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(54) **ULTRASOUND TRANSDUCER**

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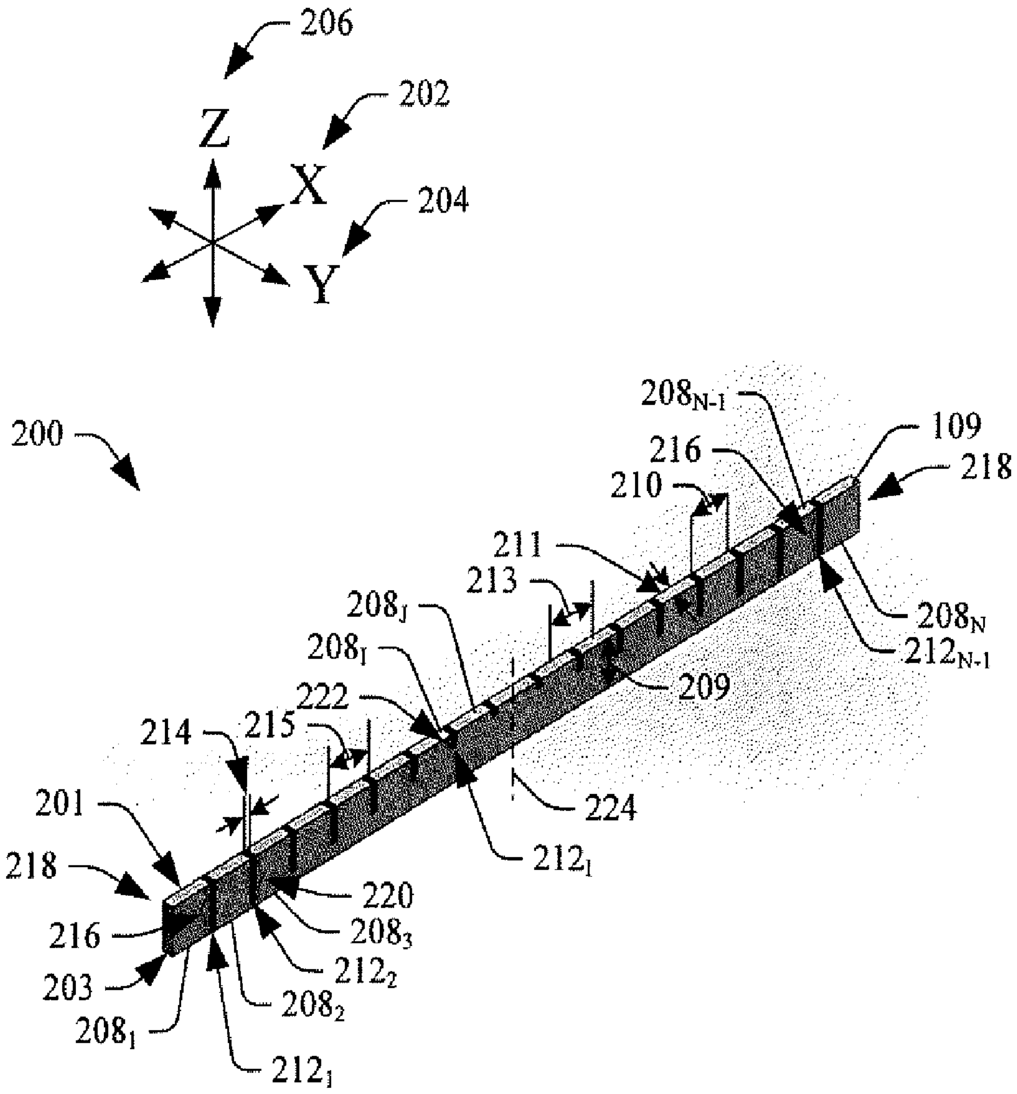
(57) **ABSTRACT**

An imaging probe includes a transducer array with transducer elements (**109**) with parallel first and second planar surface (**201**, **203**) in which an ultrasound signal is emitted from the first planar surface. A transducer element, includes a plurality of transducing sub-elements (**208**) arranged along an elevation direction in which adjacent transducing sub-elements are separated from each other by kerfs (**212**) of non-transducing material, wherein depths of the kerfs vary along the elevation direction.



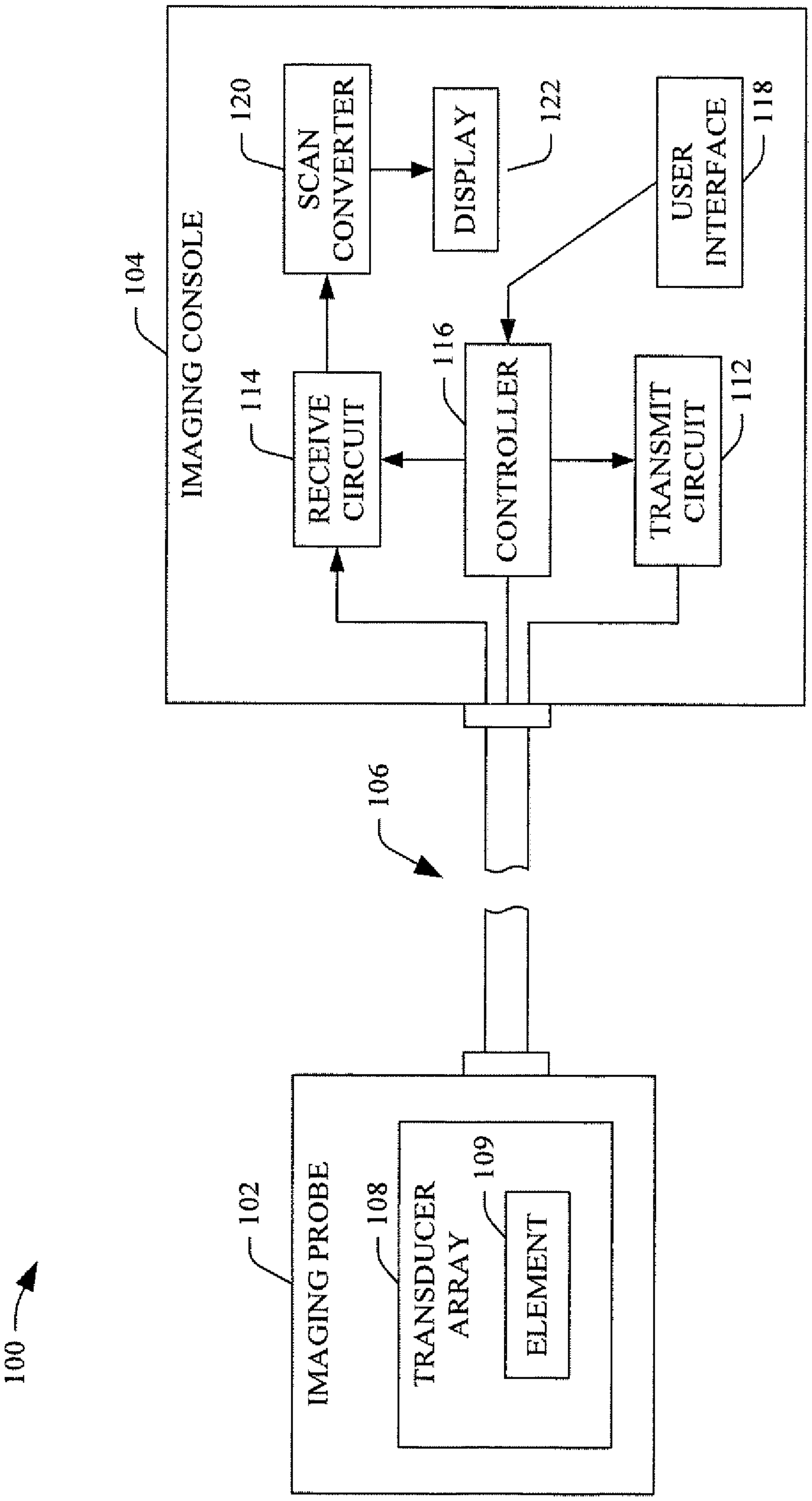

100
102
IMAGING PROBE
108
TRANSDUCER ARRAY
109
ELEMENT
106
104
IMAGING CONSOLE
114
RECEIVE CIRCUIT
116
CONTROLLER
112
TRANSMIT CIRCUIT
120
SCAN CONVERTER
122
DISPLAY
118
USER INTERFACE

FIGURE 1

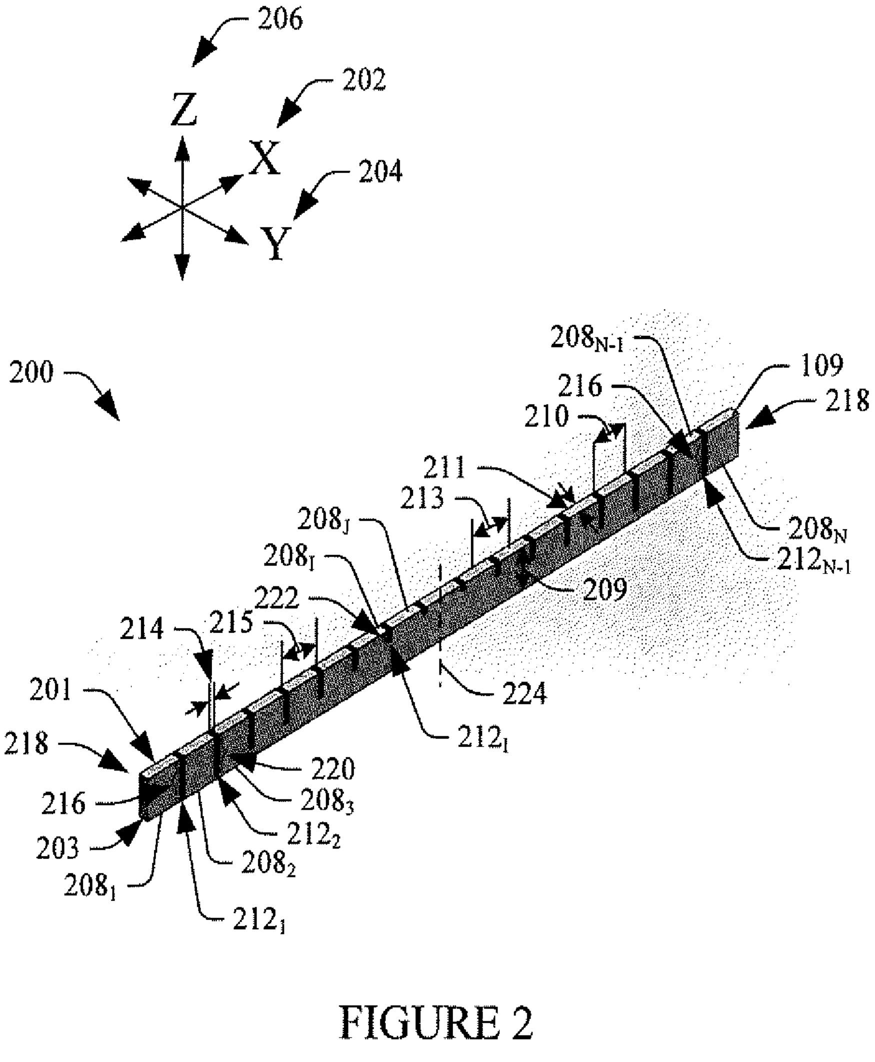

206
202
Z
X
204
Y
200
208N-1
109
216
218
210
211
213
208J
208I
209
208N
212N-1
222
215
214
224
201
212I
218
220
216
2083
2122
203
2082
2081
2121

FIGURE 2

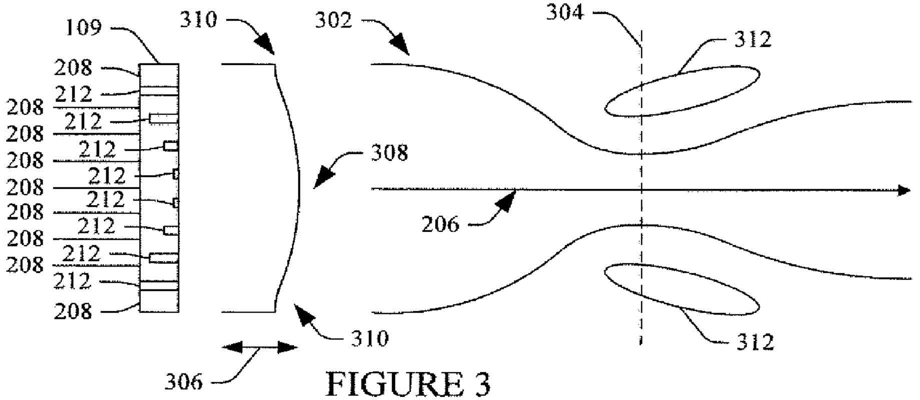


FIGURE 3

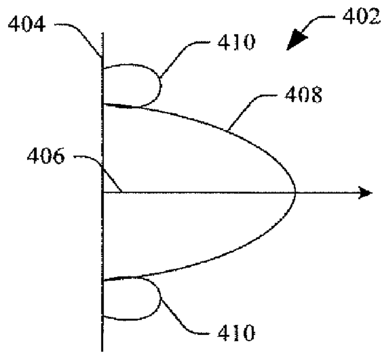


FIGURE 4

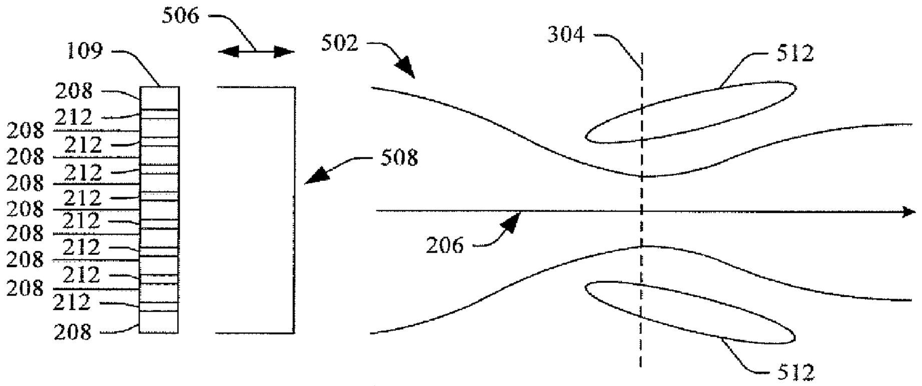


FIGURE 5
(PRIOR ART)

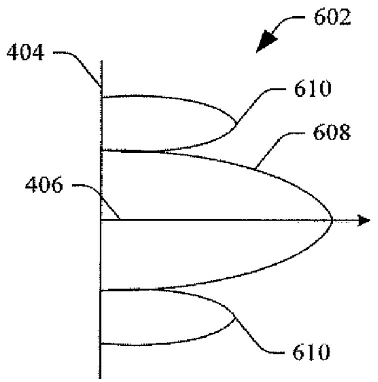


FIGURE 6
(PRIOR ART)

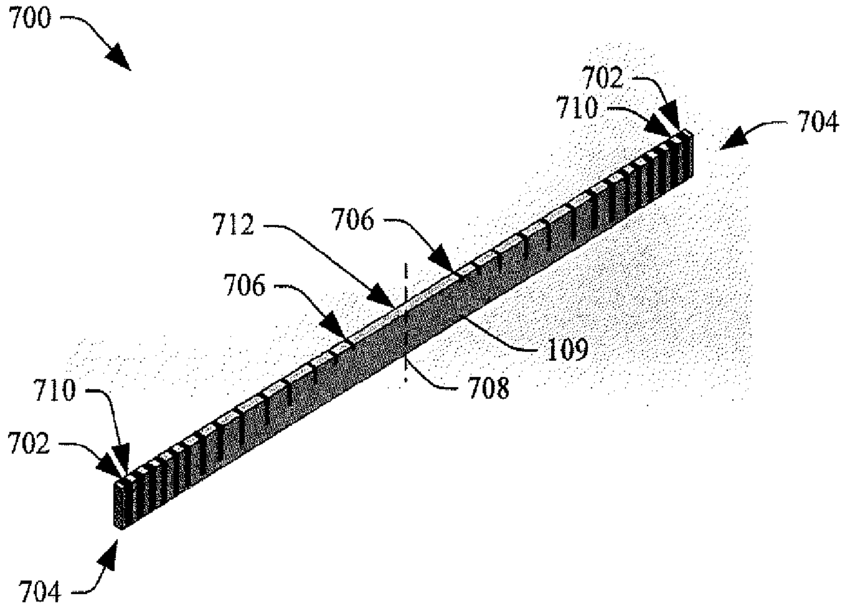


FIGURE 7

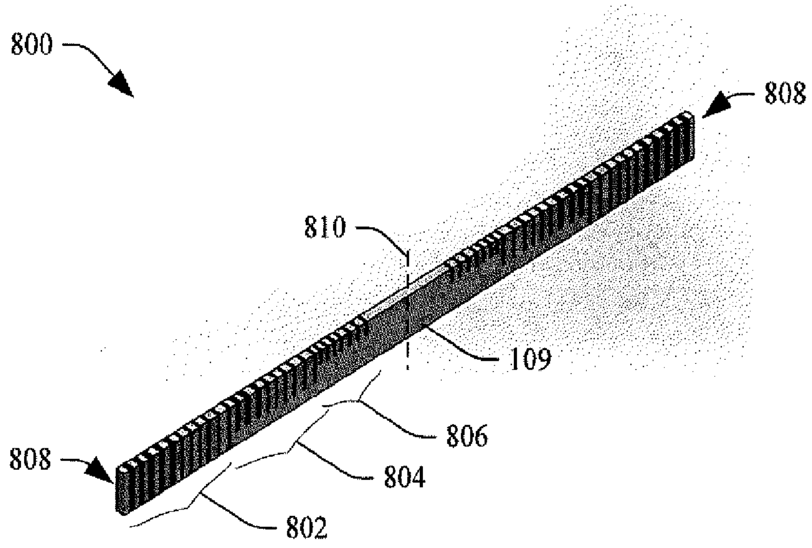


FIGURE 8

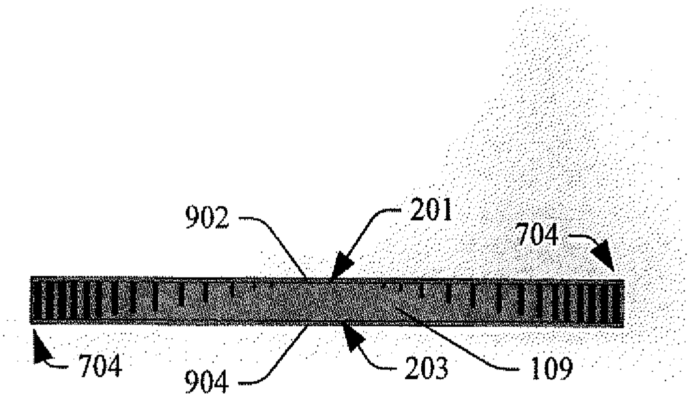


FIGURE 9

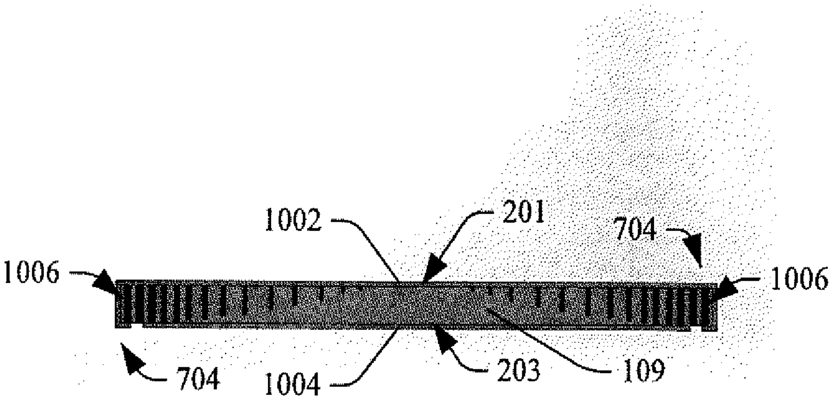


FIGURE 10

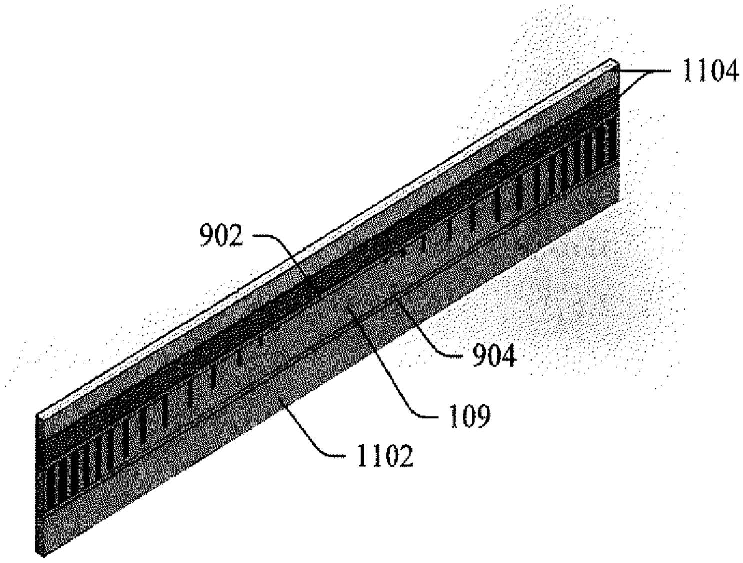


FIGURE 11

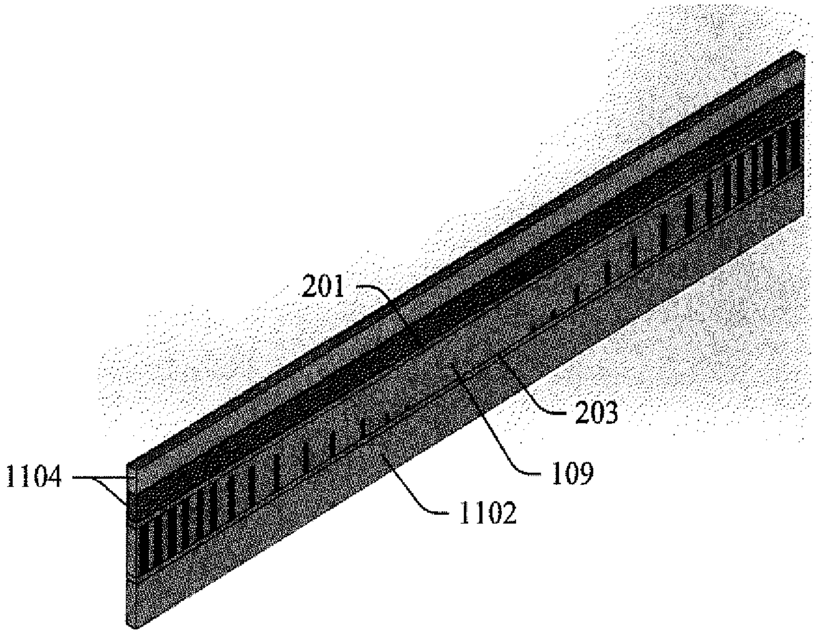


FIGURE 12

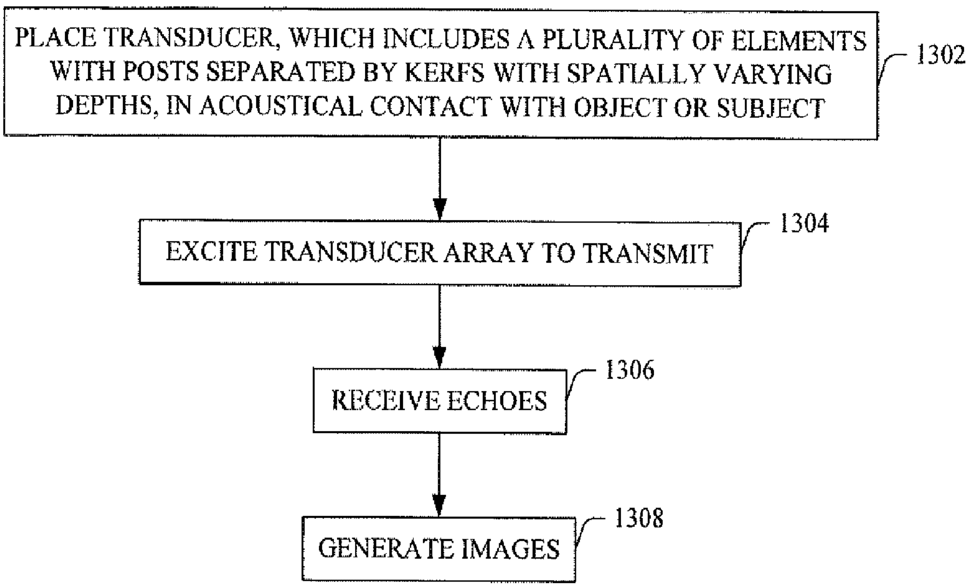


FIGURE 13

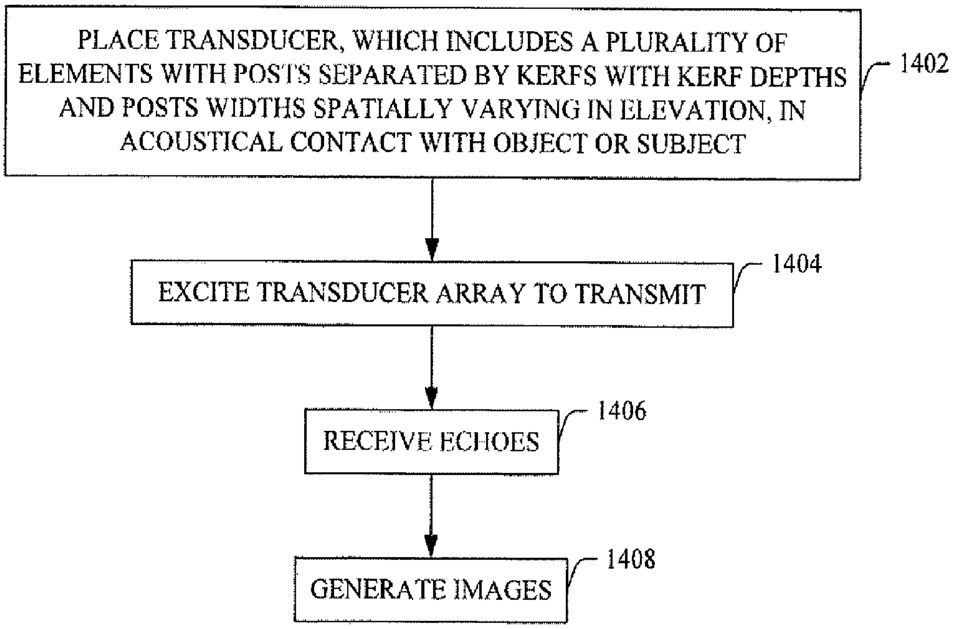


FIGURE 14

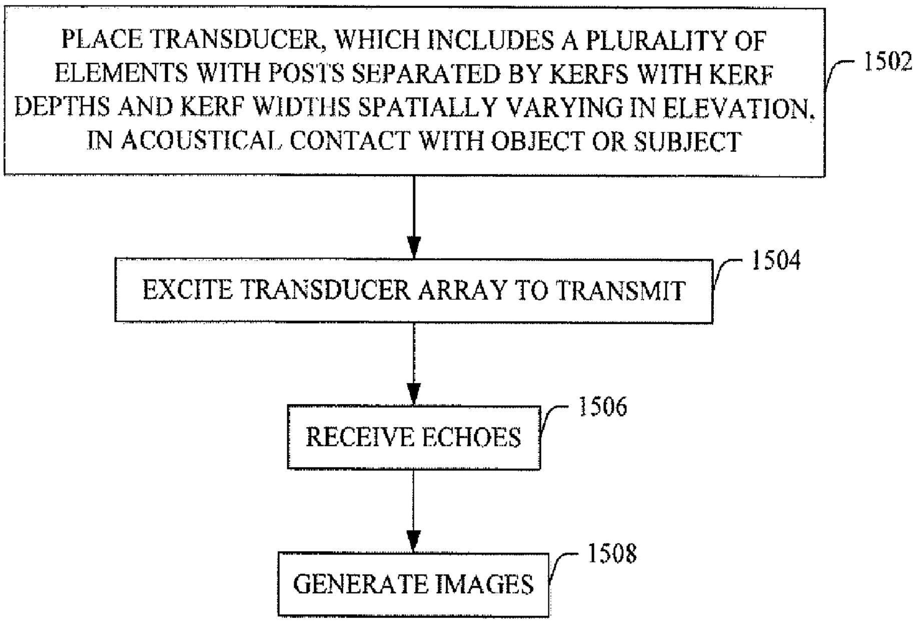


FIGURE 15

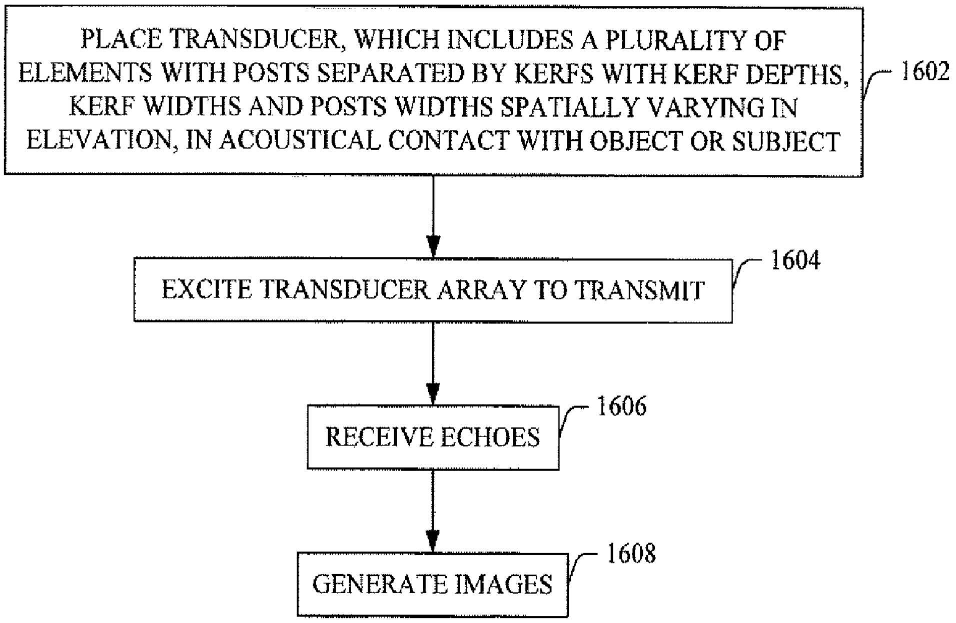


FIGURE 16

FIGURE 17

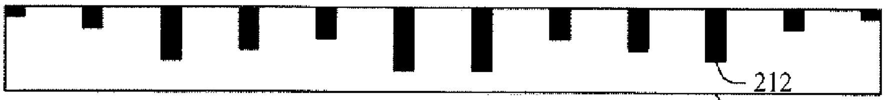


FIGURE 18

FIGURE 19

FIGURE 20

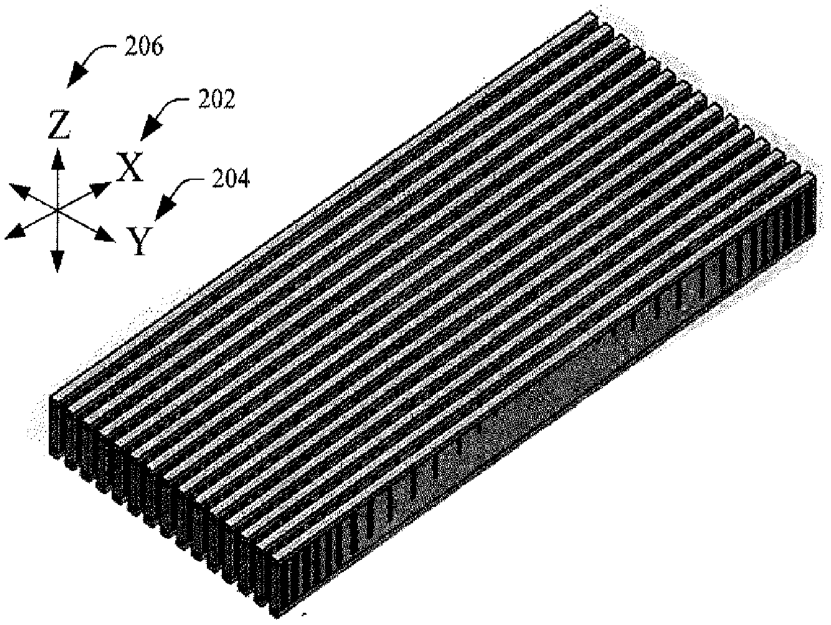


FIGURE 21

ULTRASOUND TRANSDUCER

TECHNICAL FIELD

[0001] The following generally relates to an ultrasound transducer and is described with particular application herein to ultrasound imaging.

BACKGROUND

[0002] Ultrasound (US) image quality is adversely affected by the spread of the acoustic energy perpendicular to the imaging plane. Energy that spreads outside of this plane degrades the image by capturing confounding features in the image, thereby reducing the overall image signal-to-noise ratio. Ideally, the energy would be narrower and collimated in the imaging plane. However, with one-dimensional arrays, some non-negligible fraction of the radiated energy spreads outside of the imaging plane.

[0003] The out-of-plane energy can be in the form of general spreading of the central on-axis energy lobe or as discrete sidelobes. The energy tends to spread increasingly at greater depths, so deep imaging applications (with a large abdominal probe, for instance) may be particularly susceptible to sidelobes. Also, when the features are very small (for example, applications that might call for a high-frequency linear probe), excess image clutter induced by out-of-plane energy is especially unhelpful.

[0004] Ultrasound image quality is also affected by the variation of the focal depth across the frequency range. Tissue attenuation is greater for higher frequencies, so the higher frequencies emitted by the array are attenuated more than the lower frequencies. Consequently, the higher frequencies are generally more useful for shallower imaging since their penetration is limited by the tissue attenuation, and the lower frequencies are more useful for deeper imaging since the low-frequency penetration is greater.

[0005] A transducer array has relatively uniform frequency response across its elevation and a natural focus, which typically is wider and deeper than desired. An acoustic lens provides a narrower focus at a depth of interest. The geometric focal depth applied by the acoustic lens is mostly independent of frequency, but the natural focal depth increases with increasing frequency. As a result, the net acoustic focal depth is shallower for lower frequencies and deeper for higher frequencies, which, unfortunately, is opposite the desired relationship between focal depth and frequency established by tissue attenuation.

SUMMARY

[0006] Aspects of the application address the above matters, and others.

[0007] In one aspect, an imaging probe includes a transducer array, with transducer elements with parallel first and second planar surface in which an ultrasound signal is emitted from the first planar surface, a transducer element, including: a plurality of transducing sub-elements arranged along an elevation direction in which adjacent transducing sub-elements are separated from leach other by kerfs of non-transducing material, wherein depths of the kerfs vary along the elevation direction.

[0008] In another aspect, a method includes exciting a transducer array, thereby producing an ultrasound beam that traverses an examination field of view, wherein the transducer array elements include a plurality of sub-elements arranged along an elevation direction wherein each element in elevation has kerfs of non-transducing material located between sub-elements, wherein depths of the kerfs vary along the elevation direction.

[0009] In another aspect, an ultrasound imaging system includes an imaging probe with transducer array elements that include sub-elements arranged along an elevation direction in which adjacent sub-elements are separated from each other by kerfs of non-transducing material with depths that extend only part way through the sub-elements and a console in electrical communication with the imaging probe, wherein the console controls transmission of an ultrasound signal by the array and processes echoes received by the array.

[0010] Those skilled in the art will recognize still other aspects of the present application upon reading and understanding the attached description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The application is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0012] FIG. **1** schematically illustrates an example imaging probe with a transducer array in connection with an imaging console.

[0013] FIG. **2** schematically illustrates an example of a transducer element of the transducer array of FIG. **1** in which the element includes spatially varying kerf depths.

[0014] FIG. **3** shows an excitation profile of the transducer element of FIG. **2**.

[0015] FIG. **4** shows a pressure profile at a focus depth for the excitation profile of FIG. **3**.

[0016] FIG. **5** shows an excitation profile of a prior art transducer element with equal or no kerfs.

[0017] FIG. **6** shows a pressure profile at a focus depth for the excitation profile of FIG. **5**.

[0018] FIG. **7** schematically illustrates another example of the transducer element in which the element includes spatially varying kerf depths (continuous), kerf widths, and post widths.

[0019] FIG. **8** schematically illustrates another example of the transducer element in which the element includes spatially varying kerf depths (discrete), kerf widths, and post widths.

[0020] FIG. **9** schematically illustrates the transducer element of FIG. **7** in connection with a first electrode configuration.

[0021] FIG. **10** schematically illustrates the transducer element of FIG. **7** in connection with another electrode configuration.

[0022] FIG. **11** schematically illustrates the transducer element of FIG. **7** in connection with electrodes, a backing support, and multiple layers of impedance matching layers.

[0023] FIG. **12** schematically illustrates another transducer element in connection with electrodes, a backing support, and multiple layers of impedance matching layers.

[0024] FIG. **13** illustrates an example method in accordance with an example imaging probe having varying kerf depths.

[0025] FIG. **14** illustrates an example method in accordance with an example imaging probe having varying kerf depths and varying post widths.

[0026] FIG. **15** illustrates an example method in accordance with an example imaging probe having varying kerf depths and varying kerf widths.

[0027] FIG. **16** illustrates an example method in accordance with an example imaging probe having varying kerf depths, varying kerf widths, and varying post widths.

[0028] FIG. **17** illustrates an embodiment in which a transducer element has kerf depths that increase monotonically from outer edges to a central region, symmetrically about the central region.

[0029] FIG. **18** illustrates an embodiment in which a transducer element has kerf depths that vary symmetrically about a central region, but not monotonically between outer edges and the central region.

[0030] FIG. **19** illustrates an embodiment in which a transducer element has kerf depths that vary asymmetrically about a central region, but not monotonically between outer edges and the central region.

[0031] FIG. **20** illustrates an embodiment in which a transducer element has equal kerf depths that do not extend completely through the sub-element.

[0032] FIG. **21** illustrates an embodiment in which a plurality of sub-elements are arranged to form a 1D array of sub-elements.

DETAILED DESCRIPTION

[0033] FIG. **1** illustrates a non-limiting example imaging system **100** such as an ultrasound imaging system. The imaging system **100** includes an imaging probe **102** and an imaging console **104**, which are in electrical communication through a communications channel **106**.

[0034] The imaging probe **102** includes a one dimensional transducer array **108** consisting of at least one transducer (e.g., piezoelectric) elements **109**. As described in greater detail below, in one non-limiting instance, a shape of an element **109** in transducer array **108** is a rectangular prism or parallelepiped and includes a plurality of transducer (e.g., piezoelectric) sub-elements or posts, which are separated from each other by kerfs filled with a passive or non-transducing material. In one instance, depths of the kerfs spatially vary in size, continuously or in discrete steps, across an elevation direction, from deeper to shallower, from ends of the element **109** towards a central region of the element **109**. Additionally or alternatively, widths of the kerf and/or widths of the posts likewise spatially vary in size across the elevation direction.

[0035] In one non-limiting instance, such spatial variations lead to a spatially-varying response in magnitude of the element **109**. For example, regions with deeper kerfs have less vibration relative to regions with shallower kerfs. As such, the magnitude of the excitation energy rolls off nearer the ends of the element **109** relative to the central region of the element **109**, thereby mitigating side lobes and improving image quality. The spatial variations also lead to a spatially-varying response in frequency of the element **109**. For example, regions with deeper kerfs have a lower resonance frequency relative to regions with shallower kerfs. As such, the probe **102** is well-suited for both deep (lower frequency) and shallow (higher frequency) imaging applications.

[0036] The imaging console **104** includes a transmit circuit **112** that controls phasing and/or time of excitation of the elements of the transducer array **108**, which allows for steering and/or focusing the transmitted beam from predetermined origins along the array and at predetermined angles. The ultrasound imaging console **104** also includes receive circuit **114** that receives the echoes received by the transducer array **108**. For B-mode and/or other applications, the receive circuit **114** beamforms (e.g., delays and sums) the echoes from the transducer elements into a sequence of focused, coherent echo samples along focused scanlines of a scanplane. In other embodiments, the receive circuit **114** otherwise processes the echoes. Examples of other imaging techniques include, but are not limited to, synthetic aperture, shear wave elastography, etc., which may employ other computational approaches.

[0037] A controller **116** of the ultrasound imaging console **104** controls the transmit circuit **112** and/or the receive circuit **114**. Such control may include, but is not limited to, controlling the frame rate, number of scanline groups, transmit angles, transmit energies, transmit frequencies, transmit and/or receive delays, the imaging mode (e.g., B-mode, C-mode, Doppler, etc.), etc. A user interface **118** includes various input and/or output devices for interacting with the controller **116**, for example, to select a data acquisition mode, a data processing mode, a data presentation mode, etc. The user interface **118** may include various controls such as buttons, knobs, a keypad, a touch screen, etc. The user interface **118** may also include various types of visual and/or audible indicators.

[0038] A scan converter **120** of the ultrasound imaging console **104** scan converts the frames of data to generate data for display, for example, by converting the data to the coordinate system of the display. The scan converter **120** can be configured to employ analog and/or digital scan converting techniques. A display **122** can be used to present the acquired and/or processed data. Such presentation can be in an interactive graphical user interface (GUI), which allows the user to selectively rotate, scale, and/or manipulate the displayed data. Such interaction can be through a mouse or the like and/or a keyboard or the like. The display **122** can alternatively be remote from the console **104**.

[0039] FIG. **2** illustrates a perspective view **200** of an example of the transducer element **109** in elevation, azimuth and depth directions **202**, **204** and **206**. The transducer element **109** is a rectangular prism with planar surfaces **201** and **203** that extend parallel to each other along the elevation direction **202**, where the ultrasound beam is emitted toward the patient from the surface **201**. Of course, some ultrasound energy also travels away from the patient.

[0040] The transducer element **109** includes N transducing sub-elements or posts $\mathbf{208}_1$, $\mathbf{208}_2$, $\mathbf{208}_3$, . . . , $\mathbf{208}_I$, $\mathbf{208}_J$, . . . , $\mathbf{208}_{N-1}$, $\mathbf{208}_N$ (where N is an integer), collectively referred to herein as posts **208**. In the illustrated example, a height **209** (depth direction) of the posts **208** is greater than widths **210** (elevation direction) of the posts **208**, which is greater than thicknesses **211** (azimuth direction) of the posts. In this example, all of the posts **208** have the same height **209**, the same width **210** and a same pitch **213** (center to center distance). In a variation, at least two posts **208** have a different height **209** and/or same width **210**, and/or a same pitch **213** relative to another pair of posts **208**.

[0041] The posts **208** are separated by N−1 kerfs $\mathbf{212}_1$, $\mathbf{212}_2$, . . . , $\mathbf{212}_I$, . . . $\mathbf{212}_{N-1}$, collectively referred to herein as kerfs **212**, which include a non-transducing material. Likewise, the kerfs **212** have a same width **214** and a same pitch **215**, and thickness equal to the thickness **211** of the posts **208**. However, in the illustrated embodiment, depths of kerfs **212** vary along the elevation direction **202**, with greater depths **216** at end regions **218** and decreasing depths **220** and **222** approaching a central region **224**. In other embodiments, as discussed in greater detail below, the depths of the kerfs **212** vary along the elevation direction, with greater depths at the central region, decreasing towards the end regions, the depths of kerfs **212** vary along the elevation direction neither monotonically increasing nor monotonically decreasing, the depths of the kerfs vary along the elevation direction symmetrically or asymmetrically, etc.

[0042] In the illustrated example, the depths of kerfs **212** vary symmetrically about the central region **224**. In a variation, the depths of kerfs **212** vary asymmetrically about the central region **224**. Furthermore, in the illustrated example, the change in the depths of the kerf **212** from the ends **218** to the central region **224** is smooth and gradual. In a variation, the depths of kerfs **212** vary in groups in a step-wise manner. As described below, in other embodiments, the kerf width **214** and/or the post width **210** may also vary across the elevation dimension.

[0043] FIG. **3** illustrates an excitation energy distribution of the example transducer element **109** of FIG. **2** and a resulting beam profile **302** at a given focus depth **304**, and FIG. **4** shows a magnitude profile **402** across the beam profile **302** at the focus depth **304**.

[0044] In FIG. **3**, the variable depth kerfs **212** produce an excitation profile **306** that rolls off from a central region **308** to end regions **310**. As discussed herein, vibration, generally, is inversely proportional to kerf depth in that there is less vibration in portions of the element **109** in which the kerf depths are greater and vice versa. In the illustrated embodiment, kerfs depths are greater at the end regions **310**, hence, the lower magnitude. FIG. **3** also shows out-of-plane energy **312** for the excitation profile **306**. In FIG. **4**, a y-axis **404** represents elevation and an x-axis **406** represents magnitude. The profile **402** includes a main lobe **408** and side lobes **410**, which corresponds to the out-of-plane energy **312**.

[0045] For comparative purposes, FIGS. **5** and **6** show a configuration of the transducer element in which the kerfs **212** have equal depth along the elevation direction and thus equal vibration, resulting in an excitation profile **506** with a constant magnitude **508**. (A transducer element with no kerfs will also produce an excitation profile with a constant magnitude.) Likewise, a beam profile **502** is focused at the focus depth **304**. In this embodiment, out-of-plane energy **512** is greater relative to the out-of-plane energy **312** of FIG. **3**. As a result, as shown in FIG. **6**, the profile **602** includes a main lobe **608** with a greater peak magnitude and a narrower width and side lobes **610** that are larger, relative to the main lobe **408** and side lobes **410** of FIG. **4**.

[0046] FIG. **7** illustrates perspective view **700** of another non-limiting example of the transducer element **109**. In FIG. **7**, kerfs vary in depth, as discussed herein. However, kerf widths also vary in size across elevation, from larger widths **702** at ends **704** of the element **109** and smaller widths **706** nearer a central region **708** of the element **109**. Similar to FIG. **2**, the kerf widths gradually decrease from the ends **704** to the central region **708**. In this example, post widths also vary in size across elevation, however, from smaller widths **710** at the ends **704** of the element **109** to a largest width **712** at the central region **708** of the element **109**. As a consequence of either or both, there is a decrease in the fractional amount of transducing material as the ends **704** relative the central region **708**, and thus, further decrease in vibration at the ends **704**.

[0047] FIG. **8** illustrates perspective view **800** of another non-limiting example of the transducer element **109**. In FIG. **8**, kerfs vary in depth, as discussed herein, except that depths of sets of kerfs **802**, **804** and **806** decrease in discrete step-sizes from the ends **808** to the central region **810**, such that the kerfs of the posts in set **802** are taller than the kerfs of the posts in set **806**, ... Similar to FIG. **7**, kerf widths also vary in size; however, in this example, kerfs widths vary across each of the sets of kerfs **802**, **804** and **806**. These kerf widths may vary in a continuous or discrete manner. Likewise, post widths vary in size across each of the sets of kerfs **802**, **804** and **806**. These post widths may also vary in a continuous or discrete manner. In a variation, the kerf widths and/or post widths may not vary across one or more of the sets.

[0048] In FIG. **2**, kerf depths decrease monotonically from the outer edges of the element **109** to the central region and are symmetric about the central region. In FIG. **17**, the kerfs **212** have depths that increase monotonically from the outer edges of the element **109** to the central region and are symmetric about the central region. In FIG. **18**, the kerfs **212** have depths that do not vary monotonically between the outer edges and the central region, but are symmetric about the central axis. In FIG. **19**, the kerfs **212** have depths that do not vary monotonically between the outer edges and the central region and vary asymmetrically about the central axis. In FIGS. **17-19**, kerf widths are equal and post widths are equal. However, at least two kerf widths may not be equal and/or at least two post widths may not be equal. In FIG. **20**, kerf depths are equal and do not extend completely through the element **109**, and neither kerf widths nor post widths are equal. In a variation, one or both the kerf widths or the post widths can be equal.

[0049] FIG. **9** illustrates the transducer element **109** with electrodes **902** and **904** affixed thereto. In this example, the electrode **902** is affixed to the surface **201** and extends between the ends **704**, and the electrode **904** is affixed to the surface **203** and extends between the ends **704**. With the configuration, the electrodes **902** and **904** are located on opposing sides of the element **109** and electrical connections thereto are on opposing sides of the element **109**.

[0050] FIG. **10** illustrates another example of the transducer element **109** but with electrodes **1002** and **1004** affixed thereto. In this example, the electrode **1002** is affixed to the surface **201** and extends along sides **1006** of the element **109** and between the ends **704**, whereas the electrode **1002** is affixed to the surface **203** and extends along a sub-portion of the element **109** between the ends **704**. With the configuration, although the electrodes **1002** and **1004** are located on opposing sides of the element **109**, electrical connections thereto can be on opposing sides or the same side of the element **109**.

[0051] It is to be understood that the electrode configurations of FIGS. **9** and **10** are provided for explanatory purposes and are not limiting, and other approaches are also contemplated herein.

[0052] FIG. **11** shows the transducer element **109** of FIG. **9**, with a backing layer or support **1102** affixed to the electrode **904** and a plurality of passive layers **1104** (two shown, but more or less can be included) affixed to the electrode **902**. An acoustic lens (not shown) can be affixed to the plurality of passive layers **1104** to provide geometric focus. The plurality of passive layers **1104** and/or acoustic lens provides an impedance matching layer with skin of a subject being scanned. A gel or other fluid can be applied between the passive layers **1104** and the skin.

[0053] FIG. **12** is substantially similar to FIG. **11** except that the kerfs **212** extend from the surface **203** and in to element **109** instead of from the surface **201** and in to element **109**. In yet another instance, a sub-set of the kerfs **212** extend from the surface **201** and into element **109** and another sub-set of the kerfs extend from the surface **203** and into the element **109**.

[0054] Although the above examples include a rectangular prism shaped element **109**, it is to be appreciated that the element **109** can be non-rectangular, for example, the surface **201** can be concave, convex, and/or otherwise shaped such that the element **109** is non-rectangular. In one or more of these configurations, even greater control over the spatial field characteristics can be accomplished. However, the rectangular embodiment may provide a more-easily-controlled manufacturing process.

[0055] FIG. **21** shows the element **109** of FIG. **9** in connection with a plurality of other elements **109** of FIG. **9** arranged in a one dimensional (1D) array. Again, reference numeral **204** represents the azimuth direction and reference numeral **202** represents the elevation direction. It is to be appreciated the elements **109** can also be arranged in a two dimensional (2D) array.

[0056] FIG. **13** illustrates a method in accordance with the imaging probe **102** described herein.

[0057] At **1302**, a transducer array, which includes a plurality of elements **109** with transducing posts separated by non-transducing kerfs with depths that spatially vary (continuously or in discrete steps), is placed in acoustical contact with a subject or object.

[0058] At **1304**, the transducer array is excited to transmit an ultrasound beam into the subject or object.

[0059] At **1306**, the transducer array receives echoes produced in response to the ultrasound beam reflecting off structure in the subject or object.

[0060] At **1308**, the echoes are processed to generate one or more images of the subject or object.

[0061] FIG. **14** illustrates another method in accordance with the imaging probe **102** described herein.

[0062] At **1402**, a transducer array, which includes a plurality of elements **109** with transducing posts separated by non-transducing kerfs, wherein depths of the kerfs and widths of the posts spatially vary (continuously or in discrete steps), is placed in acoustical contact with a subject or object.

[0063] At **1404**, the transducer array is excited to transmit an ultrasound beam into the subject or object.

[0064] At **1406**, the transducer array receives echoes produced in response to the ultrasound beam reflecting off structure in the subject or object.

[0065] At **1408**, the echoes are processed to generate one or more images of the subject or object.

[0066] FIG. **15** illustrates another method in accordance with the imaging probe **102** described herein.

[0067] At **1502**, a transducer array, which includes a plurality of elements **109** with transducing posts separated by non-transducing kerfs, wherein depths and widths of the kerfs spatially vary (continuously or in discrete steps), is placed in acoustical contact with a subject or object.

[0068] At **1504**, the transducer array is excited to transmit an ultrasound beam into the subject or object.

[0069] At **1506**, the transducer array receives echoes produced in response to the ultrasound beam reflecting off structure in the subject or object.

[0070] At **1508**, the echoes are processed to generate one or more images of the subject or object.

[0071] FIG. **16** illustrates another method for in accordance with the imaging probe **102** described herein.

[0072] At **1602**, a transducer array, which includes a plurality of elements **109** with transducing posts separated by non-transducing kerfs, wherein depths and widths of the kerfs and widths of the posts spatially vary (continuously or in discrete steps), is placed in acoustical contact with a subject or object.

[0073] At **1604**, the transducer array is excited to transmit an ultrasound beam into the subject or object.

[0074] At **1606**, the transducer array receives echoes produced in response to the ultrasound beam reflecting off structure in the subject or object.

[0075] At **1608**, the echoes are processed to generate one or more images of the subject or object.

[0076] It is to be appreciated that the order of the above acts is provided for explanatory purposes and is not limiting. As such, one or more of the following acts may occur in a different order. Furthermore, one or more of the following acts may be omitted and/or one or more additional acts may be added.

[0077] In addition, the methods herein may be implemented by one or more processors executing computer executable instructions stored, encoded, embodied, etc. on computer readable storage medium such as computer memory, non-transitory storage, etc. In another instance, the computer executable instructions are additionally or alternatively stored in transitory or signal medium.

[0078] The application has been described with reference to various embodiments. Modifications and alterations will occur to others upon reading the application. It is intended that the invention be construed as including all such modifications and alterations, including insofar as they come within the scope of the appended claims and the equivalents thereof.

1. An imaging probe, comprising:

a transducer array, with transducer elements with parallel first and second planar surface in which an ultrasound signal is emitted from the first planar surface, a transducer element, including: a plurality of transducing sub-elements arranged along an elevation direction in which adjacent transducing sub-elements are separated from leach other by kerfs non-transducing material, wherein depths of the kerfs vary along the elevation direction.

2. The imaging probe of claim **1**, wherein a shape of the element is a rectangular prism.

3. The imaging probe of claim **1**, wherein a depth of a kerf located nearer an end region of the array is greater than a depth of a kerf located nearer a central region of the array.

4. The imaging probe of claim **1**, wherein the depths of the kerf vary symmetrically along the elevation direction.

5. The imaging probe of claim **1**, wherein the depths of the kerf vary from kerf to kerf.

6. The imaging probe of claim **1**, wherein the depths of the kerfs vary from sub-set to sub-set of kerfs, wherein a sub-set includes at least two kerfs having a same depth.

7. The imaging probe of claim **1**, wherein the kerfs extend from the first planar surface into the array.

8. The imaging probe of claim **1**, wherein the kerfs extend from the second planar surface into the array.

9. The imaging probe of claim **1**, wherein a first sub-set of the kerfs extend from the first planar surface into the array and a second sub-set of the kerfs extend from the second planar surface into the array.

10. The imaging probe of claim **1**, wherein the kerfs have a same width in the elevation direction and the transducing elements have a same width in the elevation direction.

11. The imaging probe of claim **1**, wherein at least two of the kerfs have a different width in the elevation direction and the transducing sub-elements have a same width in the elevation direction.

12. The imaging probe of claim **1**, wherein the kerfs have a same width in the elevation direction and at least two of the transducing sub-elements have different widths in the elevation direction.

13. The imaging probe of claim **1**, wherein at least two of the kerfs have a different width in the elevation direction and at least two of the transducing sub-elements have different widths in the elevation direction.

14. A method, comprising:

exciting a transducer array, thereby producing an ultrasound beam that traverses an examination field of view, wherein the transducer array elements include a plurality of sub-elements arranged along an elevation direction wherein each element in elevation has kerfs of non-transducing material located between sub-elements, wherein depths of the kerfs vary along the elevation direction.

15. The method of claim **14**, wherein the depths of the kerf vary from kerf to kerf.

16. The method **14**, wherein the depths of the kerfs vary from sub-set to sub-set of kerfs, wherein a sub-set includes at least two kerfs having a same depth.

17. The method of claim **14**, wherein at least two of the kerfs have a different width in the elevation direction.

18. The method of claim **14**, wherein at least two of the transducing sub-elements have different widths in the elevation direction.

19. The method of claim **14**, wherein an excitation profile of the ultrasound beam has at least one of a greater magnitude or a response at higher frequency near a central region of the array.

20. An ultrasound imaging system, comprising:

an imaging probe with transducer array elements that include sub-elements arranged along an elevation direction in which adjacent sub-elements are separated from each other by kerfs of non-transducing material with depths that extend only part way through the sub-elements; and

a console in electrical communication with the imaging probe, wherein the console controls transmission of an ultrasound signal by the array and processes echoes received by the array.

21. The ultrasound imaging system of claim **20**, wherein the depths vary along the elevation direction.

22. The ultrasound imaging system of claim **21**, wherein the depths of the kerfs vary monotonically from outer edges of a sub-element to a central region of the sub-element.

23. The ultrasound imaging system of claim **21**, wherein the depths of kerfs nearer the outer edges are greater than the depths of the kerfs nearer the central region.

24. The ultrasound imaging system of claim **21**, wherein the depths of kerfs nearer the central region are greater than the depths of the kerfs nearer the outer edges.

25. The ultrasound imaging system of claim **21**, wherein the depths of the kerfs do not vary monotonically between outer edges of a sub-element to a central region of the sub-element.

26. The ultrasound imaging system of claim **20**, wherein the depths vary symmetrically about the central region.

27. The ultrasound imaging system of claim **20**, wherein the depths vary asymmetrically about the central region.

28. The ultrasound imaging system of claim **20**, wherein the sub-elements are rectangular in shape.

29. The ultrasound imaging system of claim **20**, wherein the sub-elements are not-rectangular in shape.

* * * * *

专利名称(译)	超声波传感器		
公开(公告)号	US20150297191A1	公开(公告)日	2015-10-22
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[标]申请(专利权)人(译)	声音技术公司		
申请(专利权)人(译)	SOUND TECHNOLOGY INC.		
当前申请(专利权)人(译)	SOUND TECHNOLOGY INC.		
[标]发明人	BEERS CHRISTOPHER		
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摘要(译)

成像探头包括具有换能器元件（ 109 ）的换能器阵列，其具有平行的第一和第二平面表面（ 201,203 ），其中从第一平面发射超声信号表面。换能器元件包括沿着仰角方向布置的多个换能子元件（ 208 ），其中相邻的换能子元件通过切口彼此分开（ 212 ）非转换材料，其中切口的深度沿着仰角方向变化。