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(54) THREE DIMENSIONAL IMAGING ULTRASOUND PROBE

ULTRASCHALLSONDE FÜR DREIDIMENSIONALE BILDGEBUNG

SONDE ULTRASONORE D'IMAGERIE TRIDIMENSIONNELLE

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Description

[0001] This invention relates to medical diagnostic ultrasound probes for imaging the body and, in particular, to ultrasound probes which perform three-dimensional (3D) scanning.

[0002] Common ultrasound imaging probes scan and provide echo information from a planar region of the body and the generation of a two-dimensional (2D) image. In recent years 3D probes have been developed for scanning and imaging volumetric regions of the body. Three-dimensional imaging probes enable an entire chamber of the heart to be viewed three dimensionally in real time, for example. The 3D probes for these application are in generally either electronic or mechanical. An electronic 3D probe steers the transmit beams in three dimensions electronically with a two-dimensional array transducer as illustrated in US Pat. 5,997,479 (Savord et al.), for instance. With transducer elements extending in two dimensions, the transmit and receive beams can be steered in three dimensions by phased steering of the beams. A mechanical 3D probe uses a one-dimensional (1D) array transducer of the type used for standard 2D imaging and oscillates it back and forth. This causes the image plane of the 1D array to be swept through a volumetric region. The advantage of the mechanical 3D probe is that it uses conventional 1D array technology, but with the limitation that a mechanical arrangement to sweep the 1D array must be employed.

[0003] There are several ways to sweep the 1D array. One way is to spin the 1D array around its center as shown in US Pat. 5,159,931 (Pini). The spinning of the 1D array will scan a cylindrical or conical volumetric region. Another approach is to rock the array back and forth so that the image plane will sweep through a wedge-shaped volumetric region. Examples of this sweeping technique are shown in US Pats. 5,152,294 (Mochizuki et al.), 5,460,179 (Okunuki et al.) and 6,572,548 (Cerofolini). The wedge is narrow at the probe aperture and widens at deeper depths of the body. The mechanical probe of the '179 patent is particularly designed to have a sharp axis at the top of the wedge so that the probe can image from between the ribs.

[0004] These 3D mechanical scanning techniques all provide a volumetric image which is very narrow immediately in front of the probe. There are diagnostic applications, however, where it is desirable to have a wide field of view immediately in front of the probe. A wide field of view in the near field can be especially useful for fetal scanning, for example, where the fetus may be close to the wall of the abdomen. Accordingly it is desirable to have a mechanical 3D probe which scans a wide field of view immediately in front of the probe.

[0005] US 2005/0288587 A1 discloses a wobbler transducer in which a drive shaft of a motor is positioned orthogonal to an array rather than parallel with the array. The drive shaft may be more perpendicular than parallel to the direction of the transducer movement as well.

[0006] EP 1 744 178 A2 discloses a device for moving a transducer of an ultrasonic probe in an ultrasonic diagnostic apparatus for acquiring a 3-dimensional ultrasound image. A motor for generating power to move the transducer and guide rails for guiding the movement of the transducer are mounted to a frame. The rotational force of a driving shaft of the motor is transmitted to a driven shaft through pulleys (52,54,56) and belts. A portion of a wire is wound around the driven shaft and both ends of the wire are fixed to two opposing surfaces of the transducer. A reel having a spiral groove on the peripheral surface is coupled to the driven shaft. The wire is wound along the spiral groove.

[0007] In accordance with the principles of the present invention, a 3D ultrasound probe is described as defined in claim 1, which scans a wide field of view in front of the probe aperture. A 1D array transducer is mounted in the probe to travel back and forth over an integral rolling surface preferably formed as a curved set of rails in the probe. The transducer array is mounted on a carriage which is pulled back and forth over the rails by a belt or cable pulled by a motor. In an illustrated example of the present invention, the cable which moves the transducer carriage wraps around a cam which maintains proper tension on the cable as the carriage moves in its arcuate path of
travel. The motor oscillates the cam to pull the cable and move the 1D transducer array through its path of volumetric scanning.

[0008] In the drawings:

FIGURE 1 illustrates an external view of a mechanical 3D probe of the present invention.
FIGURE 2 is a perspective view of the mechanical assembly of a 3D probe of the present invention as viewed from above the transducer array.
FIGURE 3 is a perspective view of the mechanical assembly of FIGURE 2 as viewed from the side.
FIGURE 4 is a detailed perspective view of the bearing structure at the end of the carriage of the mechanical assembly of FIGURE 2.
FIGURE 5 is a cutaway perspective view illustrating the cable and idler pulleys of the mechanical assembly of FIGURE 2.
FIGURE 6 is a perspective view of the drive cam of the mechanical assembly of FIGURE 2.

[0009] Referring first to FIGURE 1, a 3D ultrasound probe 10 constructed in accordance with the principles of the present invention is shown in an external view. The probe includes an outer case having a distal end 12 in which a transducer assembly 20 (see FIGURE 2) is mounted such that the image plane of a moving transducer array extends from a lens or end cap 14. The transducer array is located in a fluid compartment inside the distal end 12 containing fluid such as mineral oil which acoustically couples ultrasound energy between the transducer array and the end cap 14. As the transducer array moves back and forth its image plane is swept through a volumetric region in front of the end cap 14 to perform a 3D scan of the material in the volumetric region. In the distance between the transducer array and the exterior surface of the end cap 14 the image plane has diverged so that it can scan a relatively wide aperture in the near field just in front of the end cap. The probe 10 has a handle portion 16 below the distal end in which electrical connection is made to the terminating conductors of a cable from flex circuit conductors attached to the elements of the transducer array. The cable (not shown) extends from the probe case through a strain relief located at the proximal end 18 of the probe case. In use, a sonographer holds the probe by the handle portion and presses the end cap 14 against the skin of a patient to image the volumetric region of the patient's body in front of the end cap.

[0010] FIGURE 2 is a view of the transducer assembly 20 from above the transducer array 24. The transducer array 24 is mounted on a carriage assembly 26 which is pulled back and forth (from left to right and back again in FIGURE 2) along a pair of rails 30,32. At each end of the carriage assembly is a set of ball bearing rollers 34,36 which ride on the rails 30,32. The carriage assembly 26 is pulled back and forth by a cable 40 attached to the underside of the carriage assembly as shown in greater detail in FIGURE 5. From the points of attachment to the carriage assembly the cable 40 passes around a pair of idler pulleys 42,44 and then partially around circumferential grooves of a cam 46. The ends of the cable 40 are attached by screws in the middle of the cam 46. The cam is rotated back and forth by a brushless DC motor 80 attached to a cam shaft 48 extending from the bottom of the cam into the handle portion where the motor is located. See FIGURE 3.

[0011] The aforementioned components of the transducer assembly 20 are mounted on a bulkhead 22. The bulkhead has grooves around its periphery which seat O-ring seals to seal the fluid compartment in which the carriage assembly 26 is located from the interior of the handle portion 16 of the probe in which the motor and transducer/cable electrical connections are located. The flex circuit from the transducer array 26 passes through a seal in the bulkhead to the interior of the handle portion and the cam shaft 48 of the cam is sealed by passage through a dynamic fluid seal in the bulkhead 22. A fluid passageway extends through the bulkhead for attachment to a non-elastomeric balloon in the handle portion which provides compensation for changes in fluid volume with pressure and temperature as described in international patent application publication WO2005/094690 (Wickline et al.)

[0012] The ball bearing rollers at the ends of the carriage assembly 26 are in sets of three rollers, two of which ride on the top of the rails 30,32 and one of which rides in an undercut 38 in the side of each rail. In the view of FIGURE 2 rollers 34a and 34b at one end of the carriage assembly and rollers 36a and 36b at the other end of the carriage assembly are rollers which ride on the top surface of the rails 30 and 32. The rails 30,32 in this example are slightly curved in an arc. This slightly cylindrical profile of the rails defines the path of the carriage assembly motion and causes the plane of the transducer array to sweep through a trapezoidal volume rather than simply a square or rectangular volume, providing a wider field of view than would occur through the use of flat, linear rails. The successive image planes scanned by the array transducer as it travels back and forth thus diverge in the elevation direction of the planes as the transducer array is moved.

[0013] FIGURE 3 is a view of the transducer assembly 20 of FIGURE 2 as seen from the side. In this view the rollers 36a and 36b can be seen riding on top of the rail 32 and roller 34a is seen riding on top of the rail 30. A roller 34c which rides in the undercut 38 of rail 30 is partially visible at the left side of the carriage assembly 26. The cylindrical arc of the rails 30,32 is also plainly shown in this drawing. The rollers are mounted to bearing mounts 50 which are attached to the bottom of the carriage assembly. The pivoting connection of the cable 40 to the underside of the carriage assembly is seen in this view. The cam shaft 48 is seen projecting from the bottom of the bulkhead 22.

[0014] FIGURE 4 is another embodiment of the attachment of the rollers to the carriage assembly 26, in which the bearing mount 50 is integrally formed at the bottom of the carriage assembly 26. The upper rollers 34a and 34b are mounted to the side of the carriage assembly and a bearing clip 52 to which the lower bearing 34c which rides in the undercut 38 is attached provides preloading of the carriage assembly against the bulkhead 22.

[0015] FIGURE 5 is a cutaway view through the centers of the idler pulleys 42 and 44. This view shows the connections of the ends of the cable to cable fittings 62,64 pivotally attached to the underside of the carriage assembly. Swage balls at the ends of the cable bear against springs inside the cable fittings which provide continuous tensioning of the cable as it pulls the carriage assembly 26 back and forth along the rails 30 and 32.

[0016] FIGURE 6 illustrates the cam 46 in a perspective view. The cable from the idler pulleys 42 and 44 wrap around the cam 46 in grooves 82 and 84 on the circumference of the cam, and the ends of the cable pass into the interior 76 of the cam and are attached to the cam by screws which are fastened in screw holes 72 and 74. A center screw hole 70 provides attachment of the cam axially to the cam shaft 48 on the back of the cam. In this example the cam is not perfectly circular but is slightly oblong. This eccentric shape of the cam causes the carriage assembly to travel with linear motion as it travels back and forth over the arcuate rails 30 and 32. The linear motion provides a uniform spacing of the ultrasound beams and image plane produced by the transducer array as it travels back and forth for a consistently scanned volumetric image. In a constructed embodiment the cam travels approximately 180° as it rotates first in one direction (e.g., clockwise) and then the other (counterclockwise) to move the carriage assembly from one end of the rails to the other and back again.

[0017] Other variations will readily occur to those skilled in the art. For instance, in lieu of a cable 40, ballscrews, belts, or a chain may be used to couple the motor to the carriage assembly. The rails do not have to be arcuately curved, but can be linear if a more rectangular volumetric scan is to be obtained. A cable driven rail mechanism as illustrated above can provide approximately a 40% reduction in weight as compared to the swing arm mechanisms of the prior art. This efficient, compact mechanism requires that only the motor for the mechanism be located in the handle, enabling the probe to be designed with a slimmer handle girth or grip size than is the case of other 3D mechanical probes of the prior art.

Claims

1. An ultrasonic probe for scanning a volumetric region by movement of an array transducer comprising:

    a probe case (12) having a fluid compartment at a distal end and a handle portion(16) below the distal end;
    an array transducer (24) mounted on a carriage assembly (26) in the fluid compartment;
    a pair of rails (30,32) on which the carriage assembly travels in the fluid compartment, said rails comprising an undercut region (38);
    a drive cable (40) attached to the underside of the carriage assembly;
    a cam (46) axially attached to a cam shaft(48), which extends into the handle portion, wherein said drive cable is wrapped around the cam;
    a motor located in the handle portion and attached to the cam shaft to move the carriage assembly and array transducer on the rails; and
    a first ball bearing roller (34a) located at one side of the carriage assembly and adapted to ride on a first one of the rails, and a second ball bearing roller (36a) located at the other side of the carriage assembly and adapted to ride on a second one of the rails; wherein:

    - the probe further comprises third (34c) and fourth rollers riding in the undercut region of each rail,
    - the drive cable passes around at least a portion of a cam surface (82,84) to provide relatively linear motion to the carriage assembly,
    - the motor is coupled to the cam to drive the cam in alternating directions of rotation, and
    - the ends of the cable are attached to the cam

2. The ultrasonic probe of Claim 1, wherein the cam surface of the cam is oblong to drive the carriage assembly in relatively linear motion between the ends of the rails.

3. The ultrasonic probe of Claim 1 or 2, further comprising idler pulleys (42, 44) around which the cable passes between the carriage assembly and the cam.

4. The ultrasonic probe of any of Claims 1 to 3, wherein the cable is coupled to the carriage assembly by a spring fitting for cable tensioning.

5. The ultrasonic probe of any of Claims 1 to 4, wherein the probe case further comprises an end cap (14) through which ultrasonic energy passes to and from the array transducer, and
wherein coupling fluid is located between the array transducer and the inner surface of the end cap.

6. The ultrasonic probe of any of Claims 1 to 5, wherein the rails are curved to provide an arcuate path of travel for the array transducer.

7. The ultrasonic probe of Claim 6, wherein the arcuate path of travel causes the image plane of the array transducer to diverge in the elevation direction as the array transducer is moved.

8. The ultrasonic probe of any of Claims 1 to 5, wherein the rails are flat to provide a linear path of travel for the array transducer.

Patentansprüche

1. Ultraschallsonde zum Abtasten eines volumetrischen Bereichs durch Bewegen eines Array-Wandlers, umfassend:

    ein Sondengehäuse (12) mit einer Fluidkammer an einem distalen Ende und einem Griffabschnitt (16) unterhalb des distalen Endes;
    einen Array-Wandler (24), der an einer Schlittenanordnung (26) in der Fluidkammer montiert ist;
    ein Paar Schienen (30, 32), auf denen die Schlittenanordnung in der Fluidkammer fährt, wobei die Schienen einen hinterschnittenen Bereich (38) umfassen;
    ein Antriebskabel (40), das an der Unterseite der Schlittenanordnung befestigt ist;
    einen Nocken (46), der axial an einer Nockenwelle (48) befestigt ist, die sich in den Griffabschnitt hinein erstreckt, wobei das Antriebskabel

um den Nocken herum gewickelt ist;
einen Motor, der sich im Griffabschnitt befindet und an der Nockenwelle befestigt ist, um die Schlittenanordnung und den Array-Wandler auf den Schienen zu bewegen; und
eine erste kugelgelagerte Walze (34a), die sich auf einer Seite der Schlittenanordnung befindet und zum Mitfahren auf einer ersten der Schienen angepasst ist, und eine zweite kugelgelagerte Walze (36a), die sich auf der anderen Seite der Schlittenanordnung befindet und zum Mitfahren auf einer zweiten der Schienen angepasst ist;
wobei:

- die Sonde weiter dritte (34c) und Walzen Rollen umfasst, die im hinterschnittenen Bereich jeder Schiene mitfahren,
- das Antriebskabel um mindestens einen Abschnitt einer Nockenoberfläche (82, 84) herum verläuft, um der Schlittenanordnung eine relativ lineare Bewegung zu ermöglichen,
- der Motor mit dem Nocken gekoppelt ist, um den Nocken in wechselnden Drehrichtungen anzutreiben, und
- die Enden des Kabels an der Nocke befestigt sind.

2. Ultraschallsonde nach Anspruch 1, wobei die Nockenoberfläche der Nocke länglich ist, um die Schlittenanordnung in einer relativ linearen Bewegung zwischen den Enden der Schienen anzutreiben.

3. Ultraschallsonde nach Anspruch 1 oder 2, weiter umfassend Umlenkrollen (42, 44), um die herum das Kabel zwischen der Schlittenanordnung und dem Nocken verläuft.

4. Ultraschallsonde nach einem der Ansprüche 1 bis 3, wobei das Kabel mit der Schlittenanordnung durch ein Federbauteil zum Spannen des Kabels gekoppelt ist.

5. Ultraschallsonde nach einem der Ansprüche 1 bis 4, wobei das Sondengehäuse weiter eine Endkappe (14) umfasst, durch die Ultraschallenergie zum und vom Array-Wandler gelangt, und
wobei sich Kopplungsflüssigkeit zwischen dem Array-Wandler und der Innenfläche der Endkappe befindet.

6. Ultraschallsonde nach einem der Ansprüche 1 bis 5, wobei die Schienen gekrümmt sind, um einen bogenförmigen Verfahrweg für den Array-Wandler bereitzustellen.

7. Ultraschallsonde nach Anspruch 6, wobei der bogenförmige Verfahrweg bewirkt, dass die Bildebene des Array-Wandlers beim Bewegen des Array-Wandlers in Höhenrichtung divergiert.

8. Ultraschallsonde nach einem der Ansprüche 1 bis 5, wobei die Schienen flach sind, um einen linearen Verfahrweg für den Array-Wandler bereitzustellen.

Revendications

1. Sonde ultrasonore pour balayer une région volumétrique par un déplacement d'un transducteur réseau comprenant :

un étui de sonde (12) ayant un compartiment de fluide au niveau d'une extrémité distale et une portion de poignée (16) en dessous de l'extrémité distale ;
un transducteur réseau (24) monté sur un ensemble chariot (26) dans le compartiment de fluide ;
une paire de rails (30, 32) sur lesquels l'ensemble chariot circule dans le compartiment de fluide, lesdits rails comprenant une région de dégagement (38) ;
un câble d'entraînement (40) fixé au côté inférieur de l'ensemble chariot ;
une came (46) fixée axialement à un arbre de came (48), qui s'étend dans la portion de poignée, ledit câble d'entraînement étant enroulé autour de la came ;
un moteur situé dans la portion de poignée et fixé à l'arbre de came pour déplacer l'ensemble chariot et le transducteur réseau sur les rails ; et
un premier rouleau à roulement à billes (34a) situé au niveau d'un côté de l'ensemble chariot et conçu pour parcourir un premier des rails, et un deuxième rouleau à roulement à billes (36a) situé au niveau de l'autre côté de l'ensemble chariot et conçu pour parcourir un second des rails ;
dans laquelle

- la sonde comprend en outre des troisième (34c) et quatrième rouleaux parcourant la région de dégagement de chaque rail,
- le câble d'entraînement passe autour d'au moins une portion d'une surface de came (82, 84) pour fournir un mouvement relativement linéaire à l'ensemble chariot,
- le moteur est accouplé à la came pour entraîner la came dans des directions de rotation alternées, et
- les extrémités du câble sont fixées à la came.

2. Sonde ultrasonore selon la revendication 1, dans la-

quelle la surface de came de la came est oblongue pour entraîner l'ensemble chariot en mouvement relativement linéaire entre les extrémités des rails.

3. Sonde ultrasonore selon la revendication 1 ou 2, comprenant en outre des poulies folles (42, 44) autour desquelles le câble passe entre l'ensemble chariot et la came.

4. Sonde ultrasonore selon l'une quelconque des revendications 1 à 3, dans laquelle le câble est accouplé à l'ensemble chariot par un ajustement à ressort pour tendre le câble.

5. Sonde ultrasonore selon l'une quelconque des revendications 1 à 4, dans laquelle l'étui de sonde comprend en outre un embout (14) à travers lequel l'énergie ultrasonore passe vers et depuis le transducteur réseau, et
dans laquelle un fluide d'accouplement est situé entre le transducteur réseau et la surface intérieure de l'embout.

6. Sonde ultrasonore selon l'une quelconque des revendications 1 à 5, dans laquelle les rails sont incurvés pour fournir un trajet de circulation arqué pour le transducteur réseau.

7. Sonde ultrasonore selon la revendication 6, dans laquelle le trajet de circulation arqué amène le plan d'image du transducteur réseau à diverger dans la direction d'élévation lorsque le transducteur réseau est déplacé.

8. Sonde ultrasonore selon l'une quelconque des revendications 1 à 5, dans laquelle les rails sont plats pour fournir un trajet de circulation linéaire pour le transducteur réseau.

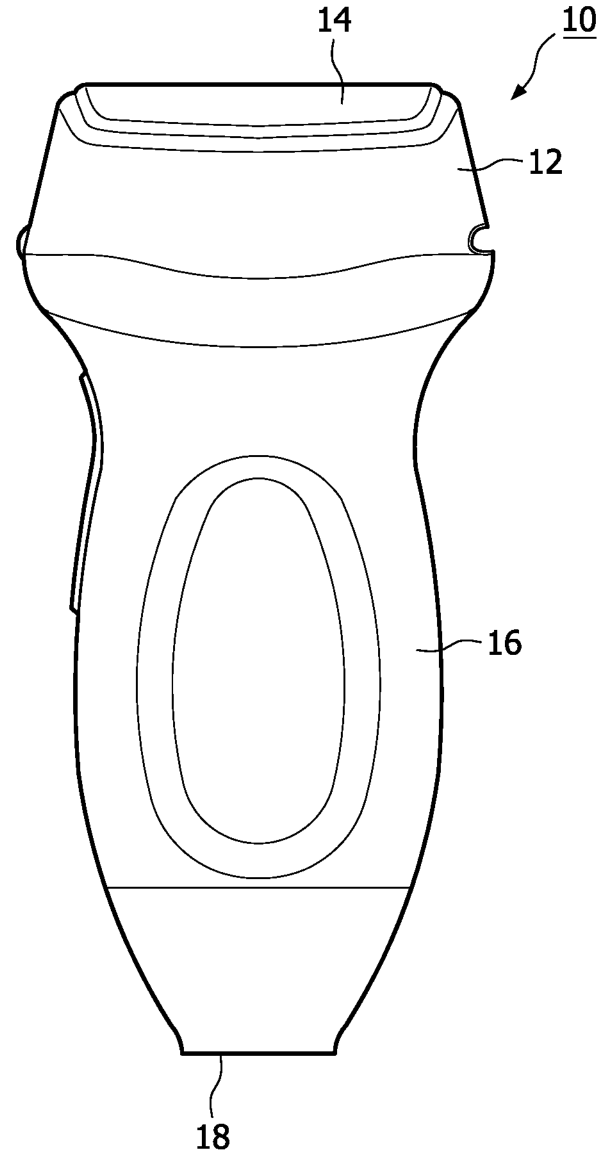

FIG. 1

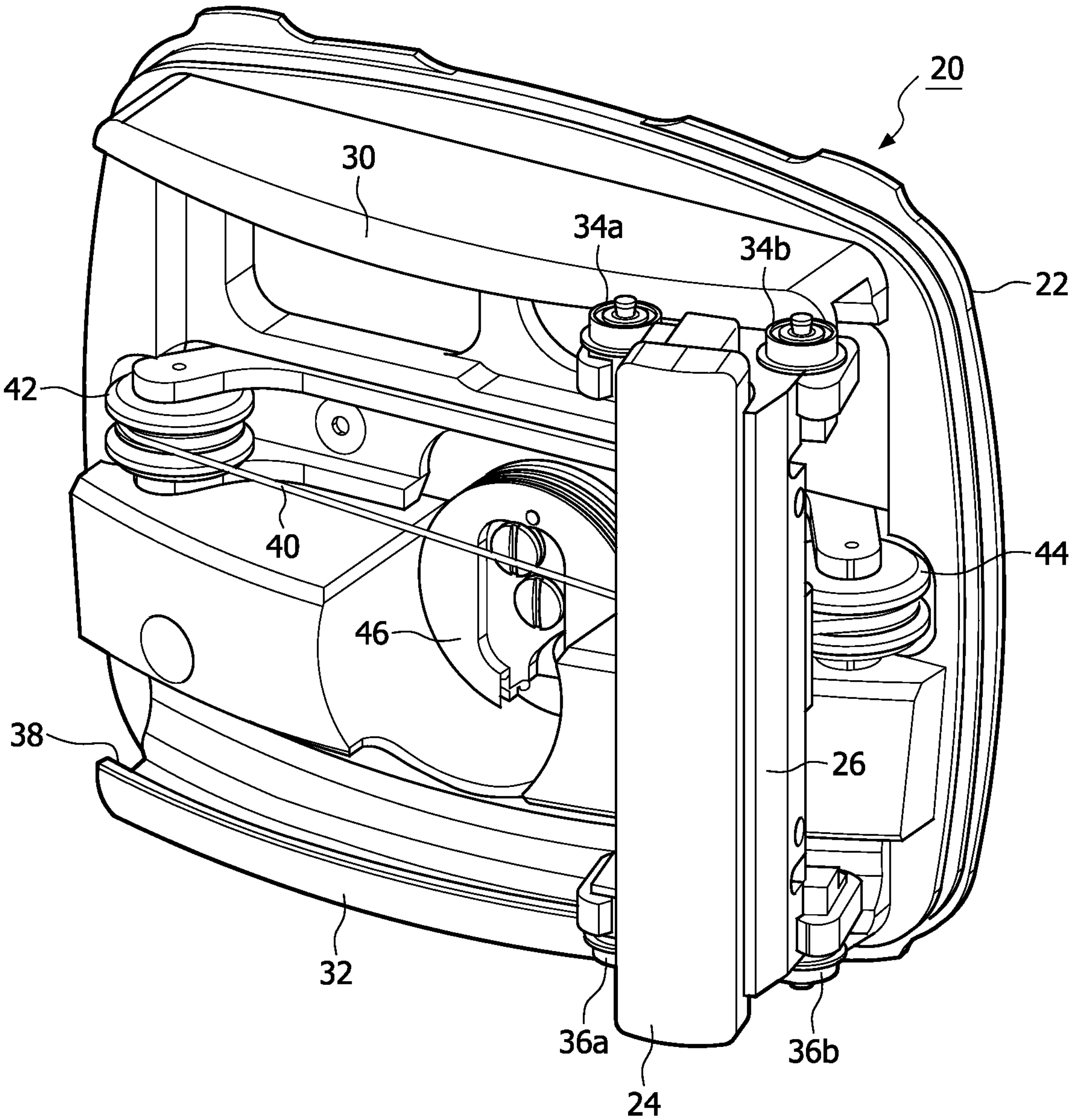

FIG. 2

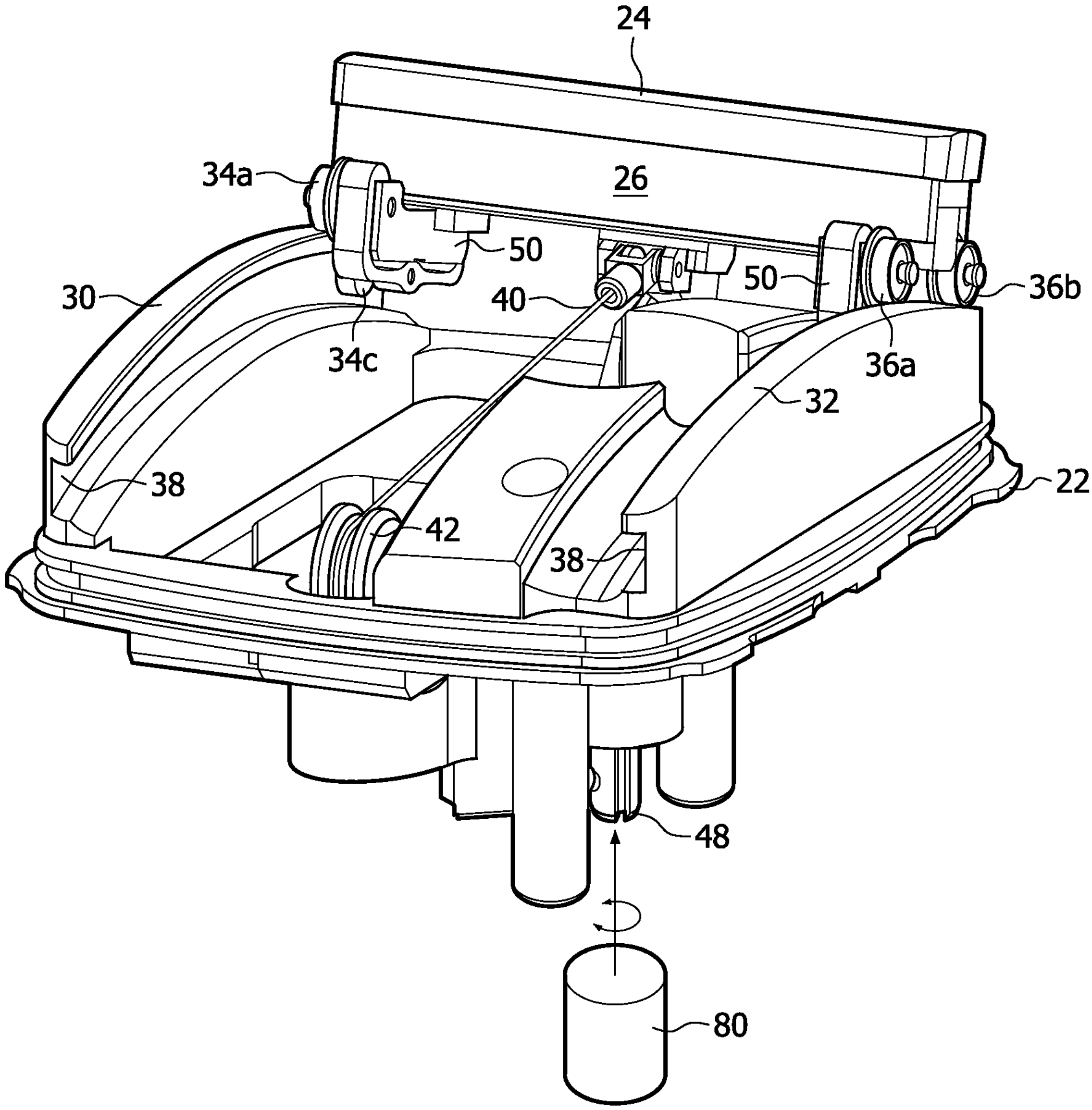

FIG. 3

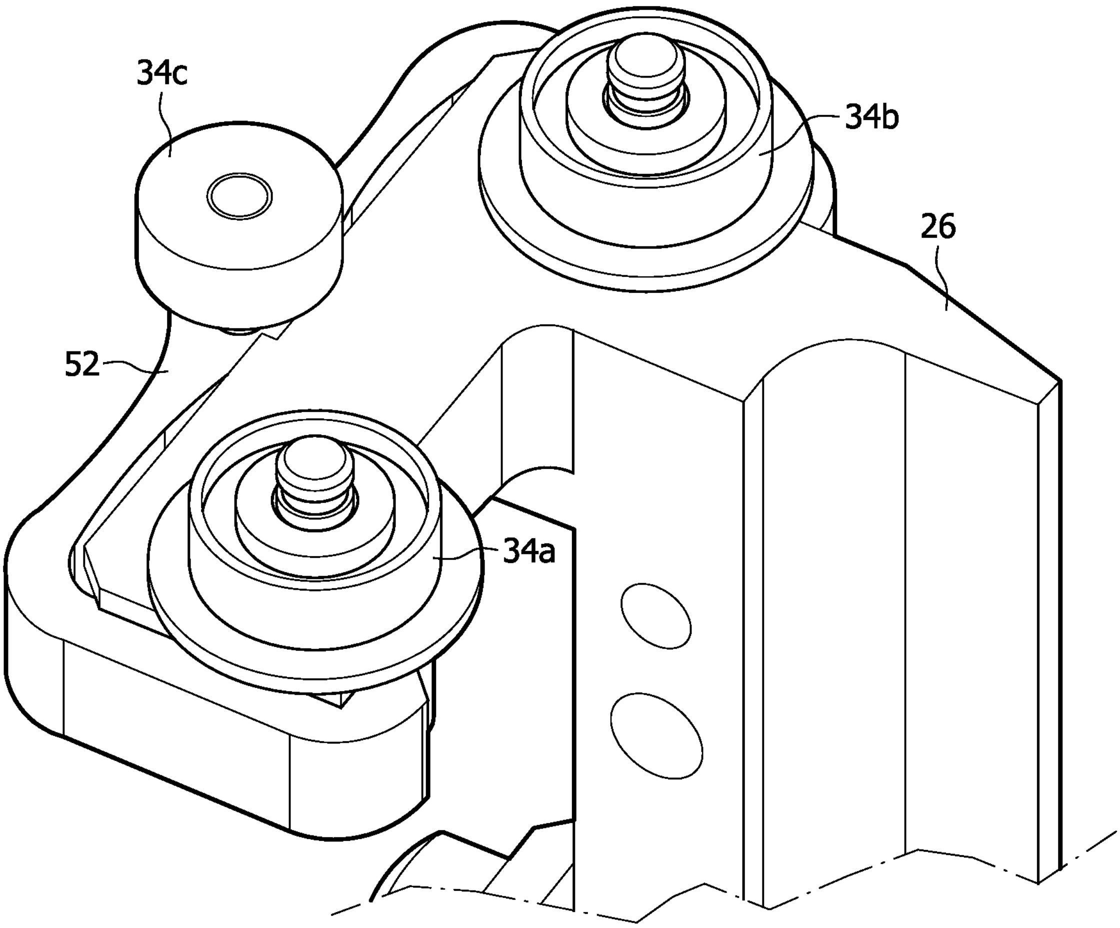

FIG. 4

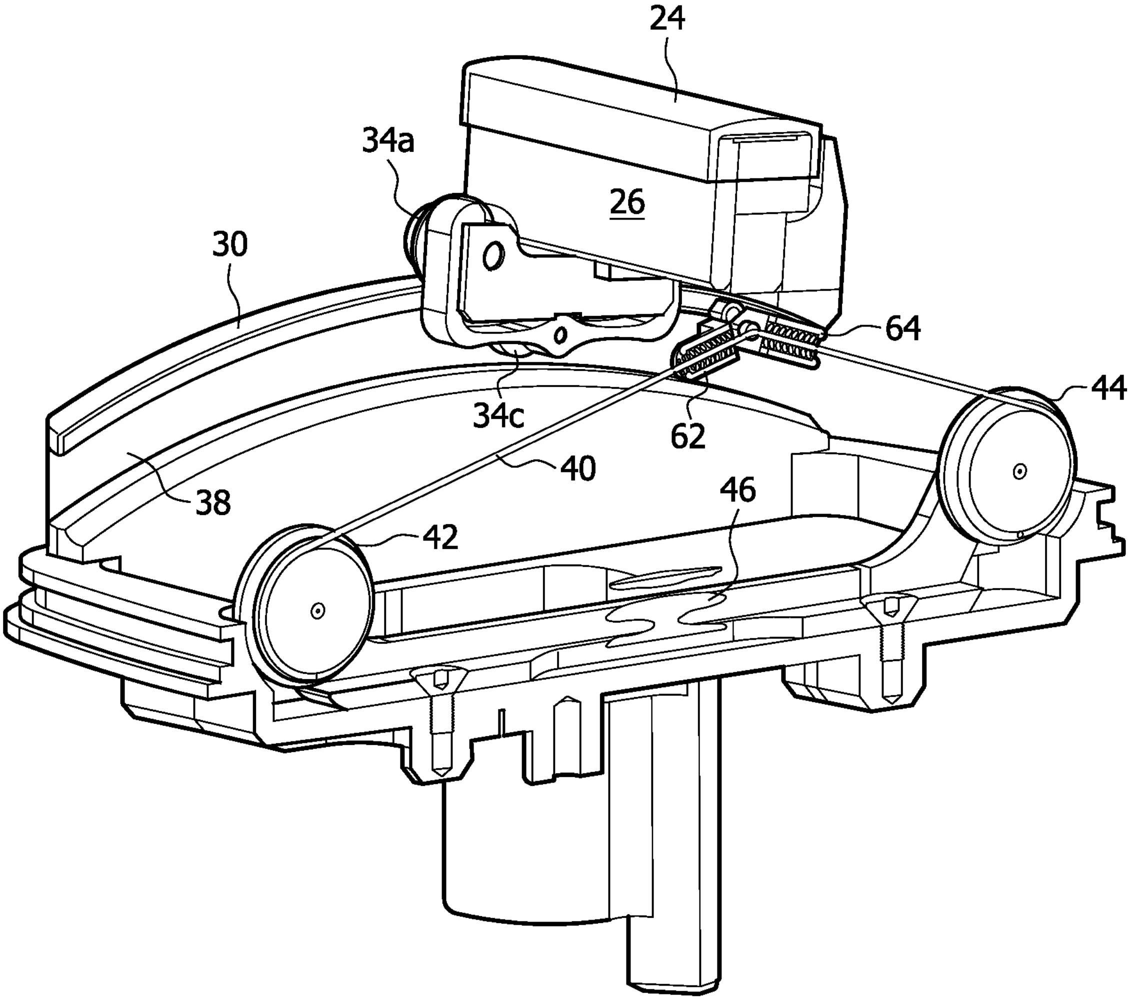

FIG. 5

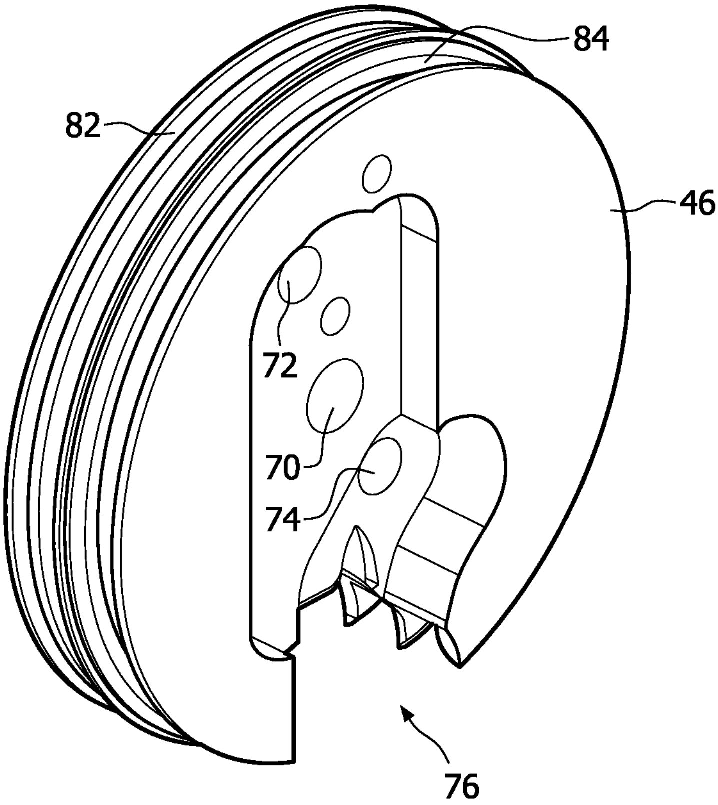

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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摘要(译)

超声探头包括换能器阵列，该换能器阵列来回移动以扫过阵列的图像平面通过用于3D扫描的体积区域。换能器阵列安装在滑架组件上，滑架组件在探头中的流体隔室内的一对导轨上来回移动。导轨优选地弧形弯曲，以提供在近场中具有相对宽的孔的高度发散扫描。提供一种用于滑架组件的电机驱动的电缆驱动器的凸轮，其通过换能器阵列的行进路径提供相对线性的运动。

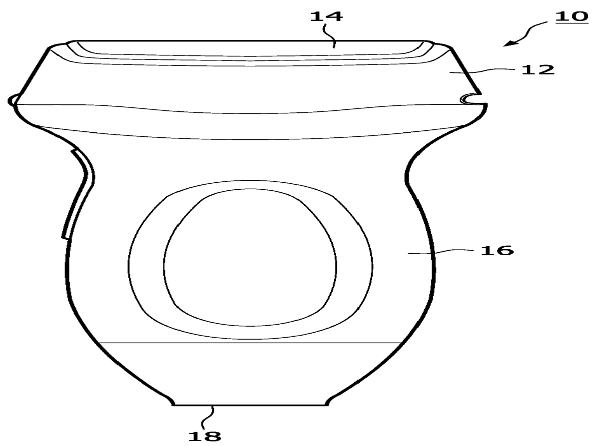

FIG. 1