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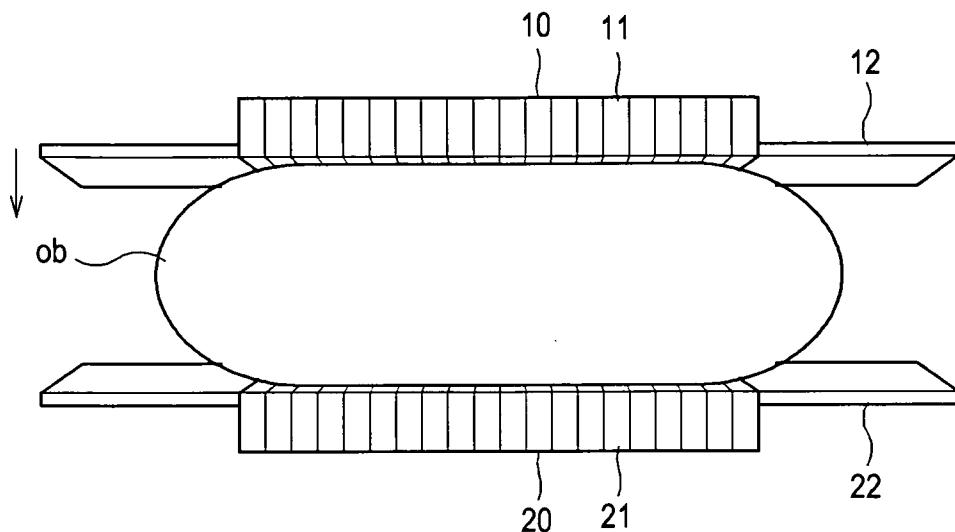
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### (54) Ultrasound diagnostic device having transducers facing each other

(57) The present invention relates to an ultrasound diagnostic device. The ultrasound diagnostic device comprises a pair of transducers (10,20) operable to trans-

mit/receive ultrasound signals. The transducers are arranged to face each other. The transducers may be an array transducer including a plurality of elements (11,21), which are linearly arranged.

FIG. 5B



## Description

**[0001]** The present application claims priority from Korean Patent Application No. 10-2007-0116168 filed on November 14, 2007, the entire subject matter of which is incorporated herein by reference.

## BACKGROUND OF THE INVENTION

### **[Technical Field]**

**[0002]** The present invention generally relates to an ultrasound diagnostic device, and more particularly to an ultrasound diagnostic device having a pair of array transducers facing each other.

### **[Background Art]**

**[0003]** An ultrasound diagnostic device has become an important and popular diagnostic tool due to its non-invasive and non-destructive nature. The ultrasound diagnostic device may form an ultrasound image by utilizing wave characteristics of ultrasound such as reflection, scattering and absorption as ultrasound signals propagate through tissues of a human body. The ultrasound diagnostic device may have a transducer for transmitting ultrasound signals to a target object and receiving ultrasound echoes reflected back from it. An array transducer including a plurality of elements is widely used to obtain an enhanced ultrasound image.

**[0004]** Generally, as the ultrasound signals propagate through the target object, they are attenuated. Thus, it is difficult to obtain an ultrasound image having a high signal-to-noise ratio (SNR) for a relatively far area from the transducer.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0005]** FIG. 1 is a schematic diagram illustrating a pair of transducers.

**[0006]** FIGS. 2A and 2B are schematic diagrams showing examples of transmitting and receiving ultrasound signals by using two transducers.

**[0007]** FIGS. 3A to 3C are schematic diagrams illustrating examples of steering a plane wave used as an ultrasound transmit beam.

**[0008]** FIG. 4 is a schematic diagram showing an example of extension plates extended from both edges of the transducers.

**[0009]** FIGS. 5A and 5B are schematic diagrams showing examples of pressing a target object by using the transducers with extension plates mounted.

**[0010]** FIG. 6 is a schematic diagram showing elasticity images obtained under the condition that a target object is pressed.

**[0011]** FIG. 7 is a schematic diagram showing elasticity images with the motion of a target object compensated.

**[0012]** FIG. 8 is a block diagram showing an ultrasound

diagnostic device in accordance with one embodiment of the present invention.

**[0013]** FIG. 9 is a block diagram showing an ultrasound diagnostic device in accordance with another embodiment of the present invention.

**[0014]** FIGS. 10A to 10C are schematic diagrams showing examples of obtaining ultrasound plane images by rotating the transducers.

**[0015]** FIG. 11 is a schematic diagram showing an example of rotating one of the transducers.

**[0016]** FIG. 12 is a schematic diagram illustrating an example of rotating one transducer around the other transducer.

**[0017]** FIG. 13 is a schematic diagram illustrating two pairs of transducers in accordance with further another embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

**[0018]** FIG. 1 is a schematic diagram showing an illustrative embodiment of a pair of transducers. As illustrated in FIG. 1, the ultrasound diagnostic device may include a pair of transducers 10 and 20. The pair of the transducers 10 and 20 may be arranged to face each other.

**[0019]** As illustrated in FIGS. 2A and 2B, each of the transducers 10 and 20 may have an array transducer having a plurality of elements 11 and 21. The elements 11 and 21 may transmit the ultrasound signals to a target object and receive ultrasound echoes reflected from the target object to thereby output analog receive signals. The transducers 10 and 20 may be a linear array transducer in which the elements are linearly arranged. A distance between two array transducers 10 and 20 may be adjustable by moving at least one of the transducers 10 and 20 in an axial direction. The distance may be adjusted according to the type of a target object or diagnostic conditions. The target object may be positioned between two array transducers 10 and 20, so that an imaging error caused by a motion of the target object such as a human body may be reduced.

**[0020]** Since two array transducers 10 and 20 are arranged such that they face each other in one embodiment, images may be obtained in both reflection and transmission modes. That is, when one transducer emits ultrasound signals to a target object, the ultrasound signals may be reflected by the target object and received by the opposite transducer. The reflected ultrasound signals may be used to form a B-mode image in the reflection mode and the transmitted ultrasound signals may be used to form speed of sound and attenuation images in the transmission mode. Two array transducers 10 and 20 may alternately transmit an ultrasound transmit beam to the target object. In response to the transmission, each of two array transducers 10 and 20 may receive an ultrasound echo reflected from the target object in the reflection mode. With this configuration of two array trans-

ducers, it is possible to obtain two image frames corresponding to the same plane in the target object, each of which is formed based on the ultrasound echo. The two image frames may be compounded again by using a technique such as averaging. The so-obtained compound image frame may be presented as a new image frame.

**[0021]** In some embodiments, each of two array transducers 10 and 20 may be operable to transmit an ultrasound transmit beam several times at different steering angles. In this case, a plurality of image frames corresponding to the individual steering angles may be obtained based on the ultrasound echoes. The plurality of image frames may be compounded, so that two compound images corresponding to individual array transducers 10 and 20 may be obtained. Thereafter, the two compound images may be superposed again. Thus, speckles may be reduced through the compounding. Also, the degradation of resolution and SNR with increasing depth may be compensated for.

**[0022]** In the meantime, if the ultrasound transmit beam is transmitted by using a single element, the SNR may be decreased. A plane wave (e.g., a limited-diffraction beam) may be used as the ultrasound transmit beam to increase the SNR. The plane waves transmitted from the respective transducers 10 and 20 may be steered to obtain an ultrasound image which covers a large imaging area without physically or mechanically tilting the transducers 10 and 20. For example, if transmission is repeated in steering angle steps of 1° over a steering angle range of  $\pm 10^\circ$ , a total of 21 frames may be obtained. Thus, it has an effect equivalent to tilting the transducer by 20°. An ultrasound image may be formed through synthetic focusing of receive signals obtained through the individual array transducers 10 and 20 by steering the plane wave. When the ultrasound transmit beams are transmitted after being steered at transmit angles of  $\theta_1$  and  $\theta_2$  from the individual array transducers 10 and 20, shadow regions, which are not scanned, may result from one of the steered ultrasound transmit beams. However, the shadow region may be compensated by the ultrasound transmit beam emitted from the other transducer, as illustrated in FIGS. 3A to 3C. That is, since a pair of transducers is used to obtain an image frame in one embodiment, the shadow region may be reduced when the steered transmit beams are adopted to get a wide field of view in imaging. Numeral references "14" and "24" in FIGS. 3A and 3B represent wave fronts of the plane waves used as the ultrasound transmit beams.

**[0023]** In the transmission mode, the receive signals may be obtained based on the ultrasound transmit beam emitted from the opposite transducer through the target object. In such a case, the speed of sound and attenuation may be measured based on the arrival time and amplitude of the ultrasound transmit beam emitted from one array transducer upon reception on the other array transducer. A tomography image showing the attenuation and the speed of the ultrasound signal in the target object

may be obtained by using a tomographic reconstruction technique. The speed of sound may be 1450 m/s in normal tissues of the breast and 1550 m/s in the tumor, so that it may be determined whether or not the tumor exists

5 through the speed of sound image. Also, the attenuation of the ultrasound signal in the tumor is greater than that in the normal tissue. Thus, the tumor may be diagnosed through the attenuation image. As mentioned above, the B-mode image may be obtained together with the tomography image in both the reflection and transmission modes in accordance with one embodiment, so that the examination time may be reduced.

**[0024]** In the meantime, the conventional ultrasound computerized tomography (CT) may be carried out by immersing an imaging object in water to obtain an ultrasound CT image such as an ultrasound breast image. Thus, ultrasound refraction may occur due to the water. However, since two transducers 10 and 20 are in direct contact with the target object in accordance with one embodiment, the refraction of the ultrasound signals may be reduced, so that an enhanced ultrasound image resolution may be obtained.

**[0025]** An ultrasound signal of 7 MHz, which is typically used to obtain a breast image, may be largely attenuated during propagation in the breast. Therefore, ultrasound echoes reflected from a relatively far region from the transducer may be very weak. However, since breast images may be obtained from each of both array transducers 10 and 20, and compounded to form a compound breast image in one embodiment, depth-dependent image characteristics such as the attenuation may be compensated for.

**[0026]** In order to form the compound ultrasound image, the bidirectional pixel based focusing may be used in addition to the synthetic focusing. Also, various focusing methods may be applied by using two transducers 10 and 20.

**[0027]** When the target object is positioned between two transducers 10 and 20, the distance between the transducers may be finely adjusted in accordance with one embodiment such that a pressure may be applied to the target object. That is, the pressure applied to the target object may be changed by adjusting the distance between two transducers 10 and 20. In such a case, the pressure applied to the target object may be in inverse proportion to the distance therebetween. Thus, the pressure applied to the target object may be indirectly computed by using the distance between the transducers 10 and 20 in accordance with one embodiment.

**[0028]** In accordance with another embodiment, the transducers 10 and 20 may include extension plates 12 and 22, which are extended from both edges of the transducers 10 and 20, respectively, as illustrated in FIG. 4. The extension plates 11 and 12 may be a compression plate for applying the pressure to the target object. When the pressure is applied to the target object Ob such as a breast to form the strain image, the pressure may be uniformly applied to the squeezed target object Ob

through the compression plates 12 and 22, as illustrated in FIGS. 5A and 5B. Thus, a good strain image may be obtained compared with the strain image obtained by pressing the target object with palpation.

**[0029]** FIG. 6 is a schematic diagram showing examples of elasticity images (strain images) F1, F2, F3 and F4 obtained by pressing the target object in an axial direction of the transducers 10 and 20. FIG. 7 is a schematic diagram showing examples of elasticity images in which motions are compensated. The motion compensation may be performed by expanding the elasticity images F1, F2, F3 and F4 by a factor defined by a reciprocal number of the strain, so that the motion-compensated elasticity images F11, F12, F13 and F14 corresponding to different strains may be obtained. The elasticity images F11, F12, F13 and F14 may be averaged to form a final elasticity image. Thus, an error in strain calculation may be reduced through the averaging of the elasticity images. In accordance with one embodiment, two elasticity images may be obtained at every transmission and reception of the ultrasound signals from the two transducers 10 and 20 in the same manner of forming the B-mode images.

**[0030]** FIG. 8 is a block diagram showing an ultrasound diagnostic device including two array transducers 110 and 120. The two array transducers 110 and 120 may be arranged to face each other. The array transducers 110 and 120 may include a plurality of elements for transmitting ultrasound signals along scan lines, which are set in the target object in response to transmit pulse signals, and outputting analog receive signals based on ultrasound echoes reflected from the target object. A transmitting beamformer 130 may be operable to apply delays to the transmit pulse signals such that the ultrasound signals are focused on the scan lines. A receive beamformer 140 may be operable to sample the analog receive signals at a predetermined sampling rate to thereby form receive signals corresponding to the scan lines. The receive beamformer 140 may include an analog-to-digital converter operable to convert the analog receive signals to digital receive signals. The receive beamformer 140 may be operable to apply delays to the digital receive signals in consideration of a distance between the element and a focal point, and sum delayed digital receive signals to thereby form receive data. A storage unit 150 may store the receive data. A digital signal processor (DSP) 160 may be operable to form image data corresponding to image modes such as a B-mode, a C-mode and a D-mode based on the receive data. A digital scan converter 170 may be operable to scan convert the image data to a data format suitable for display. A display unit 180 may be operable to display an ultrasound image based on the scan-converted image data.

**[0031]** A moving unit 190, which is coupled to the transducers 110 and 120, may be operable to move at least one of the transducers 110 and 120 in an axial direction. A pressure determination unit 195 may be operable to determine a pressure applied to the target object based

on a distance between the transducers 110 and 120. The DSP 160 may be operable to form elasticity image data based on the pressure determined by the pressure determination unit 195. The digital scan converter 170 may be operable to scan convert the elasticity image data to an image format suitable for display. The display unit 180 may display an elasticity image based on the scan-converted elastic image data.

**[0032]** FIG. 9 is a block diagram showing an ultrasound diagnostic device including two array transducers 110 and 120 arranged to face each other in another embodiment. The ultrasound diagnostic device may further include a rotation angle calculation unit 196 in addition to all elements of the ultrasound diagnostic device illustrated in FIG. 8. The transducer moving unit 190 may be further operable to rotate the transducers 110 and 120 on the same planes, as illustrated in FIGS. 10A to 10C. The rotation angle calculation unit 196 may be operable to calculate a rotation angle of the array transducers 110 and 120.

**[0033]** Referring to FIGS. 10A to 10C, the transducers 10 and 20 may be rotated about a rotating axis AX<sub>1</sub>, so that the DSP 160 may form a plurality of plane images 200, 201, 202 and 203. The DSP 160 may be further operable to synthesize the plane images in consideration of a rotation angle θ<sub>3</sub> to form a 3-dimensional image. The resolution of the 3-dimensional image may be determined by finely adjusting the rotation angle θ<sub>3</sub>. The rotation angle θ<sub>3</sub> may be set to a small angle when a region of interest such as a cancer is scanned to get a high-resolution 3-dimensional ultrasound image for the region of interest.

**[0034]** FIG. 11 is a schematic diagram showing an example of obtaining a plurality of ultrasound plane images by rotating only one transducer 20 on the same plane while the other transducer is fixed. Referring to FIG. 11, one of the transducers (e.g., transducer 20) may rotate to obtain a plurality of ultrasound plane images 20a, 20b and 20c. The DSP 160 may be operable to synthesize the ultrasound plane images 20a, 20b and 20c to thereby form a 3-dimensional ultrasound image.

**[0035]** The transducer moving unit 190 may be further operable to rotate one transducer around the other transducer as illustrated in FIG. 12. In such a case, the moving transducer 20 may move along a surface of the target object while the two ultrasound transducers 10 and 20 face each other. That is, the transducer 10 is also rotated about a rotation axis AX<sub>2</sub> to face the transducer 20. Since the transducer 20 moves along the surface of the target object, a plurality of ultrasound plane images 204, 205, 206, 207 and 208 may be obtained. Thus, a wide region of the target object may be scanned. The DSP 160 may be operable to synthesize the ultrasound plane images 204, 205, 206, 207 and 208 in consideration of a rotation angle θ<sub>4</sub> to thereby form a 3-dimensional ultrasound image. A volume of internal tissues in the target object may be calculated by using the 3-dimensional ultrasound image.

**[0036]** FIG. 13 is a schematic diagram illustrating two pairs of transducers in accordance with further another embodiment. As illustrating in FIG. 13, a pair of additional array transducers 30 and 40 may be further included in addition to the pair of array transducers 10 and 20. The array transducers 30 and 40 may be arranged such that they face each other similar to the array transducers 10 and 20. Each of the array transducers 30 and 40 may have a plurality of elements 31 and 41. Further, the array transducers 30 and 40 may be arranged to be perpendicular to the array transducers 10 and 20. Four images corresponding to the individual array transducers 10 to 40 may be obtained, and then compounded to form a compound image. Thus, an enhanced ultrasound image resolution may be obtained.

**[0037]** As mentioned above, the ultrasound diagnostic device of the present invention adopts two transducers facing each other, so that the amount of ultrasound image data that can be acquired may become twice that of the conventional ultrasound diagnostic device to form the ultrasound image. Thus, an enhanced ultrasound image may be formed.

**[0038]** In accordance with one embodiment of the present invention, there is provided an ultrasound diagnostic device, comprising a pair of transducers operable to transmit/receive ultrasound signals, wherein the transducers are arranged to face each other.

**[0039]** Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," etc. means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such a feature, structure or characteristic in connection with that of other embodiments.

**[0040]** Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, numerous variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

## Claims

1. An ultrasound diagnostic device, comprising:

a pair of transducers operable to transmit/receive ultrasound signals, wherein the transducers are arranged to face each other.

5. 2. The ultrasound diagnostic device of Claim 1, wherein each of the transducers is a linear array transducer including a plurality of elements.
3. The ultrasound diagnostic device of Claim 2, further comprising:  
10 a transmit beamformer operable to delay transmit pulse signals applied to the transducers such that the ultrasound signals are focused on scan lines set in a target object;  
15 a receive beam former operable to convert analog receive signals outputted from the transducers in response to reception of ultrasound echoes reflected from the target object and delay the digital receive signals to form receive data;  
20 a digital signal processor operable to form image data based on the receive data; and  
25 a display unit operable to display an ultrasound image based on the image data.
4. The ultrasound diagnostic device of Claim 3, further comprising a moving unit operable to move at least one of the transducers in an axial direction.  
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5. The ultrasound diagnostic device of Claim 4, further comprising a pressure determination unit operable to determine a pressure applied to the target object based on a distance between the transducers,  
35 wherein the digital signal processing unit is operable to form elasticity image data based on the digital receive data and the determined pressure, and the display unit is operable to display an elasticity image based on the elasticity image data.  
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6. The ultrasound diagnostic device of Claim 5, further comprising compression plates extended from both edges of the respective transducers.  
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7. The ultrasound diagnostic device of Claim 4, wherein the moving unit is further operable to rotate at least one of the transducers about a rotation axis on a same plane, or one transducer around the other transducer while the transducers face each other.  
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8. The ultrasound diagnostic device of Claim 7, further comprising a rotation angle calculation unit operable to calculate a rotation angle of the transducers, wherein the digital signal processing unit is further operable to form a plurality of plane images and form a 3-dimensional image by synthesizing the plane images based on the calculated rotation angle.  
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9. The ultrasound diagnostic device of Claim 1, further comprising a pair of additional transducers, wherein the additional transducers are arranged to face each other and to be perpendicular to the transducers.

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FIG. 1

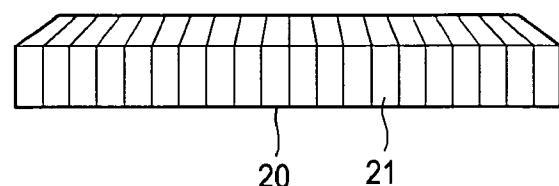
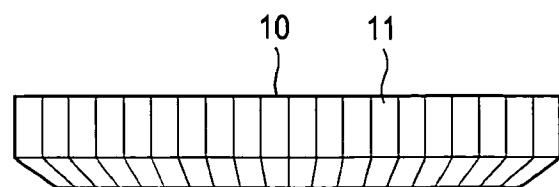


FIG. 2A

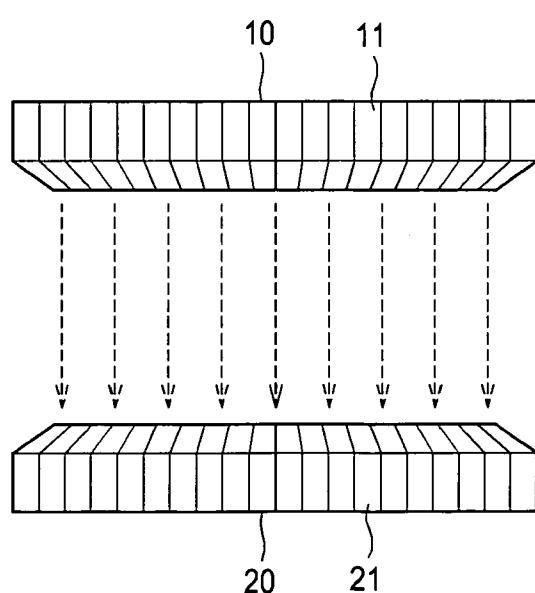


FIG. 2B

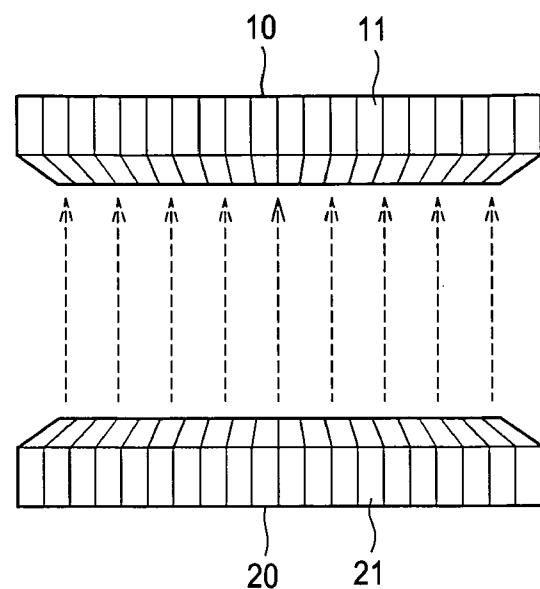


FIG. 3A

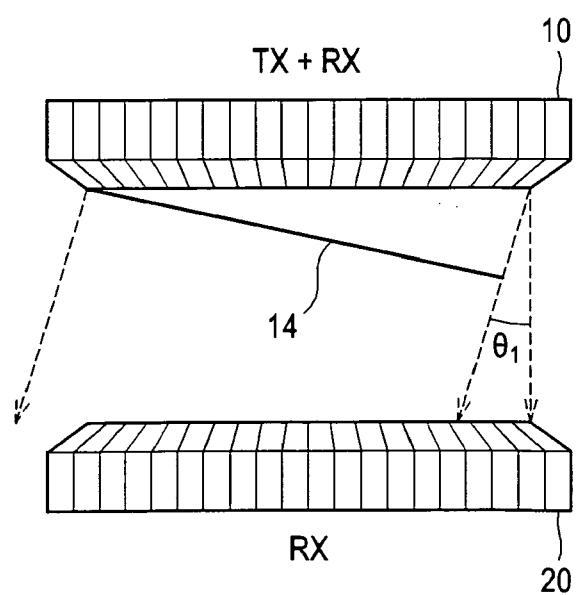


FIG. 3B

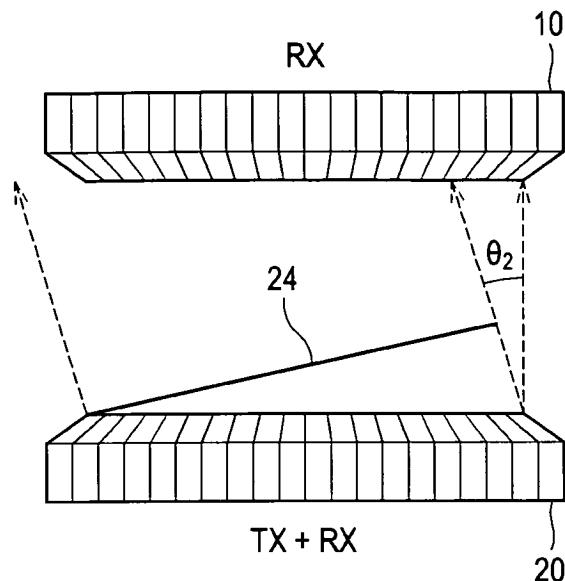


FIG. 3C

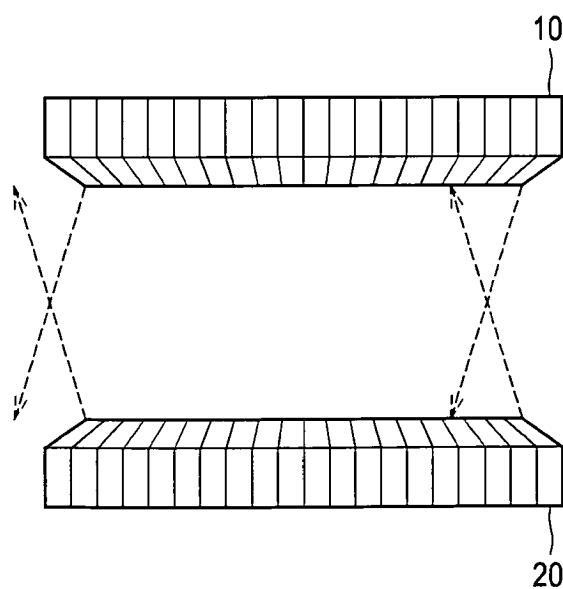


FIG. 4

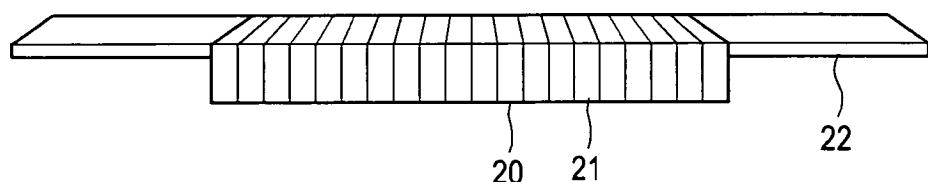
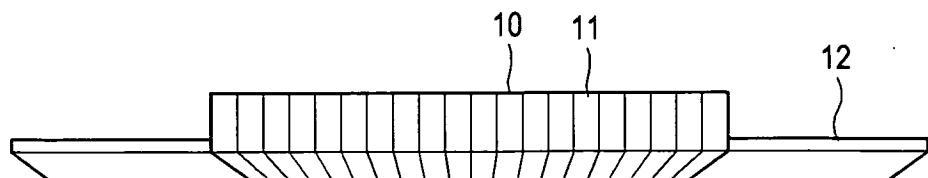


FIG. 5A

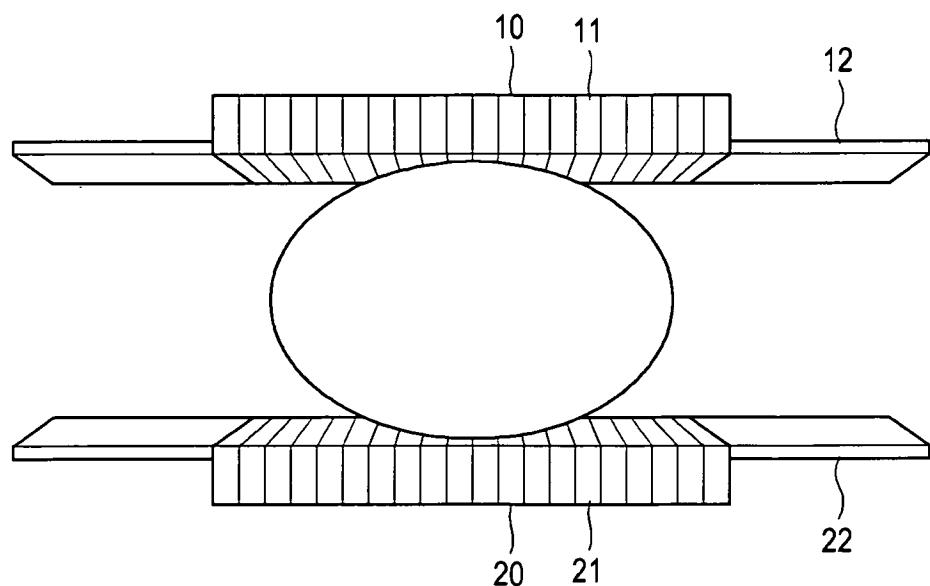


FIG. 5B

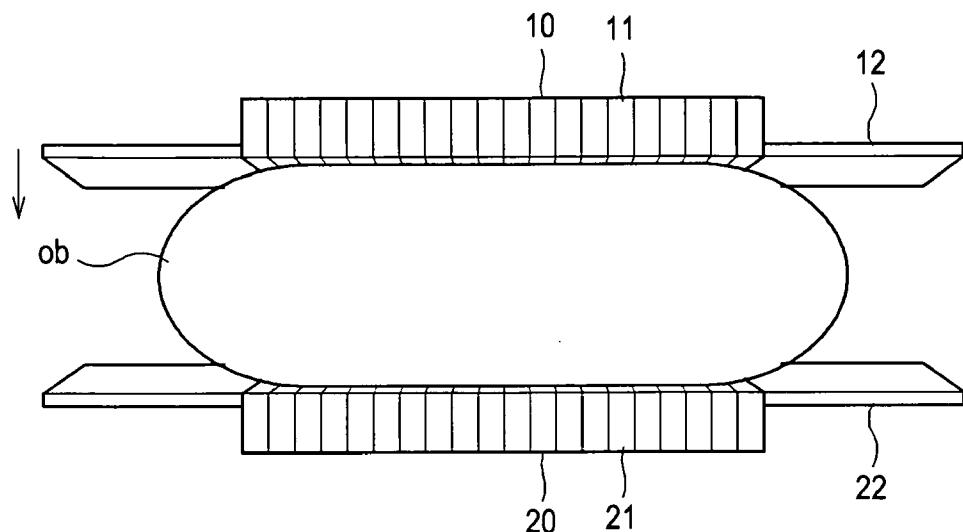


FIG. 6

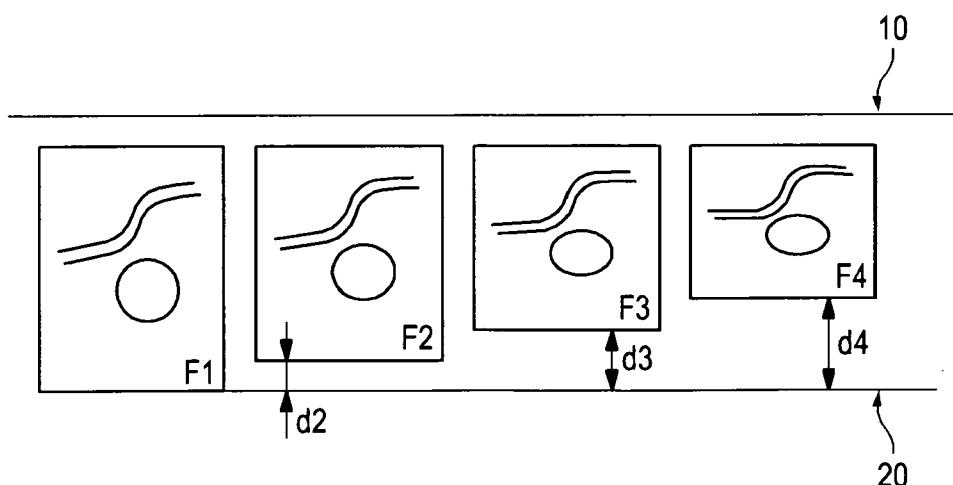


FIG. 7

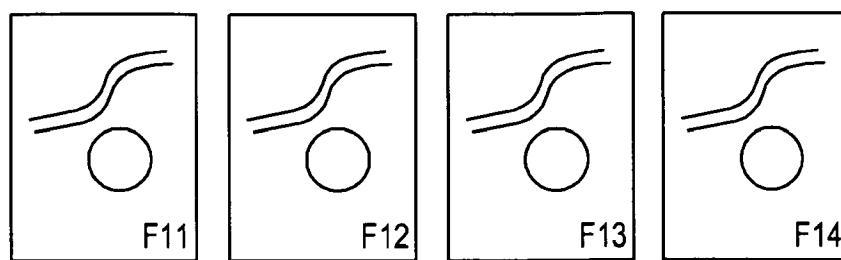


FIG. 8

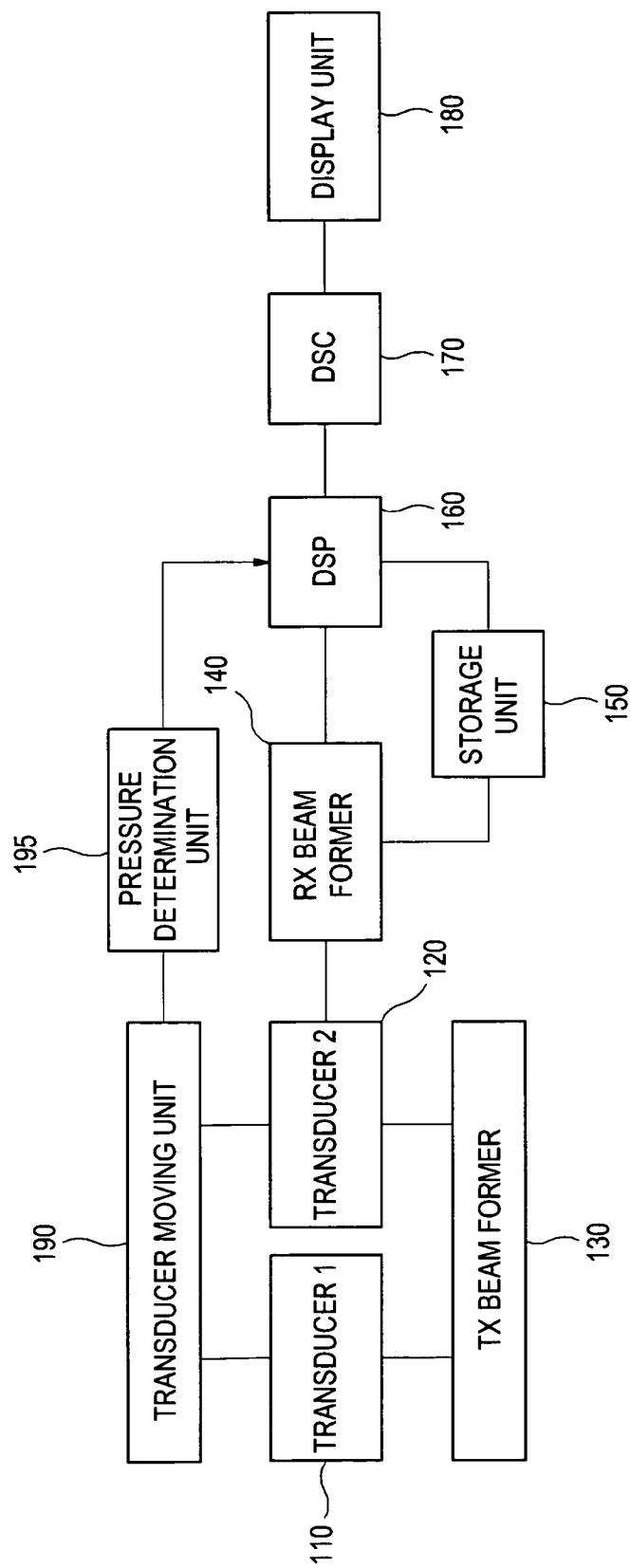


FIG. 9

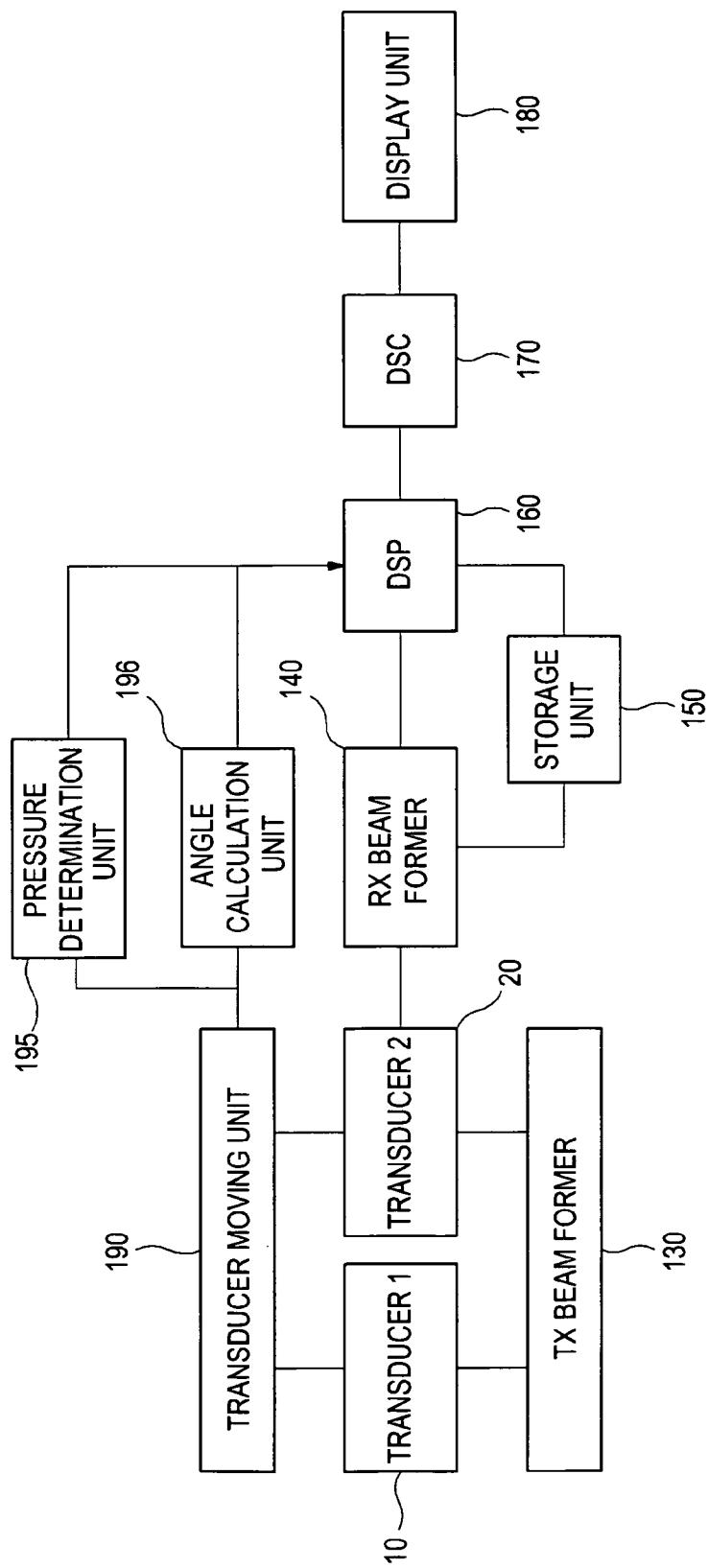


FIG. 10A

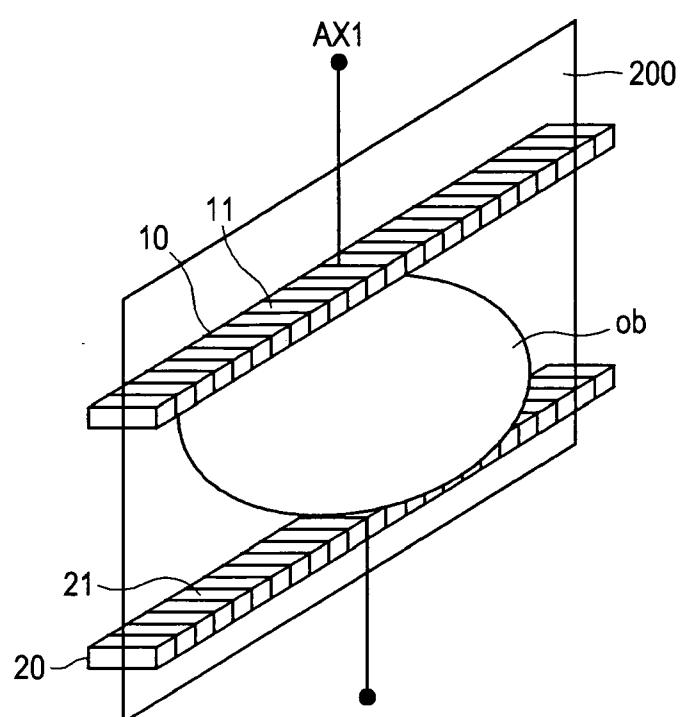


FIG. 10B

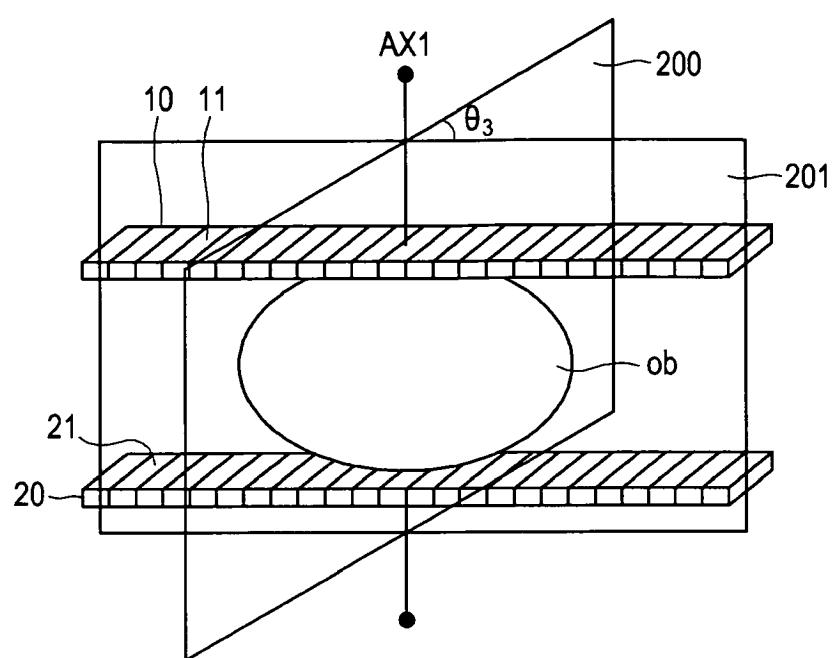


FIG. 10C

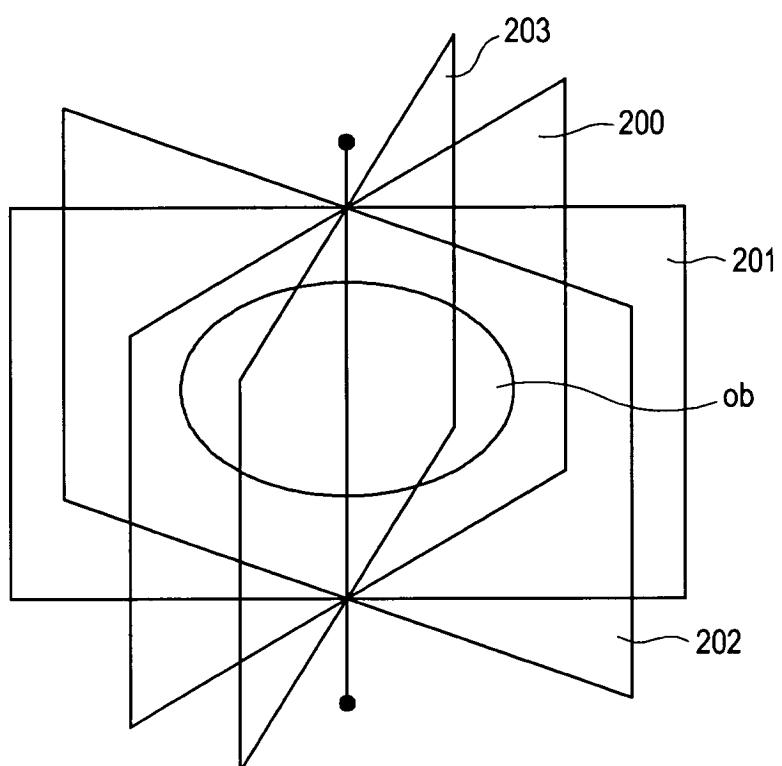


FIG. 11

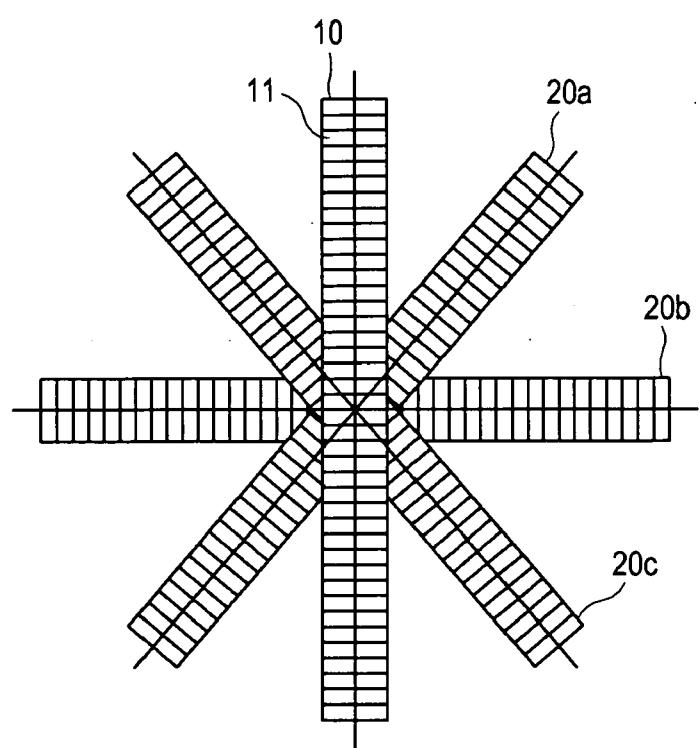


FIG. 12

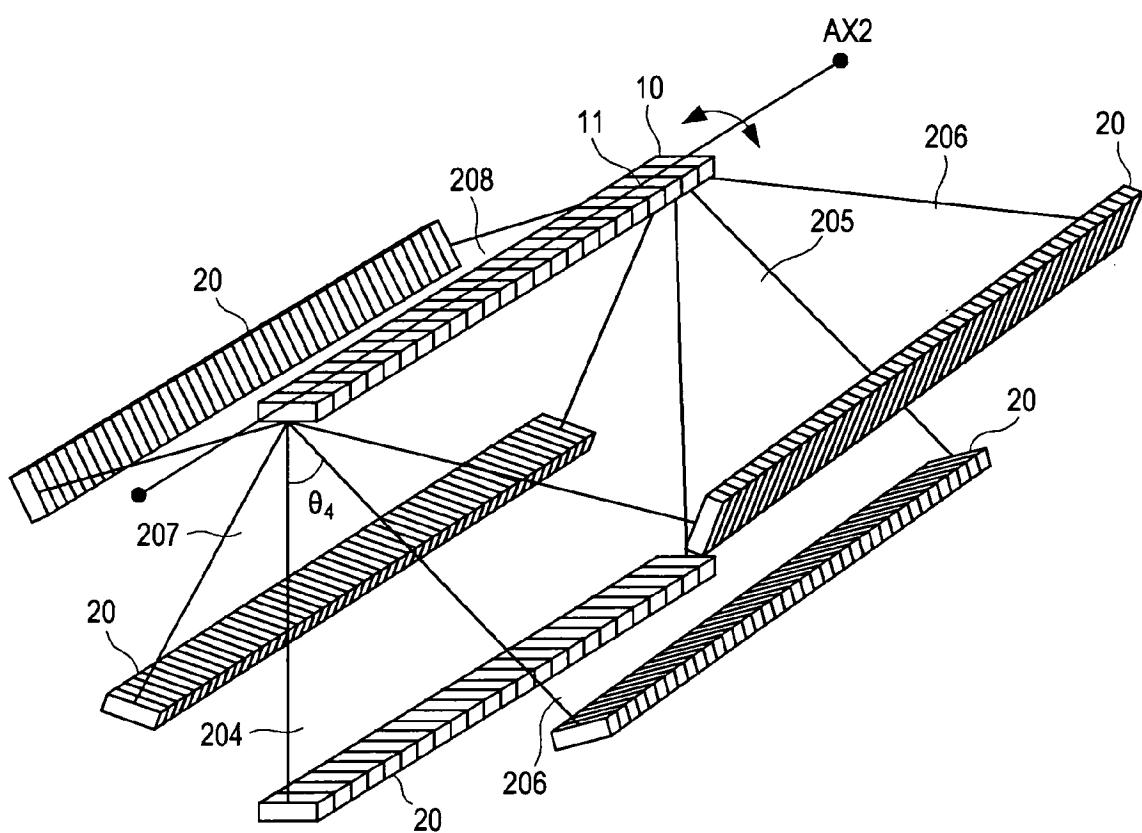
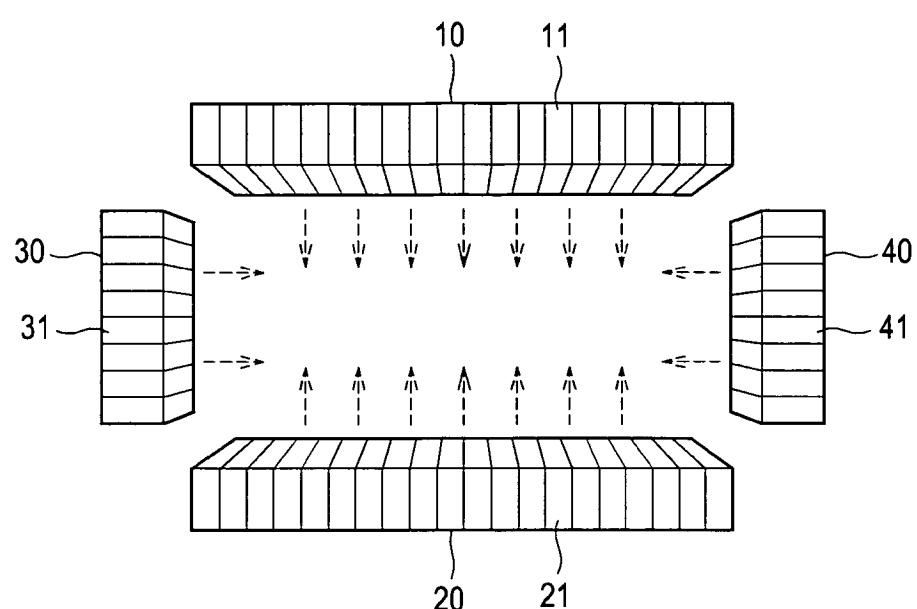


FIG. 13





## EUROPEAN SEARCH REPORT

Application Number  
EP 08 01 9896

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (IPC)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	US 2004/034307 A1 (JOHNSON STEVEN A [US]) ET AL) 19 February 2004 (2004-02-19)	1-4,9	INV. G01S15/89 A61B8/08
Y	* paragraphs [0054], [0081] - [0083] * * figures 1,4a-4e *	5,6	G10K11/34 G10K11/35
X	US 2006/173304 A1 (WANG SHIH-PING [US]) 3 August 2006 (2006-08-03) * paragraphs [0030] - [0040] * * figures 5-9 *	1-4,7,8	ADD. A61B8/15
X	WO 02/089672 A (SONNET MEDICAL LTD [IL]; KANTOROVICH EDWARD [IL]; SHAVITT AVISHAI [IL]) 14 November 2002 (2002-11-14) * figures 2B,2C *	1-3	
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The present search report has been drawn up for all claims			
2	Place of search	Date of completion of the search	Examiner
	Munich	4 March 2009	Willig, Hendrik
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-03-2009

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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- KR 1020070116168 [0001]

专利名称(译)	具有彼此面对的换能器的超声诊断设备		
公开(公告)号	<a href="#">EP2060930A1</a>	公开(公告)日	2009-05-20
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代理机构(译)	LORENZ , MARKUS		
优先权	1020070116168 2007-11-14 KR		
其他公开文献	EP2060930B1		
外部链接	<a href="#">Espacenet</a>		

## 摘要(译)

超声波诊断装置技术领域超声诊断设备包括一对可操作以发送/接收超声信号的换能器 ( 10,20 )。换能器布置成彼此面对。换能器可以是包括多个元件 ( 11,21 ) 的阵列换能器 , 这些元件线性地布置。

FIG. 5B

