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(54) **ULTRASOUND (US) IMAGING PROBE WITH ROTATING TRANSDUCER ARRAY**

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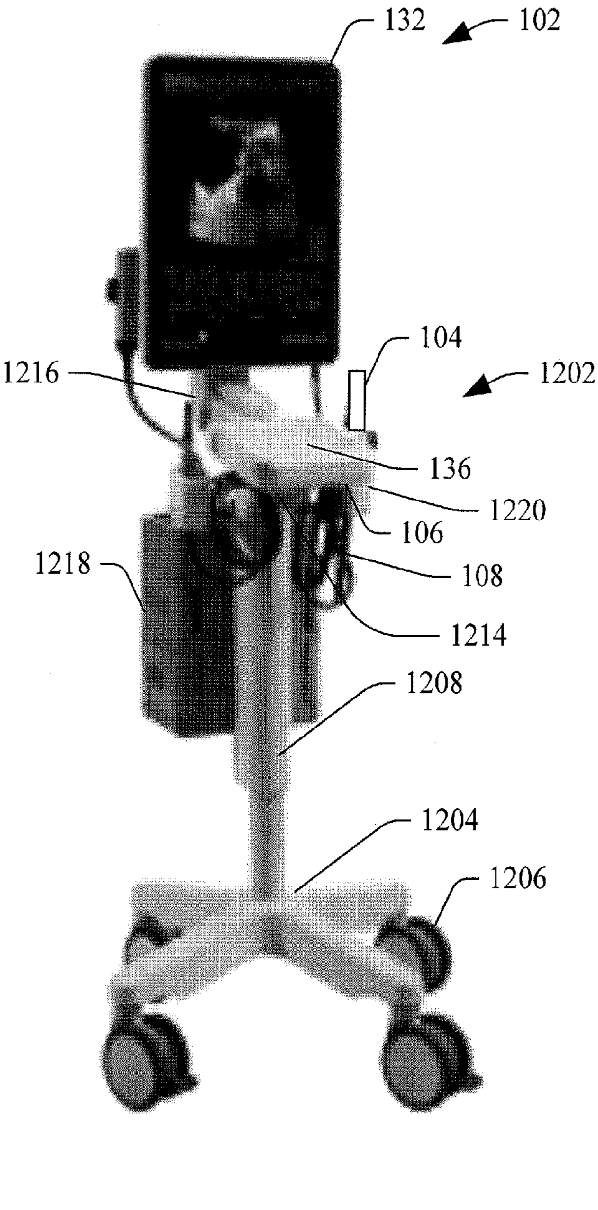
(57) **ABSTRACT**

An ultrasound imaging probe includes a housing having a tubular portion with a first long axis and a first end region having a first non-zero diameter, a non-zero height, and an inner circular perimeter that surrounds a material free region. The probe further includes a transducer array support disposed in the material free region and mechanically supported by the housing. The probe further includes a transducer array with a row of transducer elements with a transducing side and a second long axis. The transducer array is disposed in the material free region such that the second long axis extends within the perimeter and is perpendicular to the first long axis, and is rotatably affixed to the transducer array support on the first long axis with the transducing side facing out of the housing and the transducer array configured to rotate in a plane parallel to the circular inner perimeter.



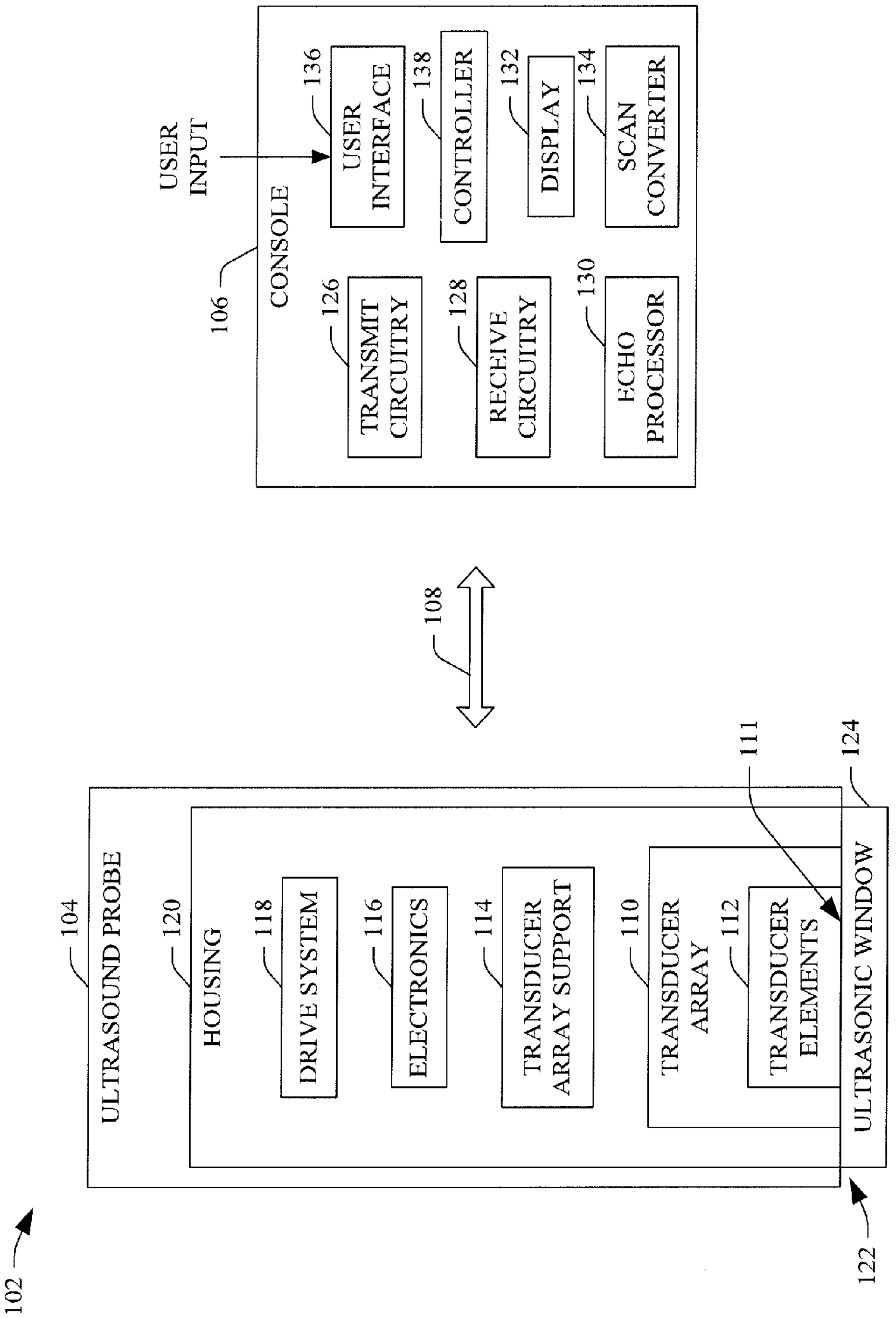

102
ULTRASOUND PROBE
104
HOUSING
120
DRIVE SYSTEM
118
ELECTRONICS
116
TRANSDUCER ARRAY SUPPORT
114
TRANSDUCER ARRAY
110
TRANSDUCER ELEMENTS
112
111
ULTRASONIC WINDOW
124
122
108
CONSOLE
106
USER INPUT
TRANSMIT CIRCUITRY
126
RECEIVE CIRCUITRY
128
ECHO PROCESSOR
130
USER INTERFACE
136
CONTROLLER
138
DISPLAY
132
SCAN CONVERTER
134

FIGURE 1

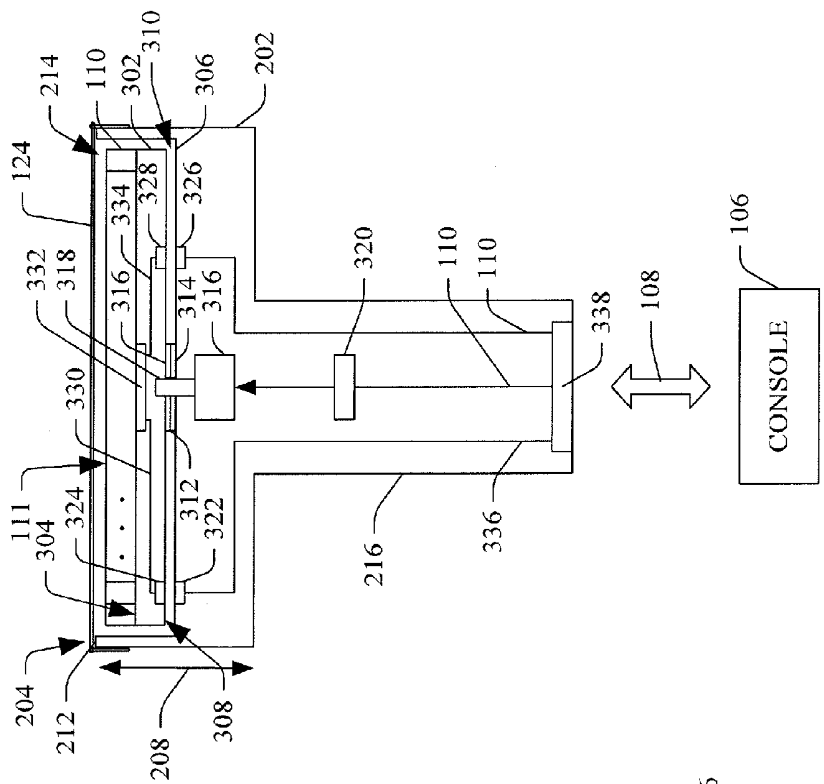


FIGURE 3

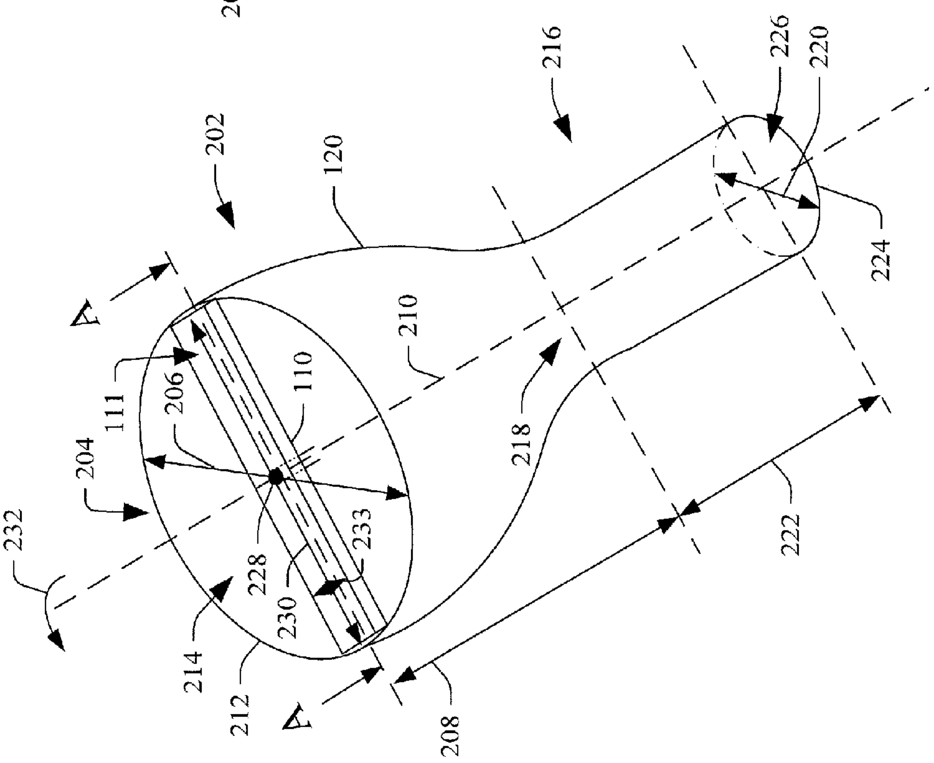


FIGURE 2

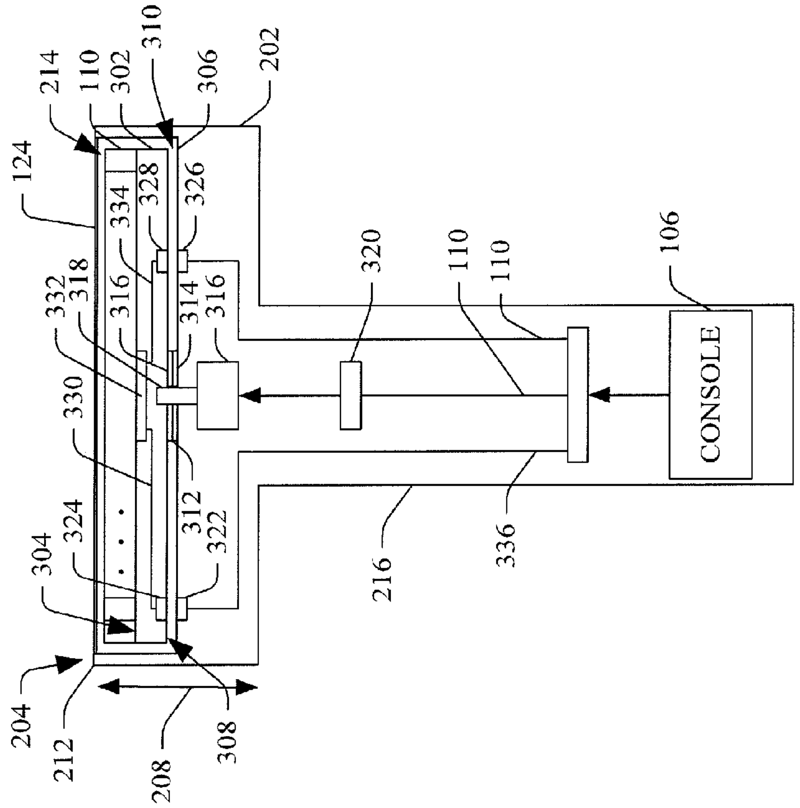


FIGURE 5

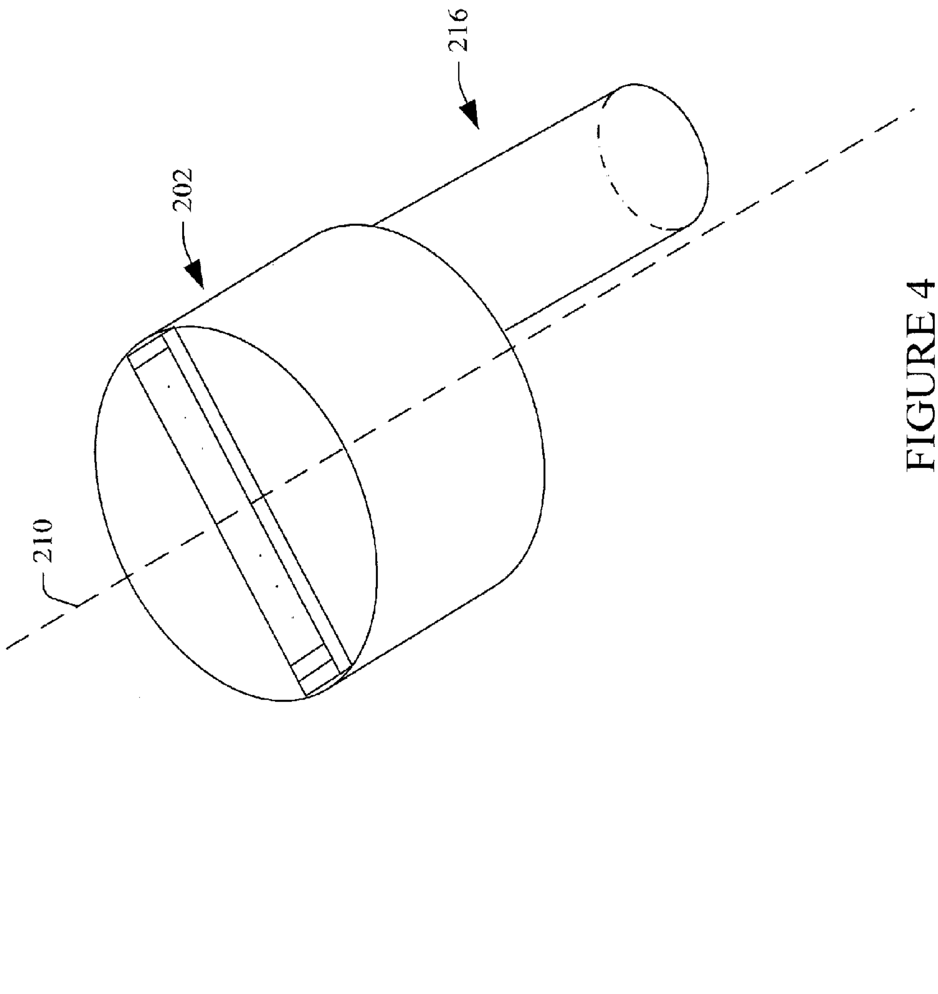


FIGURE 4

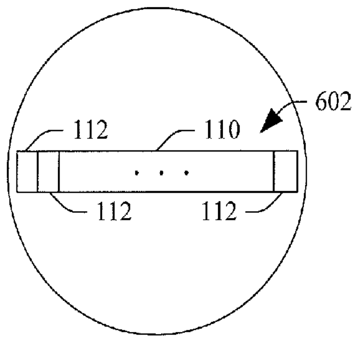


FIGURE 6

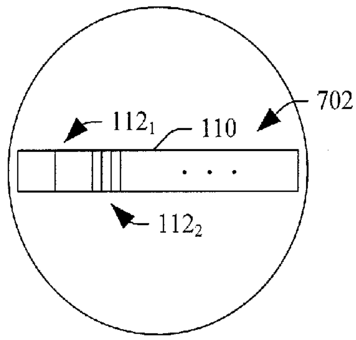


FIGURE 7

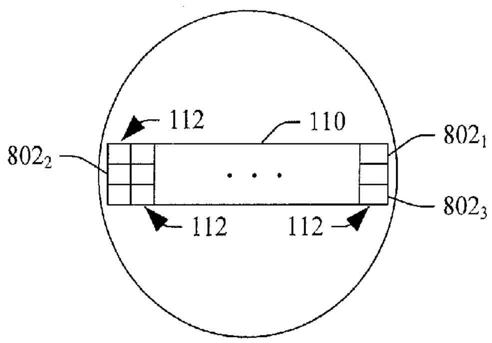


FIGURE 8

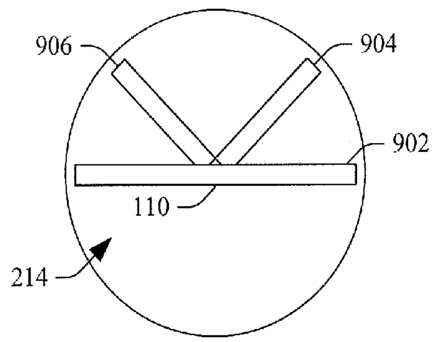


FIGURE 9

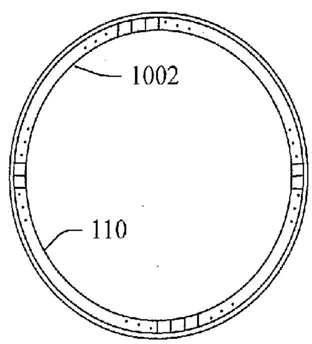


FIGURE 10

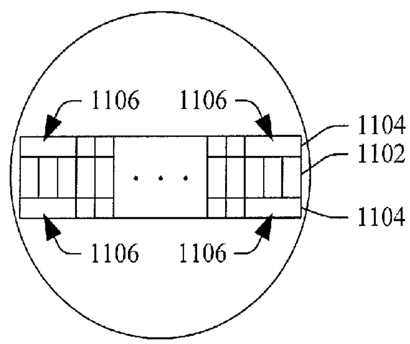


FIGURE 11

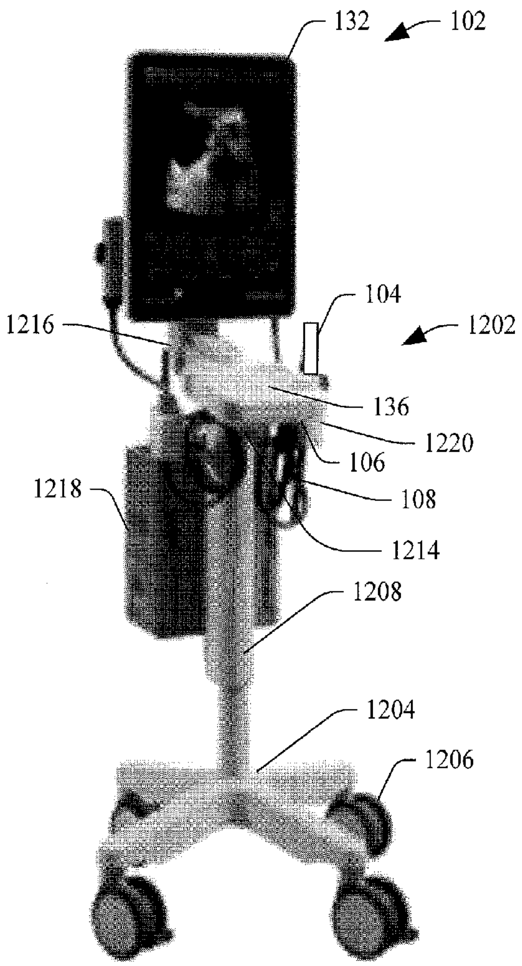


FIGURE 12

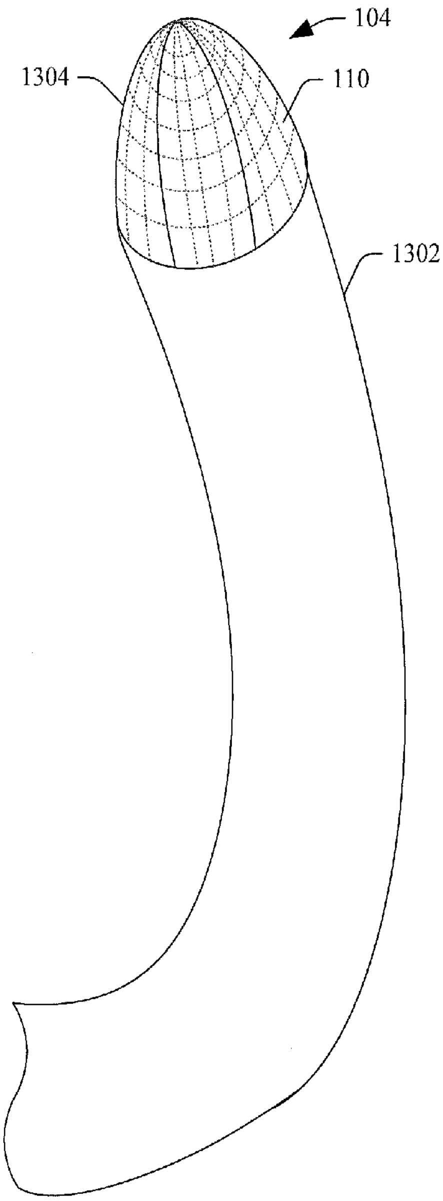


FIGURE 13

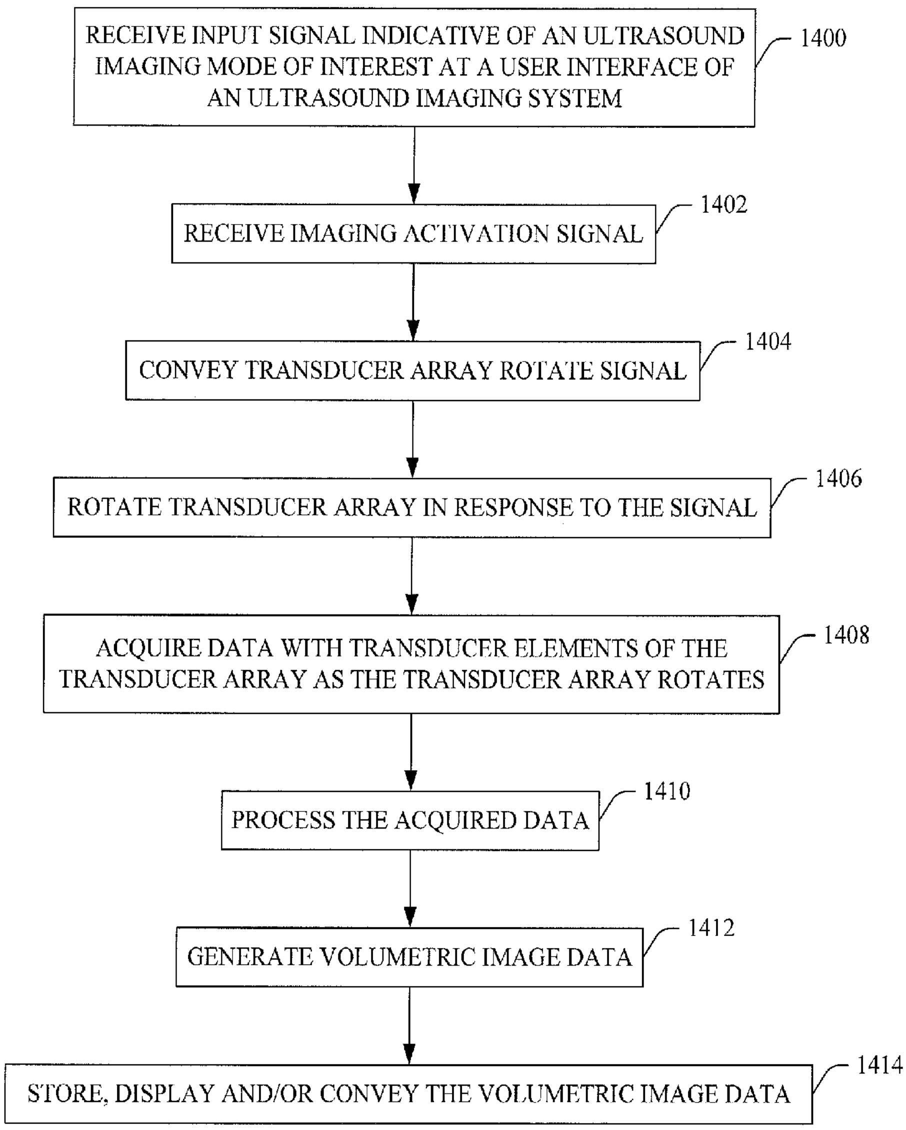

RECEIVE INPUT SIGNAL INDICATIVE OF AN ULTRASOUND IMAGING MODE OF INTEREST AT A USER INTERFACE OF AN ULTRASOUND IMAGING SYSTEM
1400
RECEIVE IMAGING ACTIVATION SIGNAL
1402
CONVEY TRANSDUCER ARRAY ROTATE SIGNAL
1404
ROTATE TRANSDUCER ARRAY IN RESPONSE TO THE SIGNAL
1406
ACQUIRE DATA WITH TRANSDUCER ELEMENTS OF THE TRANSDUCER ARRAY AS THE TRANSDUCER ARRAY ROTATES
1408
PROCESS THE ACQUIRED DATA
1410
GENERATE VOLUMETRIC IMAGE DATA
1412
STORE, DISPLAY AND/OR CONVEY THE VOLUMETRIC IMAGE DATA
1414

FIGURE 14

ULTRASOUND (US) IMAGING PROBE WITH ROTATING TRANSDUCER ARRAY

TECHNICAL FIELD

[0001] The following generally relates to ultrasound (US) imaging and more particularly to volumetric ultrasound imaging with a rotating transducer array.

BACKGROUND

[0002] Ultrasound (US) imaging provides useful information about the interior characteristics (e.g., anatomical tissue, material flow, etc.) of a subject under examination. An ultrasound imaging system has included a probe with an ultrasound transducer array and a console with controls for controlling the transducer elements of the transducer array to transmit an ultrasonic beam and receive echoes produced in response thereto. The console has also included a processor that processes the echoes and a rendering engine which visually displays the processed echoes.

[0003] A 1D transducer array includes a single row of transducer elements. A width of the elements is on the order of a wave length. By controlling the delays and weight coefficients in the beamforming, the focus can be controllably moved along a line. In the elevation direction, the height has been several millimeters. The focusing in the elevation plane is achieved with acoustic lenses, and the focus is generally fixed. The beam is narrowest at the elevation focus and diverges beyond it. Close to the transducer, the beam is as wide as the transducer array, and away from the elevation focus, the beam is wider.

[0004] A 1.5D transducer array has several rows of elements. The effective size of the elements in elevation direction is usually much larger than the width. The outer rows are electrically connected to the middle row. A switch alternately couples outer rows to the middle row, depending on the distance from the transducer surface, creating large elements at large depths. Such arrays have had acoustic lenses that focus the beam in elevation direction. A 1.75D array is similar to a 1.5D array, but each element is connected to a channel. This allows electronic focusing in the elevation direction.

[0005] A 2D transducer array includes a matrix of transducer elements, which allows for volumetric imaging. However, relative to its 1D counterpart, a 2D array includes significantly more transducer elements (e.g., N^2, for a square matrix, compared to N for a single row 1D transducer array), channels and electrical interconnects, increasing complexity and/or the physical footprint, and, unfortunately, tends to be significantly more costly than its 1D counterpart.

SUMMARY

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

[0007] As described herein, a hand-held ultrasound probe includes a rotating transducer for "real-time" volumetric ultrasound imaging, using a sparse array comprising one or several linear arrays; one or several linear arrays comprising a plurality of rows, or one or several arrays of ultrasound transducer cells arranged in an optimized sparse geometry on the surface of a rotating support element. The transducer array rotates about a long axis, which is also the axis of a non-rotatable tubular housing, with the transducing surface of the transducer array facing out of the housing and at the tissues to be imaged.

[0008] In one aspect, an ultrasound imaging probe includes a housing having a tubular portion with a first long axis and a first end region having a first non-zero diameter, a non-zero height, and an inner circular perimeter that surrounds a material free region. The probe further comprising a transducer array support disposed in the material free region and mechanically supported by the housing. The probe further comprising a transducer array with a row of transducer elements with a transducing side and a second long axis. The transducer array is disposed in the material free region such that the second long axis extends within the perimeter and is perpendicular to the first long axis. The transducer array is rotatably affixed to the transducer array support on the first long axis with the transducing side facing out of the housing and the transducer array configured to rotate in a plane parallel to the circular inner perimeter.

[0009] In another aspect, a method includes receiving, at a user interface of an ultrasound probe, an input signal indicative of an ultrasound volumetric imaging mode. The method further includes rotating, in response to receiving the input signal, a row of transducer elements of a transducer array of an ultrasound imaging probe in an examination region plane about a central region of the a row of transducer elements. The method further includes transmitting ultrasound signals and acquiring echoes with the row of transducer elements while rotating the row of transducer elements. The method further includes processing the echoes, generating volumetric image data. The method further includes visually presenting the generated volumetric image data.

[0010] In another aspect, an ultrasound system includes an ultrasound imaging probe with a row of transducer elements, a console that controls the row of transducer element to transmit ultrasound signals and receive echo signals, and means for rotating the transducer array relative to the ultrasound imaging probe to acquire volumetric image data.

[0011] 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

[0012] 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:

[0013] FIG. **1** illustrates an example ultrasound imaging system including a hand-held ultrasound probe with a rotating transducer array;

[0014] FIG. **2** schematically illustrates a perspective view of an example of the hand-held ultrasound probe;

[0015] FIG. **3** schematically illustrates a cross-sectional view along line A-A of the example hand-held ultrasound probe of FIG. **2**;

[0016] FIG. **4** schematically illustrates a perspective view of another example of the hand-held ultrasound probe;

[0017] FIG. **5** schematically illustrates a cross-sectional view along line A-A of another example of the hand-held ultrasound probe of FIG. **2**;

[0018] FIG. **6** schematically illustrates the hand-held ultrasound probe with a 1D linear array with equal size transducer elements;

[0019] FIG. **7** schematically illustrates the hand-held ultrasound probe with a 1D linear array with different size transducer elements;

[0020] FIG. **8** schematically illustrates the hand-held ultrasound probe with a plurality of 1D linear arrays or a 2D array;

[0021] FIG. **9** schematically illustrates the hand-held ultrasound probe with multiple 1D sparse arrays;

[0022] FIG. **10** schematically illustrates the hand-held ultrasound probe with a concentric array;

[0023] FIG. **11** schematically illustrates the hand-held ultrasound probe with a 1.5D or 1.75D array;

[0024] FIG. **12** illustrates an example of the ultrasound imaging system;

[0025] FIG. **13** schematically illustrates a variation of hand-held ultrasound probe; and

[0026] FIG. **14** illustrates a method in accordance with the embodiments disclosed herein.

DETAILED DESCRIPTION

[0027] FIG. **1** schematically illustrates an example imaging system **102**, such as ultrasound (US) imaging system. The imaging system **102** includes a hand-held ultrasound probe **104** and a console **106**. The hand-held ultrasound probe **104** and the console **106**, in the illustrated embodiment, are in electrical communication through an interface **108**, such as a wireless (e.g., RF, IF, optical, etc.) and/or a physical (e.g., electro-mechanical) interface. The hand-held ultrasound probe **104** and the console **106** can be part of a same device and/or separate and distinct devices.

[0028] The hand-held ultrasound probe **104** includes a transducer array **110** such as a 1D, 1.5D, 1.75D, 2D, and/or other transducer array. A multi-row 1D configuration and/or the 1.5D, 1.75D, and 2D configurations include one or more additions rows, but, generally, in the illustrated embodiment, not enough rows to cover the entire 2D field of view when the transducer array **110** is maintained at a static position relative to the probe **104**. The transducer array **110** includes a plurality of transducer elements **112** in each row of elements. For example, a row of transducer elements may include 8, 64, 128, 256, 512, etc. transducer elements **112**.

[0029] A row transducer elements of the transducer array **110** can be linear, curved, and/or otherwise shaped. At least two different rows transducer elements of the transducer array **110** may be differently shaped (e.g., one row may be linear and another row may be curved). An individual row transducer elements of the transducer array **110** can be fully populated or sparse. With a multi-row transducer array **110**, at least two rows of transducer elements can be arranged with respect to each other parallel, perpendicular, or at another angle, such as an angle there between. At least two transducer elements **112** of the transducer array **110** may also have different geometry (e.g., width or height).

[0030] The transducer elements **112** have a transducing side **111**, which faces away from the probe **104** and into the field of view. A transducer element **112** of the transducer elements **112** converts an electrical signal received thereby into an ultrasound pressured field and vice versa. For example, the transducer elements **112** of a row, when excited with an electrical pulse(s), transmit ultrasound signals from the transducing side **111** into a field of view and receive, at the transducing side **111**, echo signals generated in response to an interaction of the transmitted ultrasound signals with structure in the field of view, which are converted into electrical signals indicative of the structure.

[0031] The hand-held ultrasound probe **104** further includes a transducer array support **114**, which mechanically supports the transducer array **110** and hence the transducer elements **112** in the ultrasound probe **104**. The transducer array support **114** rotatably supports transducer array **110**. The hand-held ultrasound probe **104** further includes electronics **116** and a drive system **118**. The electronics **116** include electrically conductive paths between the plurality of transducer elements **112** and the interface **108**. The drive system **118** (e.g., a motor and a shaft coupling, a belt, a chain, a gear, etc.) rotates the transducer array **110**.

[0032] As described in greater detail below, by rotating the transducer array **110** at a suitable speed while acquiring data, the transducer array **110** can be used to acquire volumetric data with one to a few rows of transducer elements **112**. Thus, the hand-held ultrasound probe **104** described herein can acquire, via rotating the transducer array **110**, volumetric data of a field of view with less transducer elements **112** relative to a fully populated 2D configuration of the transducer array **110** that covers the entire field of view. As such, the hand-held ultrasound probe **104** described herein includes less channels and electrical interconnects, and is less complex and costly and smaller, relative to such a 2D configuration.

[0033] The hand-held ultrasound probe **104** further includes a housing **120**. The housing **120** includes structural elements, components, etc., which physically and/or mechanically support the transducer array **110**, the transducer array support **114**, the electronics **116** and/or the drive system **118**. Where the console **106** is part of the hand-held ultrasound probe **104**, the display **132** and/or user interface **136** may be part of and/or integrated with the housing **120**, for example, the display **132** and/or user interface **136** can be a physical part of a side of the hand-held ultrasound probe **104**.

[0034] The hand-held ultrasound probe **104** further includes an ultrasonic window **124**. The ultrasonic window **124** resides between the transducer elements **112** and the environment outside of the housing **120**. Similar to the display **132** and/or user interface **136**, the ultrasonic window **124** may be part of and/or integrated with the housing **120**. The ultrasonic window **124** allows signals transmitted by the transducer array **100** to exit the housing **120** and enter the field of view, and echoes from the field of view enter the housing **120** to and are received by the transducer array **100**.

[0035] In one instance, the housing **120** can be grasped by a mechanical or robotic arm, a human hand, and/or otherwise and maneuvered by the mechanical or robotic arm, the human hand, etc. for an ultrasound procedure. Non-limiting examples of different configurations are described in connection with FIGS. **2**, **3**, **4** and **5**. In another instance, the hand-held ultrasound probe **104** can be part of another physical structure, such as an instrument. An example of a suitable instrument is a catheter, a lumen, and/or other instrument. An example of this configuration is described in connection with FIG. **13**.

[0036] The console **106** includes transmit circuitry **126** that conveys a set of pulses that selectively excites one or more of the transducer elements **112** to transmit an ultrasound signal into a scan field of view.

[0037] The console **106** further includes receive circuitry **128** that receives a set of echoes signals. The echo signals, generally, are a result of the interaction between the emitted ultrasound signals and the object (e.g., flowing blood cells, organ cells, etc.) in the scan field of view.

[0038] The console **106** further includes an echo processor **130** that processes the received echoes, e.g., by applying time delays and weights to the echoes and summing the resulting echoes. Other processing by the echo processor **130** and/or other component includes, but is not limited to, spatial compounding, filtering (e.g., FIR and/or IIR), and/or other echo processing.

[0039] The console **106** further includes a display **132** that visually presents images and/or other information. The console **106** further includes a scan converter **134** that scan converts the processed data, e.g., by converting the beamformed data to the coordinate system of the display **132**.

[0040] The console **106** further includes a user interface (UI) **136** with one or more input devices (e.g., a button, a knob, a slider, etc.), which allow interaction between with the system **102** and a user.

[0041] The console **106** further includes a controller **138** that controls the various components of the imaging system **102**. For example, such control may include exciting individual or groups of the transducer elements **112**, steering and/or focusing the transmitted signal, etc., steering and/or focusing the received echoes, invoking the electronics **116** and drive system **118** to rotate the transducer array **110**, etc.

[0042] It is to be appreciated that the console **106** includes one or more processors (e.g., a microprocessor, a central processing unit, etc.) that execute one or more computer readable instructions encoded or embedded on computer readable storage medium (which excludes transitory medium) such as physical memory and other non-transitory medium. Additional or alternatively, the instructions can be carried in a signal, carrier wave and other transitory or non-computer readable storage medium. By executing the instructions, the one or more processors implement one or more of the components **126**, **128**, **130** and/or **134**.

[0043] The hand-held ultrasound probe **104** and the console **106** may be separate devices. In this configuration, the hand-held ultrasound probe **104** and the console **106** have interfaces for communication between each other, over a hard wired and/or wireless channel. For example, the hand-held ultrasound probe **104** and the console **106** may each include electro-mechanical connectors. With this configuration, a cable or like includes complementary connectors in that the cable connectors physically engage the hand-held ultrasound probe **104** and the console **106** connectors and provides an electrical pathway between the hand-held ultrasound probe **104** and the console **106**. Such a cable could be part of one of the hand-held ultrasound probe **104** and the console **106** which removably connects to the other of the hand-held ultrasound probe **104** and the console **106**.

[0044] In another instance, the console **106** is part of and/or integrated within the hand-held ultrasound probe **104**. In this configuration, the hand-held ultrasound probe **104** may include internally located power, e.g., from a power source such as a battery, a capacitor or other power storage device located in the housing **102**, to power the components therein. The hand-held ultrasound probe **104** may additionally or alternatively use external power. In another instance, at least one of the transmit circuitry **126**, the receive circuitry **128**, the echo processor **130**, the scan converter **134**, the controller **138**, the display **130** or the user interface **136** is separate from the probe **104**.

[0045] Optionally, the ultrasound imaging system **102** may include a location and guidance elements to determine in three-dimensional space the rotation axis direction, the contact surface location, and the instantaneous rotating probe position.

[0046] Turning to FIG. **2**, an example perspective view of the hand-held ultrasound probe **104** is schematically illustrated.

[0047] The housing **120** includes a tubular portion **202** with a first end region **204** having a first non-zero diameter **206**, a non-zero height **208**, and a long axis **210**, which extends along a center of the tubular portion **202**. An example of a suitable diameter is a diameter in a range of four (4) to twenty (20) centimeters (cm), and an example of a suitable height is a height in a range of 1 to 5 cm. The tubular portion **202** includes an inner circular perimeter **212** and a material free region **214** surrounded and/or enclosed by the inner circular perimeter **212**. The tubular portion **202** also includes a side **218** opposing the first end region **204**.

[0048] The housing **120** further includes a handle portion **216**, which is affixed to and/or is part of the side **218**. In this example, the handle portion **216** is also centered along the axis **210**. The illustrated handle portion **216** is also tubular having a non-zero diameter **220** and a non-zero height **222**. An example of a suitable diameter is a diameter in a range of one (1) to ten (10) cm, and an example of a suitable height is a height in a range of 7 to 20 cm. The handle portion **216** includes a perimeter **224** and a material free region **226** surrounded and/or enclosed by the perimeter **224**. In a variation, the handle portion **216** is not tubular, but instead, otherwise shaped such a square, hexagonal, elliptical, end/or other shape.

[0049] The transducer array **110** is rotatably affixed to a structural rotation support **228**, which runs along the long axis **210**, perpendicular to the long axis **210** and facing away from the housing **120**. In the illustrated embodiment, the transducer array **110** is affixed to the support at about a central region of the transducer array **110** or the transducer elements **112**. The structural rotation support **228** can be a pin, a rod, a shaft, etc., and the transducer array **110** is configured to rotate (e.g., as shown at **232**) three hundred and sixty (360) degrees about the structural rotation support **228**. The transducer array **110** has a length **2030** in a range of 3 to 12 cm and a width **233** in a range of 0.1 to 2 cm, and an area (i.e., length× width), which is less than an area of a configuration in which the transducer array **110** was a fully populated circular array with an area of approximately πr^2, where r is half of the length **230**. The transducer array **110** is configured to rotate and acquire data as it rotates so as to acquire data over such an area.

[0050] By way of non-limiting example, the speed of sound in water is on the order of 1500 m/s. If the hand-held ultrasound probe **104** were to be used to image an object at a depth of about fifteen (15) cm in a medium with characteristics (e.g., reflecting and/or scattering boundaries) similar to water, the round trip distance would be thirty (30) cm (or 0.30 m), and the transducer array **110** would need to transmit and receive within two microseconds (200 μsec) to image one line with the transducer array **110** before the next acquisition interval.

[0051] In general, the transducer array **110** is configured to rotate in a range of 0.10 to several rotations per second. For a particular scan, this number depends on the number of rows, the width of each row, and the probe diameter. For example, with two rows of 1-mm and a diameter of 100 mm, the circumference is about 314 mm. At the periphery, to advance 1 mm in 200 microsecond (or 314 mm in 62.8 ms), the array **110** is rotated no faster than approximately 16 rotations per seconds. Imaging is also possible with a single row, if the row does not advance by more than half its width until the echo comes back.

[0052] FIG. **3** shows a cross-sectional view along line A-A of FIG. **2**.

[0053] The transducer array support **114** is disposed entirely in the material free region **214** and is mechanically supported by the housing **120**. The transducer array support **114** includes rotating support **302**, which is recessed in the material free region **214** within the perimeter **212** along the height **208**. The transducer array **110** is affixed to a side **304** of the rotating support **302** and is also recessed in the perimeter **212** from the first end region **204** along the height **208** disposed entirely in the material free region **214**. The transducer array support **114** further includes a stationary support **306**, which is located next to a side **308** of the rotating support **302**, which is opposite the side **304** of the rotating support **302**.

[0054] The stationary support **306** and the rotating support **302** are separated by a non-zero gap **310**. The gap **310** is in the range of about 0.5 to 2 mm. A bearing **312** resides at least partially in the non-zero gap **310**, between the stationary support **306** and the rotating support **302**. The bearing **312** includes a stationary bearing **314** and a rotating bearing **316**. The stationary bearing **314** is affixed to the stationary support **306**, and the rotating bearing **312** is affixed to the rotating support **302**. The bearing **312** allows the rotating support **302**, and hence the transducer array **110**, to rotate relative the stationary support **306**. The bearing **312** can be a ball bearing, a roller bearing, etc.

[0055] A motor **316** turns a shaft **318**, which is fixedly attached to the rotating support **302**, which rotates the transducer array **110**. In other embodiments, the motor **316** drives a belt, a chain, a gear, and/or other device which directly or indirectly rotates the transducer array **110**. A motor controller **320** controls the motor. A probe interface **338** receives a control signal from the console **106** and routes the control signal to the motor controller **320**. The control signal, in one instance, indicates a rotational velocity at which to rotate the transducer array **110** for an ultrasound imaging procedure, and the motor controller **320** invokes the motor **316** to rotate the shaft as a rotational velocity which will cause the transducer array to rotate at the commanded rotational velocity.

[0056] A pair of electrical contacts **322** and **324** provides an electrical path from the stationary support **306** to the rotating support **302**. The pair of electrical contacts **322** and **324** may include physical contacts such as metallic brush contacts or contactless contacts. A pair of transceivers **326** and **328** provides a data and control signal path between the rotating support **302** and the stationary support **306**. The pair of transceivers **326** and **328** may include an optical, a radio frequency (RF), an infrared (IR), and/or other transceivers. In a variation, the pair of transceivers **326** and **328** is omitted, and data and control signals are also routed between the stationary support **306** to the rotating support **302** via the pair of electrical contacts **322** and **324** and/or other electrical contacts.

[0057] A first electrical path **330** provides an electrical path between the electrical contact **324** and electronics **332** of the transducer array **110**. Another different electrical path **334** provides an electrical path between the transceiver **328** and electronics **332** of the transducer array **110**. Another different electrical path **336** provides an electrical path between the electrical contact **322** and the interface **338**. Another different electrical path **340** provides an electrical path between the transceiver **326** and the interface **338**. The interface **338** can includes a wireless interface and/or an electromechanical connector. The location of the pair of electrical contacts **322** and **324**, the pair of transceivers **326** and **328**, and the electrical paths **330**, **334**, **336** and **340** are for explanatory purposes and are not limiting; other locations are contemplated herein.

[0058] In FIG. **3**, the ultrasonic window **124** includes a cover or the like that extends over the material free region **214** and is affixed to the perimeter **212** at the first end region **204**. The ultrasonic window **124** resides between the transducer elements **112** and the environment outside of the housing **120**. In one non-limiting instance, the ultrasonic window **124** includes a taught membrane including an appropriate material for the transmission of ultrasound beam energy. The taught membrane can be a disc planar shape and/or other shape. The taught membrane, in this instance, minimizes tissue displacement when the transducer array **110** rotates and the ultrasonic window **124** is in contact with the structure being imaged. In a variation, the ultrasonic window **124** is omitted. In another variation, the ultrasonic window **124** can be part of the housing **120**.

[0059] Turning to FIG. **4**, a variation of the hand-held ultrasound probe **104** of FIG. **2** is illustrated. In FIG. **2**, the handle portion **216** is centered along the axis **210**. In FIG. **4**, the handle portion **216** is not centered along the axis **210**. Rather, the handle portion **216** is shifted off center relative to the axis **210**. In one instance, the handle portion **216** is stationarily affixed at the off center position. In another instance, the handle portion **216** is moveably affixed to the tubular portion **202** and configured to move between at least two different positions. For example, the handle portion **216** can be moveably affixed to the tubular portion **202** to move between the centered position (FIG. **2**) and one or more off center positions (e.g., FIG. **4**), at least two different off center positions, etc.

[0060] Next at FIG. **5**, a variation of cross sectional view of the hand-held ultrasound probe **104** of FIG. **3** is illustrated. In FIG. **3**, the hand-held ultrasound probe **104** and the console **106** are different components, with the console **106** being external to the hand-held ultrasound probe **104**. In FIG. **5**, the console **106** is part of the hand-held ultrasound probe **104**. In particular, the console **106** shown in FIG. **5** is located at least in part in the handle **216** of the hand-held ultrasound probe **104**. Of course, the display **132** and the user interface **136**, in this configuration, are accessible, for example, they can be integrated in the handle **216**.

[0061] Moving to FIGS. **6**, **7**, **8**, **9**, **10** and **11**, non-limiting examples of various transducer arrays **110** in connection with the embodiments disclosed herein are illustrated. Where the transducer array **110** includes a multiplicity of rows, the timing of the individual cell impulses being calculated to account for the specific rotation speed selected.

[0062] FIG. **6** shows a 1D linear array **110** with a single row **602** of equal sized transducer elements **112**. FIG. **7** shows a 1D linear array **110** with a single row **702** of transducer elements **112** in which outer elements $\mathbf{112}_1$ are larger than inner elements $\mathbf{121}_2$. FIG. **8** shows an array **110** which includes three rows $\mathbf{802}_1$, $\mathbf{802}_2$, and $\mathbf{802}_3$, each with equal sized transducer elements **112**. The three rows can be individual 1D arrays where only a single row of transducer elements **112** can be used at any given moment in time, or the three rows can be part of a 2D array in which all of the transducer elements **112** can be used concurrently.

[0063] FIG. **9** shows an array **110** that includes multiple 1D arrays **902**, **904**, and **906**. The array **902** extends across the material free region **214** to about the perimeter **212**, and the arrays **904** and **906** extend from a center region of the array **902** to the material free region **214** to about the perimeter **212**. The arrays **904** and **906** are half as long as the array **902**. FIG. **10** shows an array **110** that includes a circular array **1002** including a single circular ring of transducer elements **112**. In a variation, the circular array **1002** include multiple rings. FIG. **11** shows a 1.5D or 1.75D array with a fully populated center row **1102** and sparse arrays **1104** with no elements in regions **1106**.

[0064] Turning to FIG. **12**, an example of the ultrasound imaging system **102**. In this example, the display **132** is not part of and is an external to the console **106**, which is not part of and is an external to the ultrasound probe **104** is illustrated.

[0065] The console **106** and the display **132** are affixed to a transportation apparatus **1202**. The transportation apparatus **1202** includes a base **1204** that include a plurality of wheels (or casters, etc.) **1206**. The illustrated base **1204** includes four (4) sets of wheels **1206**. However, in other embodiments, the base **1204** can include more or less sets of wheels **1206**. The wheels **1206** allow the imaging system **102** to be rolled from location to location such as from examination room to examination room or other location.

[0066] The transportation apparatus **1202** further includes a post **1208** with opposing ends **1210** and **1212**. The end **1210** is affixed to the base **1204**, and the other end **1212** provides a first support **1214** for the console **106** and an arm support **1216** for the display **132**. The post **1208** may be a fixed height or include a telescoping or otherwise height adjustable member, which can be used to adjust the height of the console **106** and the display **132**.

[0067] The transportation apparatus **1202** further includes a power source **1218**, which supplies power for the console **106**, the display **132** and the ultrasound probe **104**. The transportation apparatus **1202** further includes a probe holder **1220**. In the illustrated example, the ultrasound probe **104** is located in and supported by the probe holder **1220**. In the illustrated example, the path **108** includes a cable that electromechanically connects to the ultrasound probe **104** and the console **106**, creating a communications path there between.

[0068] In another embodiment, the console **106** and the display **132** are affixed to a cart that does not includes wheels. In another embodiment, the display **132** is mounted to a bracket that is not affixed to the transportation apparatus **1202**. For example, the display **132** is affixed to a bracket that mounts to a wall or ceiling, that rests on a desk, etc. In another example, the display **132** is part of the console **106**, for instance, integrated into a side of the housing **120** and/or otherwise physically part of the console **106**.

[0069] Next at FIG. **13**, an embodiment in which the ultrasound probe **104** is part of and/or integrated with a catheter **1302** is illustrated. In this embodiment, the catheter **1302** includes the tubular structure **120**. Furthermore, the ultrasonic window **124** includes a dome shape cover **1304** and the rotatable transducer array **110** is hemispherically shaped. A diameter of the catheter **1302** is in a range of 0.2 to 2 cm.

[0070] With this embodiment, the rotating support **302** (not visible), the transducer array **110**, the stationary support **306** (not visible), the bearing **312** (not visible), the motor **316**, the sensor **326** and **328**, etc. can be based on micro-electromechanical systems (MEMS), nano-electromechanical systems (NEMS), and/or other technology of very small devices. Such a probe is well-suited for endo-lumen, such as endo-arterial and/or catheter tips.

[0071] FIG. **14** illustrates a method in accordance with the description herein.

[0072] Note that the ordering of the following acts is for explanatory purposes and is not limiting. As such, one or more of the acts can be performed in a different order, including, but not limited to, concurrently. Furthermore, one or more of the acts may be omitted and/or one or more other acts may be added.

[0073] At **1400**, an input signal, indicative of an ultrasound imaging mode, is received at the user interface **136** of the ultrasound probe **104**. For example, in one instance, the input signal identifies a volumetric imaging mode.

[0074] At **1402**, an imaging activation signal is received.

[0075] At **1404**, a transducer array rotate signal is conveyed to the probe controller **320**.

[0076] At **1406**, the drive system **118** rotates, in response to the signal, the transducer array **110** in accordance with the identified volumetric imaging mode.

[0077] At **1408**, data is acquired with the transducer elements **112** of the transducer array **110** while the transducer array **110** rotates.

[0078] At **1410**, the acquired data is processed.

[0079] At **1412**, volumetric image data is generated.

[0080] At **1414**, the volumetric image data is at least one of stored, displayed, or conveyed to another device.

[0081] The above may be implemented by way of computer readable instructions, encoded or embedded on computer readable storage medium, which, when executed by a computer processor(s), cause the processor(s) to carry out the described acts. Additionally or alternatively, at least one of the computer readable instructions is carried by a signal, carrier wave or other transitory medium.

[0082] 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.

What is claimed is:

1. An ultrasound imaging probe, comprising:

a housing, including a tubular portion with a first long axis and a first end region having a first non-zero diameter, a non-zero height, and an inner circular perimeter that surrounds a material free region;

a transducer array support disposed in the material free region and mechanically supported by the housing; and

a transducer array, including:

a row of transducer elements with a transducing side and a second long axis, wherein the transducer array is disposed in the material free region such that the second long axis extends within the perimeter and is perpendicular to the first long axis, and is rotatably affixed to the transducer array support on the first long axis with the transducing side facing out of the housing and the transducer array configured to rotate in a plane parallel to the circular inner perimeter.

2. The ultrasound imaging probe of claim **1**, wherein the circular inner perimeter has a diameter in a range of four to twenty centimeters.

3. The ultrasound imaging probe of claim **1**, further comprising:

a drive system that rotates the transducer array; and

electronics that excite the row of transducer elements to transmit ultrasound signals and receive echo signal while the transducer array rotates for a plurality of rotation angles, acquiring volumetric imaging data.

4. The ultrasound imaging probe of claim **3**, further comprising:

a bearing, including: a rotating side; and a stationary side,

wherein the transducer array support includes: a rotating support affixed to the transducer array; and a stationary support affixed to the housing, wherein the rotating support and the stationary support are separated from each other by a non-zero gap; and

wherein the bearing is disposed between the rotating support and the stationary support and the rotating side affixed to the rotating support and the stationary side affixed to the stationary support.

5. The ultrasound imaging probe of claim **1**, wherein the tubular portion includes a second opposing side, and the housing, further comprising: a handle portion affixed to the second opposing end of the tubular portion.

6. The ultrasound imaging probe of claim **5**, wherein the handle portion has a diameter in a range of one to ten centimeters.

7. The ultrasound imaging probe of claim **5**, wherein the handle portion is centered on the first long axis.

8. The ultrasound imaging probe of claim **5**, wherein the handle portion is not centered on the first long axis.

9. The ultrasound imaging probe of claim **1**, wherein the transducer array includes at least one of: only a single 1D row of transducer elements or a plurality of single 1D rows of transducer elements that are alternatively actuated.

10. The ultrasound imaging probe of claim **1**, wherein the transducer array includes one of: a 1.5D, a 1.75D, or 2D matrix of transducer elements.

11. The ultrasound imaging probe of claim **1**, wherein the transducer array includes one of: multiple rows of transducer elements orientated at different angles with respect to each other or a circular ring of transducer elements.

12. The ultrasound imaging probe of claim **1**, further including: at least one of: transmit circuitry; receive circuitry; an echo processor; a display; or a user interface at least partially disposed in the housing.

13. The ultrasound imaging probe of any of claims **1** to **11**, further including: a probe electro-mechanical interface to a console that includes least one of: transmit circuitry; receive circuitry; an echo processor; a display; or a user interface, wherein the console is external to the ultrasound imaging probe.

14. The ultrasound imaging probe of claim **1**, wherein housing is part of a tip of an endo-lumen catheter.

15. A method, comprising:

receiving, at a user interface of a ultrasound probe, an input signal indicative of an ultrasound volumetric imaging mode;

rotating, in response to receiving the input signal, a row of transducer elements of a transducer array of an ultrasound imaging probe in an examination region plane about a central region of the a row of transducer elements;

transmitting ultrasound signals and acquiring echoes with the row of transducer elements while rotating the row of transducer elements;

processing the echoes, generating volumetric image data; and

visually presenting the generated volumetric image data.

16. The method of claim **15**, wherein the row of transducer elements includes only a single 1D row of transducer elements.

17. The method of claim **15**, wherein the row of transducer elements includes multiple single 1D rows of transducer elements.

18. The method of claim **15**, wherein the row of transducer elements includes a circular ring of transducer elements.

19. The method of claim **15**, wherein the row of transducer elements includes one of a 1.5D, a 1.75D, or a 2D array of transducer elements.

20. An ultrasound system;

an ultrasound imaging probe with a row of transducer elements;

a console that controls the row of transducer elements to transmit ultrasound signals and receive echo signals; and

means for rotating the row of transducer elements relative to the ultrasound imaging probe to acquire volumetric image data.

* * * * *

专利名称(译)	具有旋转传感器阵列的超声（US）成像探头		
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申请(专利权)人(译)	ANALOGIC CORPORATION		
[标]发明人	BESSON GUY M		
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摘要(译)

超声成像探头包括壳体，壳体具有带有第一长轴的管状部分和具有第一非零直径，非零高度的第一端部区域，以及围绕无材料区域的内部圆形周边。探针还包括换能器阵列支撑件，其设置在无材料区域中并由壳体机械支撑。探针还包括具有一排换能器元件的换能器阵列，换能器元件具有换能侧和第二长轴。换能器阵列设置在无材料区域中，使得第二长轴在周边内延伸并垂直于第一长轴，并且在第一长轴上可旋转地固定到换能器阵列支架，换能侧面向外。壳体和换能器阵列被配置为在平行于圆形内周边的平面中旋转。