher frequency and a smaller height.

[0009] In view of the above-mentioned circumstances, it is an object of the present technology to provide an array-type ultrasonic vibrator, which is excellent in productivity and practicability and has a two-dimensional array structure capable of improving a focusing property of an ultrasonic beam in a slice direction, an ultrasonic probe, an ultrasonic catheter, a hand-held surgical instrument, and a medical apparatus.

Solution to Problem

[0010] In order to accomplish the above-mentioned object, an array-type ultrasonic vibrator according to an embodiment of the present technology includes a vibrator array and a resistor.

[0011] The vibrator array is a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction.

[0012] The resistor is electrically connected between a pair of arbitrary ultrasonic vibrator elements in the element row.

[0013] In accordance with this configuration, when the wiring connected to the element row is supplied with a driving signal of the ultrasonic vibrator element, the driving signal is attenuated by the resistor and the intensity of the driving signal supplied to the ultrasonic vibrator element at the end portion of the element row is thus lowered, and the output of the ultrasonic wave radiated from the ultrasonic vibrator element at the end portion of the element row becomes smaller (apodization). In this manner, the beam width of the ultrasonic beam in the slice direction can be reduced, and the slice resolution and contrast of the ultrasonic diagnosis image can be enhanced. Further, it is only necessary to connect the single wiring to the single element row and it is unnecessary to connect the wiring to each of the ultrasonic vibrator elements. Therefore, the number of wirings can be greatly reduced.

[0014] The resistor may be electrically connected between all ultrasonic vibration elements in the element row.

[0015] By the resistor being arranged between all the ultrasonic vibration elements, the outputs of the ultrasonic waves radiated from the respective ultrasonic vibrator elements that constitute the element row can be made slightly different from one another.

[0016] The array-type ultrasonic vibrator may further include a grounding resistor connected between an ultrasonic vibration element at an end of the element row and a ground.

[0017] By providing the grounding resistor, an escape path for electric charges can be ensured at the end portion of the element row and electric charges can be prevented from being accumulated at that end portion.

[0018] The vibrator array may include a substrate that supports the ultrasonic vibrator elements, and the resistor may be implemented on a surface of the substrate or inside the substrate.

[0019] In accordance with this configuration, the vibrator array and the resistor can be configured integrally with each other, and the size and height of the array-type ultrasonic vibrator can be reduced.

[0020] The ultrasonic vibrator elements may be connected to a wiring for driving the ultrasonic vibrator elements in each of the element rows.

[0021] In accordance with this configuration, the outputs of the ultrasonic waves emitted from the ultrasonic elements in each element row can be adjusted. It should be noted that the outputs of the ultrasonic waves emitted from the ultrasonic elements are adjusted by the resistor in each element row.

[0022] In order to accomplish the above-mentioned object, an ultrasonic catheter according to an embodiment of the present technology includes an array-type ultrasonic vibrator.

[0023] The array-type ultrasonic vibrator includes a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0024] In order to accomplish the above-mentioned object, a hand-held instrument according to an embodiment of the present technology includes an array-type ultrasonic vibrator.

[0025] The array-type ultrasonic vibrator includes a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0026] In order to accomplish the above-mentioned object, a medical apparatus according to an embodiment of the present technology includes an array-type ultrasonic vibrator and a position sensor.

[0027] The array-type ultrasonic vibrator includes a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0028] The position sensor detects a position of the array-type ultrasonic vibrator.

[0029] In the medical apparatus, an ultrasonic volume image may be generated on the basis of outputs of the array-type ultrasonic vibrator and the position sensor.

[0030] In the array-type ultrasonic vibrator, in each of the element rows, a total resistance value of the resistor and the grounding resistor may be larger than a resistance value of a signal wiring that connects the ultrasonic vibrator element to a driving power supply.

[0031] By setting the total resistance value of the resistor and the grounding resistor to be larger than the resistance value of the signal wiring, a voltage drop in each vibrator element can be reduced.

[0032] In the array-type ultrasonic vibrator, in each of the element rows, provided that a frequency of a driving voltage of the ultrasonic vibrator element is f [Hz], a product of a total resistance value of the resistor and a total value of capacitance of the ultrasonic vibrator elements may be smaller than ½ f.

[0033] By setting the product of the total resistance value of the resistor and the total value of capacitance of the ultrasonic vibrator elements to be smaller than ½ f, an RC delay (phase offset) of the ultrasonic wave emitted from each ultrasonic vibrator element can be prevented.

[0034] In the array-type ultrasonic vibrator, in each of the element rows, a resistance value of the grounding resistor may be smaller than a total resistance value of the resistor.

[0035] By setting the resistance value of the grounding resistor to be smaller than the total resistance value of the resistor, the dynamic range of the ultrasonic waves in the element row can be made larger.

Advantageous Effects of Invention

[0036] As described above, in accordance with the present technology, it is possible to provide an array-type ultrasonic vibrator, which is excellent in productivity and practicability and has a two-dimensional array structure capable of improving a focusing property of an ultrasonic beam in a slice direction, an ultrasonic probe, an ultrasonic catheter, a hand-held surgical instrument, and a medical apparatus. It should be noted that the effects described here are not necessarily limitative and any effect described in the present disclosure may be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0037] FIG. **1** A perspective view of an array-type ultrasonic vibrator according to an embodiment of the present technology.

[0038] FIG. **2** A perspective view of a partial configuration of the array-type ultrasonic vibrator.

[0039] FIG. **3** A plan view of vibrator elements of the array-type ultrasonic vibrator.

[0040] FIG. **4** A cross-sectional view of the array-type ultrasonic vibrator.

[0041] FIG. **5** A schematic diagram showing an array of the vibrator elements of the array-type ultrasonic vibrator.

[0042] FIG. **6** A schematic diagram showing an electric connection relationship of an element row of the array-type ultrasonic vibrator.

[0043] FIG. **7** A schematic diagram showing an operation of the element row of the array-type ultrasonic vibrator.

[0044] FIG. **8** A schematic diagram showing resistors of the array-type ultrasonic vibrator.

[0045] FIG. **9** A schematic diagram showing independent wirings of the array-type ultrasonic vibrator.

[0046] FIG. **10** A schematic diagram showing an electric connection relationship of the element row of the array-type ultrasonic vibrator.

[0047] FIG. **11** A schematic diagram showing an electric connection relationship of the element row of the array-type ultrasonic vibrator.

[0048] FIG. **12** A cross-sectional view of an ultrasonic probe of the array-type ultrasonic vibrator.

[0049] FIG. **13** A cross-sectional view of the ultrasonic probe of the array-type ultrasonic vibrator.

[0050] FIG. **14** A graph showing a beam profile of the ultrasonic probe of the array-type ultrasonic vibrator.

[0051] FIG. **15** A schematic diagram of an ultrasonic catheter including the array-type ultrasonic vibrator according to the embodiment of the present technology.

[0052] FIG. **16** A graph showing a beam profile of the ultrasonic catheter of the array-type ultrasonic vibrator.

[0053] FIG. **17** A schematic diagram of a surgical instrument of the array-type ultrasonic vibrator according to the embodiment of the present technology.

[0054] FIG. **18** A schematic diagram showing an electric circuit configuration of each element array of the array-type ultrasonic vibrator according to the embodiment of the present technology.

[0055] FIG. **19** A graph showing percentage of resistance values of resistors **133** and a grounding resistor in the array-type ultrasonic vibrator.

[0056] FIG. **20** A graph showing simulation results of a voltage time history waveform with each of the vibrator elements in the element row of the array-type ultrasonic vibrator.

[0057] FIG. **21** A graph showing simulation results of the voltage time history waveform with each of the vibrator elements in the element row of the array-type ultrasonic vibrator.

[0058] FIG. **22** A graph showing simulation results of the voltage time history waveform with each of the vibrator elements in the element row of the array-type ultrasonic vibrator.

[0059] FIG. **23** A graph showing simulation results of the voltage time history waveform with each of the vibrator elements in the element row of the array-type ultrasonic vibrator.

[0060] FIG. **24** A graph showing simulation results of the voltage time history waveform with each of the vibrator elements in the element row of the array-type ultrasonic vibrator.

[0061] FIG. **25** Simulation results of a sound pressure beam profile of the array-type ultrasonic vibrator (opening width: 5 mm).

[0062] FIG. **26** A graph showing a beam width with the sound pressure beam profile shown in FIG. **25**.

[0063] FIG. **27** A graph showing a dynamic range with the sound pressure beam profile shown in FIG. **25**.

[0064] FIG. **28** Simulation results of a sound pressure beam profile of the array-type ultrasonic vibrator (opening width: 2 mm).

[0065] FIG. **29** A graph showing a beam width with the sound pressure beam profile shown in FIG. **28**.

[0066] FIG. **30** A graph showing a dynamic range with the sound pressure beam profile shown in FIG. **28**.

[0067] FIG. **31** A graph showing an apodization intensity distribution in the element row of the array-type ultrasonic vibrator.

[0068] FIG. **32** A schematic diagram showing a structure of the array-type ultrasonic vibrator.

[0069] FIG. **33** A graph showing a hamming window function.

[0070] FIG. **34** Simulation results of a sound pressure beam profile of the array-type ultrasonic vibrator (opening width: 5 mm).

[0071] FIG. **35** A graph showing a beam width with the sound pressure beam profile shown in FIG. **34**.

[0072] FIG. **36** A graph showing a dynamic range with the sound pressure beam profile shown in FIG. **34**.

[0073] FIG. **37** Simulation results of a sound pressure beam profile of the array-type ultrasonic vibrator (opening width: 2 mm).

[0074] FIG. **38** A graph showing a beam width with the sound pressure beam profile shown in FIG. **37**.

[0075] FIG. **39** A graph showing a dynamic range with the sound pressure beam profile shown in FIG. **37**.

MODE(S) FOR CARRYING OUT THE INVENTION

[0076] An array-type ultrasonic vibrator according to this embodiment will be described.

[Configuration of Array-Type Ultrasonic Vibrator]

[0077] FIG. **1** is a perspective view of an array-type ultrasonic vibrator **100** according to this embodiment. FIG. **2** is a perspective view of a partial configuration of the array-type ultrasonic vibrator **100**. FIG. **3** is a plan view of a partial configuration of the array-type ultrasonic vibrator **100**. FIG. **4** is a cross-sectional view of the array-type ultrasonic vibrator **100**, which is a cross-sectional view taken along the A-A line of FIG. **3**. In each figure, three directions orthogonal to one another are denoted by an X direction, a Y direction, and a Z direction.

[0078] As shown in FIG. **4**, the array-type ultrasonic vibrator **100** includes a substrate **101**, piezoelectric layers **102**, upper electrode layers **103**, lower electrode layers **104**, backing layers **105**, acoustic matching lenses **106**, an acoustic matching lens **107**, and an acoustic lens **108**.

[0079] The piezoelectric layers **102**, the upper electrode layers **103**, the acoustic matching lenses **106**, the lower electrode layers **104**, and the backing layers **105** are partially separated from each other, each of which constitutes vibrator elements **150**. That is, the array-type ultrasonic vibrator **100** is an array of the vibrator elements **150**. It should be noted that although the number of vibrator elements **150** are different between FIGS. **2** and **3**, illustration of a predetermined number of vibrator elements **150** is omitted in FIG. **2**.

[0080] The substrate **101** is a wiring board such as a rigid printed board and a flexible printed circuits (FPC) board including glass epoxy and the like. The substrate **101** supports and electrically connects the vibrator elements **150**. The substrate **101** is provided with a substrate built-in resistor **121**, wirings **122**, an independent wiring **123**, and a pad **124**.

[0081] The pad **124** is provided on the surface of the substrate **101** and each of the vibrator elements **150** is electrically connected thereto. The wirings **122** electrically connect the pad **124** to the substrate built-in resistor **121**. Each of the vibrator elements **150** is connected to the substrate built-in resistor **121** via the wirings **122** and the pad **124**. The independent wiring **123** is electrically connected to the substrate built-in resistor **121**. Electric connection of each of the vibrator elements **150** will be described later.

[0082] The piezoelectric layers **102** include a piezoelectric material such as lead zirconate titanate (PZT). The piezoelectric layers **102** are provided between the lower electrode layers **104** and the upper electrode layers **103**. When a voltage is applied between the lower electrode layers **104** and the upper electrode layers **103**, vibrations due to an inverse piezoelectric effect are generated and ultrasonic waves are generated. Further, when reflected waves from an object to be diagnosed enters the piezoelectric layers **102**, polarization due to the piezoelectric effect occurs. Although the size of the piezoelectric layer **102** is not particularly limited, 250 μm square, for example, can be set.

[0083] The upper electrode layers **103** are provided on the piezoelectric layers **102**. The upper electrode layers **103** include an electrically conductive material. The upper electrode layers **103** are metal films deposited by plating, sputtering, or the like, for example. It should be noted that the upper electrode layers **103** may be separated for each of the vibrator elements **150** as shown in FIG. **4** and do not need to be separated.

[0084] The lower electrode layers **104** are provided on the backing layers **105**. The lower electrode layers **104** include an electrically conductive material. The lower electrode layers **104** are metal films deposited by plating, sputtering, or the like, for example. The lower electrode layers **104** are electrically connected to the substrate **101** via wirings **125**.

[0085] The backing layers **105** are provided on the substrate **101** and absorb unnecessary vibrations of the vibrator elements **150**. The backing layers **105** generally include a material in which a filler and a synthetic resin are mixed and the like. In the backing layers **105**, the wirings **125** that connect the lower electrode layers **104** to the pad **124** are provided.

[0086] The acoustic matching lenses **106** and the acoustic matching lens **107** reduce an acoustic impedance difference between the object to be diagnosed and the vibrator elements **150** and prevent reflection of ultrasonic waves from being reflected to the object to be diagnosed. The acoustic matching lenses **106** include a synthetic resin and a ceramic material. As shown in FIG. **4**, the acoustic matching lenses **106** can be separated for each of the vibrator elements **150** and the acoustic matching lens **107** can be set not to be separated, though not limited thereto.

[0087] The acoustic lens **108** is brought into contact with the object to be diagnosed. The acoustic lens **108** focuses ultrasonic waves generated in the piezoelectric layers **102**. The acoustic lens **108** includes a silicone rubber and the like, for example, and the size and shape thereof are not particularly limited.

[Regarding Array of Vibrator Elements]

[0088] As shown in FIGS. **2** and **3**, the vibrator elements **150** are arranged in two directions of the X direction and the Y direction as viewed in a thickness direction (Z direction) of the vibrator elements **150**.

[0089] A shorter side direction (X direction) of the array-type ultrasonic vibrator **100** will be referred to as a slice direction (or elevation direction) and the resolution in that direction is equivalent to a resolution in a depth direction in the ultrasonic diagnosis image. The number of vibrator elements **150** in the slice direction is not particularly limited and only needs to be plural.

[0090] A longer side direction (Y direction) of the array-type ultrasonic vibrator **100** will be referred to as an azimuth direction and the resolution in that direction is equivalent to a resolution of an azimuth-based direction in the ultrasonic diagnosis image. The number of vibrator elements **150** in the azimuth direction is not particularly limited and only needs to be plural.

[0091] It should be noted that a resolution in the thickness direction (Z direction) of the vibrator elements **150** is equivalent to a resolution in the distance direction in the ultrasonic diagnosis image.

[0092] The beam width of the ultrasonic beam in the slice direction acts on the slice resolution and contrast of the ultrasonic diagnosis image. Therefore, it is favorable that this beam width is smaller. In a one-dimensional array-type ultrasonic vibrators in which vibrator elements are arranged in one row in the azimuth direction, the beam width in the slice direction can be reduced by using an acoustic lens.

[0093] On the other hand, in a two-dimensional array-type ultrasonic vibrator in which a plurality of vibrator elements are arranged also in the slice direction like the array-type ultrasonic vibrator **100**, it is difficult to sufficiently reduce the beam width in the slice direction by using only the acoustic lens. Therefore, in general, keeping the outputs of the vibrator elements at array end portions small (apodization) or reducing the beam width in the slice direction by adjusting a phase difference of ultrasonic vibrations of the vibrator elements are performed.

[0094] That apodization or phase adjustment can be realized by providing a wiring in the electrodes (corresponding to the upper electrode layer **103** and the lower electrode layer **104** in this embodiment) for each vibrator element and controlling the voltage and phase for each vibrator element. However, in a case where wirings are provided in all the individual vibrator elements, the number of wirings extending from the array-type ultrasonic vibrator increases, which results in complication of manufacturing processes and an increase in cost. In addition, a processor (multiplexer and the like) for controlling vibrations of each of the vibrator elements needs to be installed near the array-type ultrasonic vibrator, and it is difficult to utilize it in a case where the ultrasonic probe has a limited inner space, for example.

[0095] In contrast, in the array-type ultrasonic vibrator **100** according to this embodiment, the wirings are provided in a manner shown below. Beam focusing in the slice direction is realized while avoiding the problem as described above.

[Regarding Wiring of Vibrator Element]

[0096] FIG. **5** is a schematic diagram showing an array of the vibrator elements **150** in the array-type ultrasonic vibrator **100**. As shown in the figure, it is assumed that a row of the vibrator elements **150** in the slice direction (X direction) is an element row S. The array-type ultrasonic vibrator **100** is constituted by a plurality of element rows S. The number of vibrator elements **150** and the number of element rows S which constitute the element rows S are not particularly limited and both need to be plural.

[0097] FIG. **6** is a schematic diagram showing an electric connection relationship of one of the element rows S. In the figure, the piezoelectric layers **102**, the upper electrode layers **103**, and the lower electrode layers **104** are schematically shown with respect to the respective vibrator elements **150**.

[0098] As shown in the figure, the upper electrode layers **103** are connected to each other via a wiring **131** and are connected to a ground G. Further, the lower electrode layers **104** are connected to each other via a wiring **132** and are connected to the independent wiring **123**. Resistors **133** are electrically connected between the vibrator elements **150** that constitute the element row S. It should be noted that the wiring **132** is realized by the wirings **125**, the pad **124**, and the wirings **122** in FIG. **4** and the resistors **133** are realized by the substrate built-in resistor **121**. It should be noted that the resistance values of the respective resistors **133** may be identical to one another or may be different from one another. For example, the resistance values of the respective resistors **133** may be configured to be gradually higher from a center portion to end portions of the element row S.

[0099] The plurality of element rows S that constitute the array-type ultrasonic vibrator **100** each have the configuration shown in FIG. **6** and are not electrically connected between the element rows S. Therefore, in the array-type ultrasonic vibrator **100**, the single independent wiring **123** is connected to each of the element rows S.

[0100] By providing the wirings in the vibrator elements **150** in the above-mentioned manner, the driving signal is supplied from the independent wiring **123** for each element row S and vibrations of the piezoelectric layers **102** are controlled for each element row S in the array-type ultrasonic vibrator **100**.

[0101] FIG. **7** is a schematic diagram showing an output of an ultrasonic wave radiated from the vibrator elements **150** in the array-type ultrasonic vibrator **100**. In the figure, the magnitude of the output of the ultrasonic wave radiated from the vibrator element is indicated by the length of the arrow.

[0102] In each of the element rows S, a driving signal supplied from the independent wiring **123** is supplied to the vibrator elements **150** connected via the resistors **133** while the driving signal is being attenuated by the resistors **133**. In this manner, as shown in FIG. **7**, the output of the ultrasonic wave generated in the piezoelectric layers **102** becomes smaller with respect to the vibrator elements **150** closer to the end portions of each element row S.

[0103] As described above, the output of the ultrasonic wave is smaller at the end portions of each of the element rows S of the array-type ultrasonic vibrator **100**. Therefore, the apodization is realized and the beam width in the slice direction is reduced.

[0104] Further, the independent wiring **123** is connected to each of the element rows S. Therefore, ultrasonic vibrations can be controlled in accordance with the driving signal in each element row S. That is, with respect to the azimuth direction, the apodization and the phase control can be realized in accordance with the driving signal.

[0105] As described above, in the array-type ultrasonic vibrator **100**, with respect to the azimuth direction, the output of the ultrasonic wave can be adjusted in accordance with the driving signal for each element row S. With respect to the slice direction, the output of the ultrasonic wave is passively adjusted by the resistors **133**. The wiring required in the array-type ultrasonic vibrator **100** is a single wiring for the single element rows S. Therefore, the number of wirings can be greatly reduced as compared to a case where the wiring is provided in each of the vibrator elements **150**.

[0106] It should be noted that substantially a low pass filter is formed by the resistors **133** between the respective vibrator elements **150**. However, a phase offset generated in each element row S can be reduced by being used at a cut-off frequency or less of the low pass filter.

[Specific Structure of Wiring of Vibrator Element]

[0107] In the array-type ultrasonic vibrator **100**, one capable of realizing the connection relationship as shown in FIG. **6** only needs to be provided and a specific structure is not particularly limited. However, as shown in FIG. **4**, it is favorable to utilize the substrate built-in resistor **121**.

[0108] FIG. **8** is a schematic diagram showing the substrate built-in resistors **121**. FIG. **8** shows the vibrator elements **150**, the substrate built-in resistors **121**, and the wirings **131**. The substrate built-in resistor **121** includes an electrically conductive material having a higher electric resistance. As shown in the figure, the substrate built-in resistor **121** is formed in such a shape that the width is gradually narrower toward the end portions of the element row S, that is, the electric resistance increases. The resistors **133** shown in FIG. **6** can be thus realized by the substrate built-in resistor **121**.

[0109] It should be noted that the substrate built-in resistor **121** can be formed by depositing a Ni film, a NiCr film, a Ni—P element, a NiCrAlSi film, or the like by plating or sputtering and patterning it.

[0110] It should be noted that the resistors **133** can also be realized by utilizing an element other than the substrate built-in resistor **121** and, for example, a resistor compatible for a small-height embedded passive device (EPD) can also be utilized.

[0111] FIG. **9** is a schematic diagram showing the independent wirings **123**. FIG. **9** shows the vibrator elements **150**, the independent wirings **123**, and the wirings **131**. As shown in the figure, the independent wiring **123** are provided to extend in the slice direction (X direction).

[Regarding Other Configurations of Array-Type Ultrasonic Vibrator]

[0112] The configuration of the array-type ultrasonic vibrator **100** is not limited to the above. FIGS. **10** and **11** are schematic diagrams showing array-type ultrasonic vibrators **100** having other configurations.

[0113] As shown in FIG. **10**, the resistors **133** do not need to be electrically connected between all the vibrator elements **150** and may be electrically connected between pairs of some of the vibrator elements **150**. Also in this structure, the output of the ultrasonic wave at the end portions of the element row S becomes smaller. Therefore, the apodization is realized and the beam width in the slice direction is reduced.

[0114] Further, as shown in FIG. **11**, the array-type ultrasonic vibrator **100** may include grounding resistors **134**. The grounding resistors **134** are electrically connected between the vibrator elements **150** positioned at both the ends of the element row S and the ground G.

[0115] In such a configuration, there is a fear that electric charges accumulated at the end portions of the element row S remain also after the driving signal is input. In contrast, by providing the grounding resistors **134**, it is possible to ensure an escape path for electric charges at the end portions of the element row S and to prevent electric charges from being accumulated at the end portions of the element row S.

[0116] It should be noted that if the resistance values of the grounding resistors **134** are too low, electric charges escape when the driving signal is input. On the other hand, if the resistance values of the grounding resistors **134** are too high, the provision of the grounding resistors **134** becomes a waste. Therefore, it is necessary to set a suitable resistance value. Further, the grounding resistors **134** may be provided with respect to the configuration in which the resistors **133** are provided between pairs of some of the vibrator elements **150**, which is shown in FIG. **10**.

[Application Example of Array-Type Ultrasonic Vibrator]

[0117] An application example of the array-type ultrasonic vibrator **100** according to this embodiment will be described.

[0118] FIGS. **12** and **13** each are a schematic diagram of an ultrasonic probe **11** including the array-type ultrasonic vibrator **100**. As shown in the figure, the ultrasonic probe **11** includes the array-type ultrasonic vibrator **100**, a casing **171** that houses the array-type ultrasonic vibrator **100**, and a wiring connection portion **172**. The independent wirings **123** are connected to the wiring connection portion **172**.

[0119] As described above, the array-type ultrasonic vibrator **100** only needs to connect the single independent wiring **123** to the single element row S. Therefore, the number of wirings can be greatly reduced as compared to a structure in which the wiring is provided in each of the vibrator elements **150**.

[0120] FIG. **14** is a graph showing simulation results of intensity of the ultrasonic wave radiated from the ultrasonic probe. FIG. **14** shows a beam profile at a measurement depth of 3.5 cm while the opening width of the ultrasonic probe in the slice direction (X direction) is set to 5 mm.

[0121] The “element row driving” in the figure indicates the intensity of the ultrasonic wave in a case where the apodization is carried out by utilizing the array-type ultrasonic vibrator **100** according to this embodiment. The “independent element driving” in the figure indicates the intensity of the ultrasonic wave in a case where the apodization is carried out by utilizing the array-type ultrasonic vibrator in which the wiring is connected to each of the vibrator elements. The “acoustic lens” in the figure indicates the intensity of the ultrasonic wave in a case where only the focusing effect by the acoustic lens is provided without utilizing the apodization.

[0122] In the “element row driving” according to this embodiment, side lobes (ultrasonic waves travelling in a direction deviated from a main radiation direction) are greatly reduced as compared to the “acoustic lens”, and a beam profile similar to that of the “independent element driving” is obtained.

[0123] Therefore, in the “element row driving”, an ultrasonic image excellent in the visibility can be generated having a dynamic range equivalent to that of the “independent element driving” while greatly reducing the number of wirings relative to the “independent element driving”.

[0124] FIG. **15** is a schematic diagram of an ultrasonic catheter **12** including the array-type ultrasonic vibrator **100**. The ultrasonic catheter **12** is an intracardiac ultrasonic catheter, for example. The ultrasonic catheter **12** includes a main body **12***a* and a catheter **12***b*. The array-type ultrasonic vibrator **100** is mounted on a distal end of the catheter **12***b*.

[0125] FIG. **16** is a graph showing simulation results of the intensity of the ultrasonic wave radiated from the ultrasonic catheter. FIG. **16** shows a beam profile in a case where the opening width of the ultrasonic probe in the slice direction (X direction) is set to 2 mm.

[0126] The “element row driving”, the “independent element driving”, and the “acoustic lens” have the same meanings as those described above. Also with the ultrasonic catheter, in the “element row driving”, the side lobes are greatly reduced as compared to the “acoustic lens”, and a beam profile similar to that of the “independent element driving” is obtained.

[0127] Further, regarding the ultrasonic catheter, it is necessary to bend and operate the catheter. Meanwhile, in the array-type ultrasonic vibrator in which the wiring is connected to each of the vibrator elements, the number of wirings inside the catheter increases, which becomes an obstacle to the operation. If the multiplexer and the like are mounted on the distal end portion of the catheter, the number of wirings inside the catheter can be reduced. However, it is not easy to do so because the mounting space of the distal end portion of the catheter is limited. Also in view of this, the array-type ultrasonic vibrator **100** which requires a smaller number of wirings is favorable.

[0128] FIG. **17** is a schematic diagram of a surgical instrument **13** including the array-type ultrasonic vibrator **100**. The surgical instrument **13** is an incision tool or forceps and has a distal end portion on which the array-type ultrasonic vibrator **100** is mounted. In a case where the array-type ultrasonic vibrator is mounted on the surgical instrument in this manner, the housing space is smaller and the opening diameter is also smaller. Therefore, the dynamic range is deteriorated.

[0129] In contrast, the array-type ultrasonic vibrator **100** according to this embodiment has a higher dynamic range as described above. Therefore, the image quality of the ultrasonic diagnosis can be improved.

[0130] Further, the array-type ultrasonic vibrator **100** can be mounted on the ultrasonic probe together with a position sensor. The position sensor is a sensor that acquires the position of the ultrasonic probe and can be a magnetic sensor, for example. With such a configuration, on the basis of a relationship between a two-dimensional ultrasonic diagnosis image generated by the array-type ultrasonic vibrator **100** and the position of the ultrasonic probe, which is output from the position sensor, a three-dimensional volume image can be generated (see Japanese Patent Application Laid-open No. 2008-178500).

[0131] As described above, the array-type ultrasonic vibrator **100** according to this embodiment is capable of generating an ultrasonic diagnosis image having a high contrast. Therefore, a three-dimensional volume image having a high contrast can be generated by mounting the array-type ultrasonic vibrator **100** together with the position sensor.

[Regarding Details of Resistance Value]

[0132] Details of the resistance values of the resistors **133** and the grounding resistors **134** in the array-type ultrasonic vibrator **100** including the resistors **133** and the grounding resistors **134**, which are shown in FIG. **11**, will be described.

[0133] FIG. **18** is a schematic diagram showing an electric circuit configuration of each of the element rows S of the array-type ultrasonic vibrator **100**. In the figure, capacitances formed by the respective vibrator elements **150** (see FIG. **11**) are denoted by C**1** to C**16**, resistances by the resistors **133** are denoted by R**1** to R**14**, and resistances by the grounding resistors **134** are denoted by Rg**1** and Rg**2**. It should be noted that the number of vibrator elements **150** and the number of resistors **133** are not limited to those shown in FIG. **18**.

[0134] FIG. **19** is a graph showing the percentage of the resistance values of the resistors **133** and the grounding resistors **134** and is a graph showing the percentage of the resistance values of the resistors **133** and the grounding resistors **134**, assuming that a total resistance value of the resistors **133** and the grounding resistors **134** is 100%. In the figure, the bracketed portion denotes a position of each of the resistors **133** and the grounding resistors **134**.

[0135] Further, in FIG. **18**, a configuration of a power supply circuit **180** connected to the element row S via the independent wiring **123** is shown. The power supply circuit **180** includes a driving power supply **181**, an inductor **182**, an inductor **183**, a resistor **184**, a resistor **185**, a resistor **186**, a resistor **187**, a capacitor **188**, and a capacitor **189**. In addition, a wiring between the element row S and the driving power supply **181** is defined as a signal wiring **190**. The signal wiring **190** is a coaxial cable. A resistance value thereof is 143 Ω, for example.

[0136] Here, it is favorable that, for the resistors **133** and the grounding resistors **134**, a total resistance value (Rg**1**+Rg**2**+R**1** + . . . +R**14**) of the resistors **133** and the grounding resistors **134** in the element row S is larger than a resistance value of the signal wiring **190**.

[0137] In addition, provided that the frequency of the driving voltage of the driving power supply **181** is f [Hz], it is favorable that a product (hereinafter, RC) of the total resistance value of (R**1**+ . . . +R**14**) of the resistors **133** in the element row S and the total value (C**1**+ . . . +C**16**) of the capacitance of the vibrator elements **150** is smaller than ½ f.

[0138] FIGS. **20** to **24** are graphs showing simulation results of a voltage time history waveform with each of the vibrator elements **150** in the element row S. In each figure, the "element at center" indicates the vibrator element **150** corresponding to C**8** or C**9** in FIG. **18** and the "fifth element from end" indicates the vibrator element **150** corresponding to C**5** or C**12** in the figure. The "element at end" indicates the vibrator element **150** corresponding to C**1** or C**16** in the figure.

[0139] The total resistance value (hereinafter, total resistance value) of the resistors **133** and the grounding resistors **134** is 10 Ω, in FIG. **20**, 100 Ω, in FIG. **21**, 1 Ω in FIG. **22**, 10 Ω, in FIGS. **23**, and 100 Ω, in FIG. **24**.

[0140] The analysis condition of the simulation is as follows: the vibrator element width in the azimuth direction (Y direction) is 90 μm; the array-type ultrasonic vibrator width (opening width) in the slice direction (X direction) is 5 mm; the number of vibrator elements in the slice direction (X direction) is 16; the thickness of the array-type ultrasonic vibrator is 120 μm; and the applied voltage waveform is 100 V, 7 MHz, Sin wave, 1 wave.

[0141] As shown in FIGS. **20** and **21**, in a case where the total resistance value is smaller than the resistance value of the signal wiring **190** (143 Ω), a maximum voltage is about 3 V or 20 V with respect to an applied voltage of 100 V and a voltage drop of each of the vibrator elements **150** is too large.

[0142] On the other hand, as shown in FIGS. **22** to **24**, in a case where the total resistance value is larger than the resistance value of the signal wiring **190** (143 Ω), a maximum voltage is about 60 V or 80 V with respect to an applied voltage of 100 V and a voltage drop of each of the vibrator elements **150** is not large.

[0143] Therefore, it is favorable that the total resistance value is larger than the resistance value of the signal wiring **190**.

[0144] Further, the RC (product of the total resistance value of (R**1**+ . . . +R**14**) of the resistors **133** and the total value (C**1**+ . . . +C**16**) of the capacitance of the vibrator elements **150**) is larger than ½ f, an RC delay (phase offset) is generated as shown in FIGS. **23** and **24**.

[0145] Therefore, it is favorable that the RC is smaller than ½ f. It should be noted that in FIGS. **20** to **24**, R is the "total resistance value" shown in the figure and C is 65.8 pF in any cases. While ½ f at 7 MHz is 71.4 nsec, the RC value is 0.658 pF under the condition of FIG. **20**, 6.58 pF under the condition of FIG. **21**, 65.8 pF under the condition of FIG. **22**, 658 pF under the condition of FIGS. **23**, and 6.58 nF under the condition of FIG. **24**.

[0146] For this reason, it is favorable that the total resistance value is larger than the resistance value of the signal wiring **190** and it is favorable that the RC is smaller than ½ f. In a case where those conditions are satisfied as shown in FIG. **22** (total resistance value: 1 kΩ), a voltage drop of each of the vibrator elements **150** is small and generation of the RC delay is also prevented.

[0147] FIG. **25** shows simulation results of a sound pressure beam profile of the array-type ultrasonic vibrator **100** in a case where the width (opening width) in the X direction is 5 mm. Here, the focal distance is 35 mm.

[0148] FIG. **26** is a graph showing a beam width (width at the time of lowering by −3 dB and −6 dB) with the sound pressure beam profile shown in FIG. **25**. FIG. **27** is a graph showing a dynamic range with the sound pressure beam profile shown in FIG. **25**.

[0149] As shown in those figures, in a case of the opening width 5 mm, the effects of the improvement of the dynamic range (in FIG. **25**, the arrow A) and the reduction of the beam width (in FIG. **25**, the arrow B) are obtained when the total resistance value is 1 kΩ.

[0150] FIG. **28** shows other simulation results of the sound pressure beam profile of the array-type ultrasonic vibrator **100** in a case where the width (opening width) in the X direction is 2 mm. Here, the focal distance is 35 mm.

[0151] FIG. **29** is a graph showing a beam width (width at the time of lowering by −3 dB and −6 dB) with the sound pressure beam profile shown in FIG. **28**. FIG. **30** is a graph showing the dynamic range with the sound pressure beam profile shown in FIG. **28**.

[0152] As shown in those figures, in a case where the opening width is 2 mm, the effect of the improvement of the dynamic range (in FIG. **28**, the arrow A) is obtained when the total resistance value is 1 kΩ.

[0153] In this manner, in a case where the total resistance value is larger than the resistance value of the signal wiring **190** and the RC is smaller than ½ f, the effects of the improvement of the dynamic range of the array-type ultrasonic vibrator **100** and the reduction of the beam width are obtained.

[0154] Further, in each of the element rows S, it is favorable that the resistance values of the grounding resistors **134** (Rg**1** and Rg**2**) are smaller than the total resistance value (R**1**+ . . . +R**14**) of the resistors **133**. FIG. **31** is a graph showing the apodization intensity distribution in each of the element rows S. As the bias value (intensity coefficient at the end) becomes smaller, the dynamic range becomes larger.

[0155] More specifically, as shown in FIG. **32**, provided that the number of vibrator elements **150** of the element row S is n, the width of the element row S in the slice direction (X direction) is w, and the center in the slice direction is a point of origin, and also provided that the distance from the point of origin in the slice direction is x, a peal value of a voltage waveform which is generated in a kth vibrator element **150** from the end is Vk due to the driving voltage of the driving power supply **181**, and a maximum value of Vk ($1 \le k \le n$) is Vmax, it is favorable that the distribution of Vk is a distribution according to a hamming window function shown in (Expression 1) below.

$$Vk/V\max=0.54+0.46\cos(2\pi * x/w) \quad \text{(Expression 1)}$$

[0156] FIG. **33** is a graph showing the hamming window function shown in (Expression 1) above.

[0157] FIG. **34** shows simulation results of the sound pressure beam profile of the array-type ultrasonic vibrator **100** in a case where the width (opening width) in the X direction is 5 mm. Here, the focal distance is 35 mm.

[0158] FIG. **35** is a graph showing a beam width (width at the time of lowering by −3 dB and −6 dB) with the sound pressure beam profile shown in FIG. **34**. FIG. **36** is a graph showing a dynamic range with the sound pressure beam profile shown in FIG. **34**.

[0159] FIG. **37** shows simulation results of the sound pressure beam profile of the array-type ultrasonic vibrator **100** in a case where the width (opening width) in the X direction is 2 mm. Here, the focal distance is 35 mm.

[0160] FIG. **38** is a graph showing a beam width (width at the time of lowering by −3 dB and −6 dB) with the sound pressure beam profile shown in FIG. **37**. FIG. **39** is a graph showing a dynamic range with the sound pressure beam profile shown in FIG. **37**.

[0161] As shown in those figures, in a case where the intensity distribution function is the hamming window function, the dynamic range becomes larger, which is favorable.

[0162] As described above, by providing the configuration in which the resistance values of the grounding resistors **134** are smaller than the total resistance value of the resistors **133** and the apodization intensity distribution is a distribution according to the hamming window function, the effect of the improvement of the dynamic range of the array-type ultrasonic vibrator **100** is obtained.

[0163] It should be noted that the present technology may also take the following configurations.

[0164] (1) An array-type ultrasonic vibrator, including:

[0165] a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction; and

[0166] a resistor electrically connected between a pair of arbitrary ultrasonic vibrator elements in the element row.

[0167] (2) The array-type ultrasonic vibrator according to (1), in which

[0168] the resistor is electrically connected between all ultrasonic vibration elements in the element row.

[0169] (3) The array-type ultrasonic vibrator according to (1) or (2), further including

[0170] a grounding resistor connected between an ultrasonic vibration element at an end of the element row and a ground.

[0171] (4) The array-type ultrasonic vibrator according to any one of (1) to (3), in which

[0172] the vibrator array includes a substrate that supports the ultrasonic vibrator elements, and

[0173] the resistor is implemented on a surface of the substrate or inside the substrate.

[0174] (5) The array-type ultrasonic vibrator according to any one of (1) to (4), in which

[0175] the ultrasonic vibrator elements are connected to a wiring for driving the ultrasonic vibrator elements in each of the element rows.

[0176] (6) An ultrasonic probe, including

[0177] an array-type ultrasonic vibrator including

[0178] a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

[0179] a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0180] (7) An ultrasonic catheter, including

[0181] an array-type ultrasonic vibrator including

[0182] a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

[0183] a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0184] (8) A hand-held surgical instrument, including:

[0185] an array-type ultrasonic vibrator including

[0186] a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

[0187] a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

[0188] (9) A medical apparatus, including:

[0189] an array-type ultrasonic vibrator including

[0190] a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

[0191] a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row; and

[0192] a position sensor that detects a position of the array-type ultrasonic vibrator.

[0193] (10) The medical apparatus according to (9), in which

[0194] an ultrasonic volume image is generated on the basis of outputs of the array-type ultrasonic vibrator and the position sensor.

[0195] (11) The array-type ultrasonic vibrator according to any one of (3) to (5), in which

[0196] in each of the element rows, a total resistance value of the resistor and the grounding resistor is larger than a resistance value of a signal wiring that connects the ultrasonic vibrator element to a driving power supply.

[0197] (12) The array-type ultrasonic vibrator according to any one of (3) to (5) and (11), in which

[0198] in each of the element rows, provided that a frequency of a driving voltage of the ultrasonic vibrator element is f [Hz], a product of a total resistance value of the resistor and a total value of capacitance of the ultrasonic vibrator elements is smaller than ½ f.

[0199] (13) The array-type ultrasonic vibrator according to any one of (3) to (5) and (11) and (12), in which

[0200] in each of the element rows, a resistance value of the grounding resistor is smaller than a total resistance value of the resistor.

REFERENCE SIGNS LIST

[0201] **11** ultrasonic probe

[0202] **12** ultrasonic catheter

[0203] **13** surgical instrument

[0204] **100** array-type ultrasonic vibrator

[0205] **101** substrate

[0206] **102** piezoelectric layer

[0207] **103** upper electrode layer

[0208] **104** lower electrode layer

[0209] **105** backing layer

[0210] **106**, **107** acoustic matching lens

[0211] **107** acoustic matching lens

[0212] **108** acoustic lens

[0213] **121** substrate built-in resistor

[0214] **123** independent wiring

[0215] **133** resistor

[0216] **134** grounding resistor

[0217] **150** vibrator element

1. An array-type ultrasonic vibrator, comprising:

a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction; and

a resistor electrically connected between a pair of arbitrary ultrasonic vibrator elements in the element row.

2. The array-type ultrasonic vibrator according to claim **1**, wherein the resistor is electrically connected between all ultrasonic vibration elements in the element row.

3. The array-type ultrasonic vibrator according to claim **1**, further comprising

a grounding resistor connected between an ultrasonic vibration element at an end of the element row and a ground.

4. The array-type ultrasonic vibrator according to claim **1**, wherein

the vibrator array includes a substrate that supports the ultrasonic vibrator elements, and

the resistor is implemented on a surface of the substrate or inside the substrate.

5. The array-type ultrasonic vibrator according to claim **1**, wherein

the ultrasonic vibrator elements are connected to a wiring for driving the ultrasonic vibrator elements in each of the element rows.

6. An ultrasonic probe, comprising

an array-type ultrasonic vibrator including

a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

7. An ultrasonic catheter, comprising

an array-type ultrasonic vibrator including

a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

8. A hand-held surgical instrument, comprising:

an array-type ultrasonic vibrator including

a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row.

9. A medical apparatus, comprising:

an array-type ultrasonic vibrator including

a vibrator array in which ultrasonic vibrator elements constitute a two-dimensional array including a plurality of element rows in which a plurality of ultrasonic vibrator elements are arranged in a slice direction, and

a resistor electrically connected between a pair of arbitrary ultrasonic vibration elements in the element row; and

a position sensor that detects a position of the array-type ultrasonic vibrator.

10. The medical apparatus according to claim **9**, wherein

an ultrasonic volume image is generated on a basis of outputs of the array-type ultrasonic vibrator and the position sensor.

11. The array-type ultrasonic vibrator according to claim **3**, wherein in each of the element rows, a total resistance value of the resistor and the grounding resistor is larger than a resistance value of a signal wiring that connects the ultrasonic vibrator element to a driving power supply.

12. The array-type ultrasonic vibrator according to claim **3**, wherein in each of the element rows, provided that a frequency of a driving voltage of the ultrasonic vibrator element is f [Hz], a product of a total resistance value of the resistor and a total value of capacitance of the ultrasonic vibrator elements is smaller than ½ f.

13. The array-type ultrasonic vibrator according to claim **3**, wherein in each of the element rows, a resistance value of the grounding resistor is smaller than a total resistance value of the resistor.

* * * * *

专利名称(译)	阵列型超声振动器，超声探头，超声导管，手持式手术器械和医疗器械		
公开(公告)号	US20200060651A1	公开(公告)日	2020-02-27
申请号	US16/462818	申请日	2017-10-13
[标]申请(专利权)人(译)	索尼公司		
申请(专利权)人(译)	索尼公司		
当前申请(专利权)人(译)	索尼公司		
[标]发明人	MORIMOTO RUI NAKATA AKIHIRO		
发明人	MORIMOTO, RUI NAKATA, AKIHIRO		
IPC分类号	A61B8/00 A61B8/12		
CPC分类号	A61B8/4488 A61B8/445 A61B8/12 A61B8/00		
优先权	2016246688 2016-12-20 JP		
外部链接	Espacenet USPTO		

摘要(译)

[目的] 提供一种阵列型超声波振子，超声波探头，超声波导管，该阵列型超声波振子的生产率和实用性优异，并且具有能够提高超声波束在切片方向上的聚焦特性的二维阵列结构。 手持式手术器械和医疗设备。 解决方案根据本技术的实施例的阵列型超声振动器包括振动器阵列和电阻器。 振动器阵列是其中超声振动器元件构成包括多个元件行的二维阵列的振动器阵列，其中多个超声振动器元件在切片方向上布置。 电阻器电连接在元件列中的一对任意的超声波振子之间。