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(54) **Title**: VERTICAL SCAN IMAGING SYSTEM

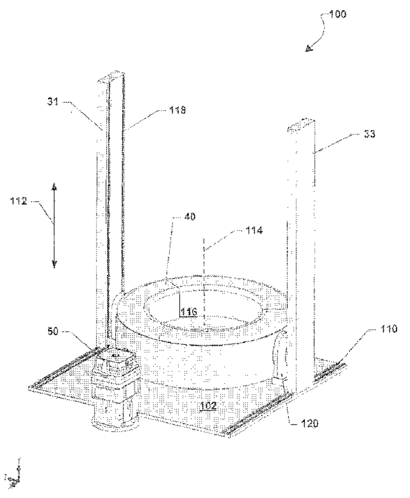

FIG. 1A

(57) **Abstract**: An imaging system and methods including a gantry defining a bore and an imaging axis extending through the bore, and at least one support member that supports the gantry such that the imaging axis has a generally vertical orientation, where the gantry is displaceable with respect to the at least one support member in a generally vertical direction. The imaging system may be configured to obtain a vertical imaging scan (e.g., a helical x-ray CT scan), of a patient in a weight-bearing position. The gantry may be rotatable between a first position, in which the gantry is supported such that the imaging axis has a generally vertical orientation, and a second position, such that the imaging axis has a generally horizontal orientation. The gantry may be displaceable in a horizontal direction and the system may perform a horizontal scan of a patient or object positioned within the bore.

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Vertical Scan Imaging System

[0001] RELATED APPLICATIONS

[0002] This application claims the benefit of priority to U.S. Provisional Application No. 61/659,609 filed on June 14, 2012, the entire contents of which are incorporated herein by reference.

[0003] BACKGROUND

[0004] Conventional medical imaging devices, such as computed tomography (CT) and magnetic resonance (MR) imaging devices, are typically large, fixed bore devices. The patient must enter the device from the front or rear of the device in a lying position. These devices are limited in the types of imaging operations that may be performed.

[0005] SUMMARY

[0006] Embodiments include an imaging system having a gantry defining a central imaging bore and an imaging axis extending through the bore, the gantry comprising at least one imaging component for obtaining images of an object located within the bore, and at least one support member that supports the gantry such that the imaging axis has a generally vertical orientation, where the gantry is displaceable with respect to the at least one support member in a generally vertical direction.

[0007] In various embodiments, the gantry comprises a generally O-shaped housing having an internal cavity, and the imaging component(s), such as an x-ray source and/or x-ray detector, are rotatable around the gantry within the internal cavity. The imaging system may be configured to obtain a vertical imaging scan, such as a helical x-ray CT scan, of a patient in a weight bearing standing position.

[0008] In various embodiments, the gantry of the imaging system is rotatable with respect to the at least one support member between a first position, in which the gantry is supported such that the imaging axis has a generally vertical orientation, and a second position, in which the gantry is supported such that the imaging axis has a generally horizontal orientation. The gantry and the at least one support member may be displaceable in a generally horizontal direction relative to an object positioned within the bore. The system may thus perform a horizontal scan of a patient or object positioned within the bore.

[0009] In various embodiments, the gantry may be rotatable with respect to the at least one support member to a desired angle with respect to a tilted axis (i.e., an axis that is neither horizontal nor vertical). The gantry may be displaced both vertically and horizontally to perform an imaging scan along the titled axis. The angle of the gantry with respect to the tilted axis may remain fixed during the scan.

[0010] In further embodiments, a method of imaging an object includes positioning an object within a central imaging bore of a gantry comprising at least one imaging component for obtaining images of the object, the gantry having an imaging axis extending through the bore in a generally vertical orientation, displacing the gantry in a generally vertical direction with respect to the object, and obtaining image data of the object using the at least one imaging component.

[0011] In various embodiments, the method may further include rotating the gantry from a generally vertical orientation to a generally horizontal orientation, and displacing the gantry in a relatively horizontal direction relative to the object to perform an imaging scan. In various embodiments, the method may further include rotating the gantry to an angle with respect to a tilted axis, and displacing the gantry in both horizontal and vertical directions to perform an imaging scan along the tilted axis.

[0012] Further embodiments include an imaging system including a gantry having at least one imaging component for obtaining images of an object positioned within a bore of the gantry, the gantry having an imaging axis extending through the bore, the imaging system further including means for tilting the gantry to change an orientation of the imaging axis, means for displacing the gantry in a generally vertical direction with respect to the object, and means for obtaining image data of the object using the at least one imaging component. The imaging system may further include means for displacing the gantry in a generally horizontal direction with respect to the object.

[0013] BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Other features and advantages of the present invention will be apparent from the following detailed description of the invention, taken in conjunction with the accompanying drawings of which:

[0015] FIG. 1Ais a perspective view of an X-ray CT imaging system with a vertically displaceable gantry ring in accordance with one embodiment of the invention.

[0016] FIG. 1B illustrates the imaging system of FIG. 1A with the gantry ring in a raised position.

[0017] FIG. 2 illustrates an embodiment imaging system imaging a patient in a weight-bearing standing position.

[0018] FIG. 3A illustrates an embodiment imaging system in which the gantry has been rotated from a vertical orientation to a horizontal orientation, with the gantry horizontally displaced from a column and support table.

[0019] FIG. 3B illustrates the imaging system of FIG. 3A with the gantry translated in a horizontal direction (along z-axis) towards the column and support table.

[0020] FIG. 3C illustrates the imaging system of FIG. 3A further translated in a horizontal direction (along z-axis) towards the column and support table.

[0021] FIG. 4 illustrates the support table rotated 90 degrees on the column.

[0022] FIG. 5A-5C illustrate an embodiment imaging system performing an imaging scan along a tilted axis.

[0023] FIG. 6 illustrates a plurality of components housed within the gantry according to one embodiment.

[0024] FIG. 7A is an exploded view of a gantry illustrating an outer shell, a rotor and a bearing system according to one embodiment.

[0025] FIG. 7B is a perspective view of the assembled gantry.

[0026] FIG. 7C schematically illustrates the assembly of the gantry according to one embodiment.

[0027] DETAILED DESCRIPTION

[0028] This application is related to U.S. Application No. 12/576,681, filed October 9, 2009, now U.S. Patent No. 8,118,488, U.S. Application No. 13/025,566, filed February 11, 2011, U.S. Application No. 13/025,573, filed February 11, 2011, U.S. Application No. 13/441,555, filed April 6, 2012, and U.S. Provisional Application No. 61/658,650, filed June 12, 2012. The entire contents of all of these applications are hereby incorporated by reference for all purposes.

[0029] The various embodiments will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. References made to particular examples and implementations are for illustrative purposes, and are not intended to limit the scope of the invention or the claims.

[0030] Referring to FIG. 1A, an imaging system 100 according to one embodiment of the invention is shown. The system 100 includes image collection components, such as a rotatable x-ray source and detector array or stationary magnetic resonance imaging components, that are housed within the gantry 40. The system 100 is configured to collect imaging data, such as, for example x-ray computed tomography (CT) or magnetic resonance imaging (MRI) data, from an object located within the bore 116 of the gantry 40, in any manner known in the medical imaging field.

[0031] The system 100 may include a base 102, which may be a stable, high-strength support structure having a generally flat top surface. The base 102 may be supported on a suitable weight-bearing surface, such as on the ground or on a floor of a building.

At least one support member 31, 33 may extend in a generally vertical direction from the base 102, and the gantry 40 may be attached to and supported above the base 102 by the at least one support member 31, 33. In the embodiment shown in FIG. 1A, two support members 31, 33 (e.g., support posts or rails) are supported by the base 102 and extend in a generally vertical direction from the top surface of the base 102. The support members 31, 33 are each attached to opposite sides of the gantry 40. The support members 31, 33 may be attached to opposite sides of the gantry by attachment members 120, as described in further detail below. It will be understood that more than two support members (e.g., 3 or more), or a single support member may support the gantry above the base 102 in various embodiments. Also, in various embodiments, the base 102 may be omitted, and the at least one support member 31, 33 may be directly supported on the ground or floor.

[0032] In further embodiments, the at least one support member 31, 33 may be supported by a ceiling, a wall or other support structure, and may be hung or cantilevered from the support structure in a generally vertical orientation.

[0033] In various embodiments, the system 100 may be a fixed room (e.g., not mobile) imaging system. Alternatively, the system may be a mobile system that includes suitable means for transporting the entire system 100 (e.g., a drive mechanism coupled to one or more wheels, casters, rollers, etc.). The system 100 may further include a column 50 for supporting one or more support tables, as described in further detail below.

[0034] As shown in FIG. 1A, the gantry 40 comprises a generally O-shaped structure having a central imaging bore 116. The bore 116 defines a central imaging axis 114. In various embodiments, the at least one support member 31, 33 may support the gantry 40 such that the imaging axis 114 has a generally vertical orientation. By generally vertical orientation, the imaging axis 114 may be normal to the flat top surface of base 102 or other planar horizontal surface on which the system 100 is supported (e.g., the ground or floor), and includes deviations up to 45° from the normal orientation (e.g., the imaging axis 114 is oriented at an more than 45° relative to the horizontal top surface of base 102).

[0035] The gantry 40 may be displaceable relative to at least one support member 31, 33. In embodiments, the gantry 40 may be displaceable along at least one dimension of the at least one support member 31, 33, such as along a length of the at least one support member 31, 33. In embodiments, the at least one support member 31, 33 may have a generally vertical orientation, and the gantry 40 may be displaceable in a generally vertical direction, such as the direction indicated by arrow 112 in FIG. 1A. By generally vertical orientation, the direction of displacement 112 may be normal to the flat top surface of base 102 or other planar horizontal surface on which the system 100 is supported (e.g., the ground or floor), and includes deviations up to 45° from the normal orientation (e.g., the direction of gantry displacement 112 is oriented at an angle more than 45° relative to the horizontal top surface of base 102).

[0036] The gantry 40 and the at least one support member 31, 33 may include mating features that enable the displacement of the gantry 40 relative to the support member(s) 31, 33 in a generally vertical direction 112, while the gantry 40 is restricted from moving in other directions relative to the support member(s) 31, 33. In the embodiment of FIG. 1A, the support members 31, 33 may each include rail(s) 118 extending along the length of the support members 31, 33. The gantry 40, or in the embodiment shown in FIG. 1A, the attachment mechanism 120, may include features that mate with the respective rails 118 to enable the displacement of the gantry 40. A drive mechanism may drive the displacement of the gantry 40 relative to the support member(s) 31, 33. The drive mechanism may comprise, for example, a traction drive, a gear system, a belt drive, a pulley, a drivewheel, etc., or various combinations thereof. The drive mechanism may be mechanically coupled to and driven by one or more motor(s), which may be located on the gantry 40 and/or on one or more support member(s) 31, 33. A controller may control the operation of the motorized drive mechanism and thereby control the displacement of the gantry 40. The controller may receive position feedback signals indicative of the relative position of the gantry 40 and one or more support members 31, 33, such as from a linear encoder.

[0037] In embodiments, the gantry 40 may be vertically displaced along substantially the entire length of the support member(s) 31, 33. FIG. 1B illustrates the system of FIG. 1A with the gantry 40 displaced along the direction of arrow 112 to a height above the base 102 and floor. In embodiments, the gantry 40 may be displaceable from a first position proximate to the base 102 and floor of a room to a second position proximate the ceiling of the room. In some embodiments, the gantry 40 may be further displaceable into the ceiling, such as into a cavity or enclosure formed in the ceiling. Alternatively, or in addition, the gantry 40 may be displaceable into the base 102 and/or floor, such as in a cavity or enclosure formed in the base 102 and/or the floor. The respective cavities or enclosures may include doors or panels that can be closed to fully house the gantry within the cavity or enclosure. In this way, the gantry 40 may be moved completely out of the way and safely stored when not in use. The support member(s) 31, 33 may also be retracted into the floor and/or ceiling, such as in a telescoping fashion, or otherwise removed, when the system is not in use.

[0038] The imaging components of the gantry 40 may obtain imaging data of an object positioned within the bore 116 while the gantry 40 is displaced in a generally vertical direction to obtain a vertical scan of the object. For an x-ray CT imaging system, for example, an x-ray source and detector may rotate within the gantry 40 while the gantry is vertically displaced to provide a helical scan in a generally vertical orientation. In various embodiments, the system 100 may perform a helical scan of a human or animal patient in a weight bearing standing position.

[0039] Various examples of diagnostic imaging applications that may be performed on a human or animal patient in a weight-bearing position using the present system include, without limitation:

[0040] -Imaging the bones of a foot. The three-dimensional relationships of the bones in the foot in a flatfoot deformity are difficult to assess with standard radiographs. CT scans demonstrate these relationships but are typically made in a non-weightbearing mode. The use of a weightbearing CT or other imaging apparatus may be useful in imaging the feet in patients with severe flexible pesplanus deformities and to better define the anatomical changes that occur.

[0041] -Imaging of a limb (e.g. leg). Weight-bearing (CT) bilateral long leg hip to ankle examination and non-weight bearing cross-sectional imaging (CT) of the affected limb may be performed on the hip, knee and ankle, for example, and may be useful for determining variations in angulation and alignment accuracy for diagnosis and/or surgical planning.

[0042] -Imaging of a spine. Weight bearing scanning (e.g., CT scanning) may be useful for improvements in the accurate diagnosis of degenerative spinal disorders by scanning a patient in the “real life” standing position. By scanning in the standing position, the spinal disc and facet joint compresses, which may enable more specific and precise diagnosis of degenerative spine disorders.

[0043] -Imaging of a joint (e.g., knee). Weight bearing scanning (e.g., CT scanning) of the knee may enable more specific and precise diagnosis of the patella-femoral kinematics and may also be useful in surgical planning.

[0044] -Angiography. Weight bearing angiography (e.g., CT angiography) may enable more accurate diagnosis, and may be used, for example, to examine the pulmonary arteries in the lungs to rule out pulmonary embolism, a serious but treatable condition. Weight bearing angiography may also be used to visualize blood flow in the renal arteries (those supplying the kidneys) in patients with high blood pressure and those suspected of having kidney disorders. Narrowing (stenosis) of a renal artery is a cause of high blood pressure (hypertension) in some patients and can be corrected. A special computerized method of viewing the images makes renal CT angiography a very accurate examination. This is also done in prospective kidney donors. Weight bearing angiography may also be used to identify aneurysms in the aorta or in other major blood vessels. Aneurysms are diseased areas of a weakened blood vessel wall that bulges out—like a bulge in a tire. Aneurysms are life-threatening because they can rupture. Weight bearing angiography may also be used to identify dissection in the aorta or its major branches. Dissection means that the layers of the artery wall peel away from each other—like the layers of an onion. Dissection can cause pain and can be life-threatening. Weight bearing angiography may also be used to identify a small aneurysm or arteriovenous malformation inside the brain that can be life-threatening. Weight bearing angiography may also be used to detect atherosclerotic disease that has narrowed the arteries to the legs.

[0045] FIG. 2, for example, illustrates a patient 105 in a standing position within an embodiment imaging system 100. The patient 105 is standing on the base 102 within the bore 116 of the gantry 40. The system 100 may be used to perform an imaging scan of the patient 105 in a generally vertical direction, as indicated by arrow 112. In embodiments, the system 100 may scan any portion of the patient's anatomy, including a full-body scan. The system 100 may also be used to perform a vertical scan of a patient in a sitting position or a reclined position.

[0046] In embodiments, the system 100 may include at least one patient/object support structure 202 that may extend from the base 102 in a generally vertical direction. The support structure 202 may be aligned with the bore 116. The support structure 202 may be made of a radiolucent (x-ray transparent) material. As shown in FIG. 2, a support structure 202 may be radiolucent (x-ray transparent) vertical rigid post or plate that the patient 105 may grab or sit on to help stabilize the patient throughout the scan. The support structure 202 may have handles or arm rests at varying heights to help the patient lean against and stay motionless during the scan. The support structure 202 may also be a post with a radiolucent chair for people who have a hard time standing during a scan, or it may be two plates that sandwich the patient in a vertical standing position to help the patient remain still during a scan.

[0047] The support structure 202 may be made entirely or partially of any radiolucent material such as carbon fiber, etc.

[0048] In embodiments, the gantry 40 may be attached to the at least one support member 31, 33 such that the gantry 40 may tilt with respect to the support member(s) 31, 33. As shown in FIG. 1A, for example, the gantry 40 may be attached to the support members 31, 33 by respective attachment mechanisms 120. The attachment mechanisms 102 may include a bearing assembly that allows the gantry 40 to tilt with respect to the support members 31, 33. In an alternative embodiment, the gantry 40 may be directly attached to the support members 31, 33 (e.g., without a separate attachment mechanism 120 as shown in FIG. 1A) via a bearing assembly (not illustrated) that enables the gantry 40 to tilt with respect to the support members. In embodiments, the gantry 40 may tilt at least about 45° relative to the support members 31, 33. In preferred embodiments, the gantry 40 may tilt more than 45°, such as at least about 90°, relative to the support members 31, 33. In some embodiments, the gantry 40 may tilt from a generally vertical orientation (such as shown in FIGS. 1A-B) to a generally horizontal orientation, as shown in FIGS. 3A-C. By generally horizontal orientation, the imaging axis 114 may be parallel to the flat top surface of base 102 or other planar horizontal surface on which the system 100 is supported (e.g., the ground or floor), and includes deviations up to 45° from this parallel orientation (e.g., the imaging axis 114 is oriented less than 45° relative to the horizontal top surface of base 102).

[0049] In a generally horizontal configuration, the system 100 may perform an imaging scan of an object positioned on a suitable support, such as tabletop support 60, shown in FIGS. 3A-C. The column 50 may be adapted to support the tabletop support 60. The tabletop support 60 may be attached to the column 50 in a cantilevered manner, such that at least a portion of the tabletop support 60 may extend over the base. A portion of the tabletop support 60 may extend into the bore 116 of the gantry 60. The tabletop support 60 may include, for example, any suitable table, such as a patient table, as well as a chair for a seated patient.

[0050] An imaging scan may be performed via a relative displacement of the gantry 40 and the tabletop support 60. The relative displacement may be in a generally horizontal direction, such as indicated by arrow 212. The relative displacement may be the displacement of the tabletop support 60, such as a displacement of the column 50 and tabletop support 60 with respect to a stationary gantry 40, or a displacement of the tabletop support 60 with respect to a stationary column 50 and gantry 40. In other embodiments, the gantry 40 may move relative to a stationary tabletop support 60. In further embodiments, both the gantry 40 and the tabletop support 60 may move.

[0051] In the embodiment illustrated in FIGS. 3A-3C, the gantry 40 and the at least one support member 31, 33 may be displaced relative to the base 102, column 50 and patient table 60, which may be stationary. The base 102 and the at least one support member 31, 33 may include mating features that enable the displacement of the support members 31,33 (along with the gantry 40 to which they are attached), relative to base 102 in a generally horizontal direction 212, while the support member(s) 31, 33 and gantry 40 are restricted from moving in other directions relative to base 102. In the embodiment of FIGS. 3A-C, the base 102 may include rails 110 extending along the length of the base 102. The support members 31, 33 may include features that mate with the respective rails 110 to enable the horizontal displacement of the support members 31, 33 and gantry 40. A drive mechanism (e.g., z-drive) may drive the displacement of the support members 31, 33 and gantry 40 relative to the base 102. The drive mechanism may comprise, for example, a traction drive, a gear system, a belt drive, a pulley, a drivewheel, etc., or various combinations thereof. The drive mechanism may be mechanically coupled to and driven by one or more motor(s), which may be located on the base 102 and/or on one or more support member(s) 31, 33. A controller may control the operation of the motorized drive mechanism and thereby control the displacement of the support members 31, 33 and gantry 40. The controller may receive position feedback signals indicative of the position of the support members 31, 33 and gantry 40 relative to the base 102, such as from a linear encoder.

[0052] The drive mechanism for vertical displacement as described above may be used to adjust the height of the gantry 40 relative to the tabletop support 60, either before or during a horizontal scan. Similarly, the drive mechanism for horizontal displacement as described above may be used to adjust the position of the gantry 40 in a horizontal direction (e.g., z-direction), either before or during a vertical scan.

[0053] FIGS. 3A-C illustrate an embodiment of a system 100 performing a horizontal scan. In FIG. 3A, the gantry 40 and support members 31, 33 are located away from the column 50 and the distal end of the tabletop support 60 is within the bore 116. In FIG. 3B, the gantry 40 and support members 31, 33 are moved towards the column 50 in the direction of arrow 212, and the tabletop support 60 extends fully through the bore 116. In FIG. 3C, the gantry 40 and support members 31, 33 have traveled to the proximal end of rails 110, and the gantry 40 is proximate to the column 50. The imaging components of the gantry 40 may obtain imaging data of an object positioned within the bore 116 while the gantry 40 is displaced in a generally horizontal direction, as shown in FIGS. 3A-C, to obtain a horizontal scan of the object. For an x-ray CT imaging system, for example, an x-ray source and detector may rotate within the gantry 40 while the gantry is horizontally displaced to provide a helical scan in a generally horizontal orientation. In various embodiments, the system 100 may perform a horizontal scan of a human or animal patient in a lying position.

[0054] FIG. 4 illustrates a system 100 according to one embodiment wherein the tabletop support 60 may be rotated at least about 90° on the column 50. In embodiments, the tabletop support 60 may be rotated to facilitate loading/unloading of a patient, or to provide better access to the patient for a medical procedure. The tabletop support 60 may be rotated back to the orientation of FIGS. 3A-C in order to perform an additional imaging scan, without having to remove the patient or move the patient relative to the tabletop support 60 between scans. The tabletop support 60 may be rotated to the orientation of FIG. 4 to perform a scan in a generally vertical orientation, such as shown in FIGS. 1A-2. In embodiments, the tabletop support 60 may also translate with respect to the column 50 in one or more directions. The height of the column 50 may also be adjustable.

[0055] FIGS. 5A-5C illustrate an embodiment imaging system 100 performing a scan along a tilted axis. In FIG. 5A, the object being imaged (e.g., patient 105) is positioned along a tilted axis 514 (i.e., neither horizontal nor vertical). The patient 105 may be supported against a support structure 60 that is similarly aligned along tilted axis 514. The gantry 40 may be tilted on the support members 31, 33 to any desired angle relative to axis 514, and may be perpendicular to axis 514. The region of interest of the patient 105 may be centered within the bore (e.g., such that the bore imaging axis is collinear with the tilted axis 514). In various embodiments, the imaging system 100 may perform an imaging scan (e.g., a helical x-ray CT scan) of the patient 105 while maintaining a fixed angle between the gantry and the tilted axis 514 and maintaining the region of interest centered within the bore. The imaging system 100 may achieve this via coordinated movement of the gantry in both a vertical direction (indicated by arrow 112) and a horizontal direction (indicated by arrow 122). The vertical movement of the gantry 40 may be with respect to the support member(s) 31, 33, and may be along rail(s) 118, as described above. The horizontal movement of the gantry 40 may be the movement of the support member(s) 31, 33 and gantry 40 with respect to the base 102, and may be along rail(s) 120, as described above. A control system of the imaging system 100 may include logic configured to determine the relative vertical and horizontal displacement of the gantry 40 needed to translate the gantry along a tilted axis 514. Drive mechanism(s) for vertical and horizontal displacement of the gantry 40 may be controlled by the control system to provide coordinated vertical and horizontal displacement of the gantry. Where the angle of the tilted axis 514 is known or may be determined, the control system may use simple trigonometric relations to determine the vertical and horizontal displacement of gantry 40. For example, where the tilted axis 514 is at a 60° angle relative to horizontal, each cm of the scan along axis 514 may include a vertical displacement of ~0.87 cm (i.e., sin 60°) and a horizontal displacement of 0.5 cm (i.e., cos 60°). Thus, the imaging system 100 may perform a scan at any tilt axis 514, and in embodiments may perform scans along complex axes, such as along an angled or curved axis.

[0056] FIGS. 5A-5C illustrate an example of an imaging scan of a patient along a tilted axis 514. The patient 105 may lean against support 60 such that the patient is aligned along the tilted axis 514. The gantry 40 may be tilted such that the gantry is perpendicular to tilted axis 514, with the patient centered within the bore of the gantry. The gantry 40 may then be displaced in both vertical and horizontal directions such that the gantry 40 may translate along the length of the patient 105, as shown in FIGS. 5B and 5C. The gantry 40 may remain perpendicular to the tilted axis 514 through the duration of the scan. Imaging components, such as an x-ray source and detector, may rotate within the gantry 40 while the gantry translates along the length of the patient 105 to obtain a helical scan.

[0057] A number of imaging components that may be included in the imaging system 100 for providing an imaging scan are illustrated in FIG. 6. The components may be housed within the gantry 40. In one embodiment, the imaging system 100 comprises an X-ray CT imaging system, and includes an x-ray source 43, high-voltage generator 44, heat exchanger 430, x-ray detector 45, power supply 63 (e.g., battery system), computer 46, rotor drive mechanism 47, and a docking system 35 (e.g., for providing intermittent power/data connection between rotating and non-rotation portions of the system). These components may be mounted on a rotor 41 to collectively define a rotating portion 101 of the system. The rotor 41 and the components mounted thereto may rotate within a housing defined by an outer shell 42 (FIG. 7A) of the gantry 40.

[0058] It will be understood that the components described and illustrated are merely exemplary, and other embodiments may omit one or more of these components and may utilize other additional components. For example, in embodiments, power for the rotating portion 101 may be provided by a slip ring or cable system, so that a power supply 63 on the rotating portion 101 may not be needed. In some embodiments, power and/or data may be continuously transferred between the rotating and non-rotating portions via cable, slip ring or wirelessly, in which case the power supply 63, computer 46 and/or docking system 35 may not be included. Further, the rotation of the rotor may be provided by a drive system on the non-rotating portion, in which case the rotor drive mechanism 47 on the rotor 41 may not be included. Also, it will be understood that other types of imaging systems, such as MRI systems, may use other suitable components for imaging, as are known in the art.

[0059] In embodiments, the x-ray source 43 and detector 45 may be configured to perform a helical x-ray CT scan. The detector 45 may comprise a plurality of x-ray sensitive detector elements arranged in a semicircular arc, with the arc center coinciding with the focal spot of the x-ray source. In some embodiments, the x-ray detector may be a flat panel detector, and the system may be configured to perform real time x-ray and/or cone beam imaging of an object within the bore of the gantry. The system may be a single plane system (i.e., having a single source and detector which can obtain an image in a single plane at one time), or in some embodiments, may be a bi-plane or multi-plane system (i.e., having multiple x-ray source(s) and/or detector(s) at different positions on the ring for obtaining images in multiple planes at the same time).

[0060] In the embodiment of FIG. 6, during an imaging scan, the rotor 41 rotates within the interior of the gantry, while the imaging components such as the x-ray source 43 and x-ray detector 45 obtain imaging data for an object positioned within the bore 116 of the gantry, as is known, for example, in conventional X-ray CT scanners. The rotor drive mechanism 47 may drive the rotation of the rotor 41 around the interior of the gantry 40. The rotor drive mechanism 47 may be controlled by a system controller that controls the rotation and precise angular position of the rotor 41 with respect to the gantry 40, preferably using position feedback data, such as from a position encoder device.

[0061] Various embodiments of the imaging system 100 may be relatively compact. One way in which the system 100 may be made compact is in the design of the gantry 40 and its interface with the rotating portion 101 (e.g., the rotor 41 and the various components mounted to the rotor 41). In embodiments, the outer shell 42 of the gantry 40 may comprise both a protective outer covering for the rotating portion 101 and a mounting surface for a bearing that enables the rotating portion 101 to rotate 360° within the outer shell 42 of the gantry 40.

[0062] FIG. 7A is an exploded view of a gantry 40 according to one embodiment that illustrates the outer shell 42, the rotor 41 and a bearing assembly 400. Fig. 7B illustrates the assembled gantry 40. As is shown in FIGS. 7A-B, the outer shell 42 of the gantry 40 may be a generally O-shaped covering of a structural material that may at least substantially fully enclose the rotating portion 101, including the rotor 41 and any components mounted to the rotor, over one or more sides of the rotating portion 101. The outer shell 42 of the gantry 40 may be conceptually considered an "exoskeleton," that both supports the rotating portion 101 of the system 100, preferably in three dimensions, and also provides a protective barrier between the rotating portion 101 and the external environment. The outer shell 42 may be fabricated from a sufficiently rigid and strong structural material, which may include, for example, metal, composite material, high-strength plastic, carbon fiber and combinations of such materials. In preferred embodiments, the outer shell 42 may be comprised of a metal, such as aluminum. The outer shell 42 may be machined or otherwise fabricated to relatively tight tolerances. The outer shell 42 may be formed as a one piece, unitary component. In other embodiments, the outer shell 42 may be comprised of multiple components and/or materials that may be joined using any suitable technique to provide the shell 42.

[0063] The outer shell 42 may have an outer circumferential surface 406 that may extend around the periphery of the rotating portion 101 of the system 100 to substantially fully enclose the rotating portion 101 around its outer circumference. The outer shell 42 may also include at least one side wall 412 that may extend from the outer circumferential surface 406 to a bore 416 of the gantry 40 and may substantially fully enclose the rotating portion 101 around one side of the rotating portion.

[0064] The bearing assembly 400 according to one embodiment is shown in FIG. 7A. In this embodiment, the bearing assembly 400 includes a first race 402 that may be securely fastened to the outer shell 42 of the gantry 40, and a second race 404 that may be securely fastened to the rotor 41. A bearing element is provided between the first race 402 and the second race 404, and is configured to allow the second race 404 (along with the rotor 41 to which it is attached) to rotate concentrically within the first race 402, preferably with minimal friction, thereby enabling the rotor 41 to rotate with respect to the outer shell 42 of the gantry 40.In some embodiments, all or a portion of the bearing assembly 400 may be integrally formed as a part of the outer shell 42 orof the rotor 41, or of both. For example, the first race 402 may be formed as an integral surface of the outer shell 42 and/or the second race 404 may be formed as an integral surface of the rotor 41. In various embodiments, the entire bearing assembly for enabling the rotation of the rotating portion 101 with respect to the non-rotating portion 103 of the imaging system 100 may be located within the generally O-shaped gantry 40.

[0065] The outer diameter of the gantry 40 can be relatively small, which may facilitate the portability of the system 100. In a preferred embodiment, the outer diameterof the gantry 40 is less than about 70 inches, such as between about 60 and 68 inches, and in one embodiment is about 66 inches. The outer circumferential wall 406 of the outer shell 42 may be relatively thin to minimize the OD dimension of the gantry 40. In addition, the interior diameter of the gantry 40, or equivalently the bore 116 diameter, can be sufficiently large to allow for the widest variety of imaging applications, including enabling different patient support tables to fit inside the bore, and to maximize access to a subject located inside the bore. In one embodiment, the bore diameter of the gantry 40 is greater than about 38 inches, such as between about 38 and 44 inches, and in some embodiments can be between about 40 and 50 inches. In one exemplary embodiment, the bore has a diameter of about 42 inches. The gantry 40 generally has a narrow profile, which may facilitate portability of the system 100. In one embodiment, the width of the gantry 40 (W) is less than about 17 inches, and can be about 15 inches or less.

[0066] FIG. 7C illustrates the gantry 40 and attachment mechanisms 201, 203 for securing the gantry 40 to the support member(s) 31, 33 (see FIG. 1A). The attachment mechanisms 201, 203, which may have an “earmuff” shape, may include bearing apparatuses that enable the tilt motion of the gantry 40, such as a tilt motion from a vertical to a horizontal orientation, and vice versa. One or both of the attachment mechanism(s) 201, 203 may also include a portion of a docking system for providing power and data transfer between rotating and non-rotating portions of the system. The system 100 may be assembled by securing the attachment mechanisms 201, 203 to opposite sides of the gantry 40. The entire assembly may then be attached to the support members 31, 33.

[0067] The foregoing method descriptions are provided merely as illustrative examples and are not intended to require or imply that the steps of the various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of steps in the foregoing embodiments may be performed in any order. Words such as “thereafter,” “then,” “next,” etc. are not necessarily intended to limit the order of the steps; these words may be used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles “a,” “an” or “the” is not to be construed as limiting the element to the singular.

[0068] The preceding description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects without departing from the scope of the invention. Thus, the present invention is not intended to be limited to the aspects shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. An imaging system, comprising:

a gantry defining a central imaging bore and an imaging axis extending through the bore, the gantry comprising at least one imaging component for obtaining images of an object located within the bore; and

at least one support member that supports the gantry such that the imaging axis has a generally vertical orientation, the gantry being displaceable with respect to the at least one support member in a generally vertical direction.

2. The imaging system of claim 1, wherein the gantry comprises a generally O-shaped housing having an internal cavity, the at least one imaging component being rotatable around the gantry within the internal cavity.

3. The imaging system of claim 1, wherein the at least one imaging component comprises an x-ray source and an x-ray detector.

4. The imaging system of claim 1, wherein the system is configured to obtain a vertical scan of a patient in a weight bearing position.

5. The imaging system of claim 1, further comprising a drive mechanism for displacing the gantry relative to the at least one support member in a generally vertical direction.

6. The imaging system of claim 5, wherein the at least one imaging component rotates within the gantry while the gantry is displaced in a generally vertical direction to obtain a helical scan of an object within the bore.

7. The imaging system of claim 1, wherein the at least one support member comprises two support members that are secured to opposite sides of the gantry.

8. The imaging system of claim 1, further comprising a patient/object support member within the bore.

9. The imaging system of claim 8, wherein the patient/object support comprises a radiolucent material.

10. The imaging system of claim 1, wherein the gantry is rotatable with respect to the at least one support member between a first position, wherein the at least one support member supports the gantry such that the imaging axis has a generally vertical orientation, to a second position, wherein the at least one support member supports the gantry such that the imaging axis has a generally horizontal orientation.

11. The imaging system of claim 10, wherein the gantry and at least one support member are displaceable in a generally horizontal direction relative to an object positioned within the bore.

12. The imaging system of claim 11, further comprising:

a column adapted to support a tabletop support such that the tabletop support extends at least in part into the bore when the imaging axis has a generally horizontal orientation.

13. The imaging system of claim 12, wherein the tabletop support is removable from the column.

14. The imaging system of claim 12, wherein the tabletop support is rotatable with respect to the column and/or floor.

15. The imaging system of claim 11, further comprising a drive mechanism for displacing the gantry and the at least one support member in a horizontal direction.

16. The imaging system of claim 15, further comprising a base having one or more rails, the at least one support member being displaceable in a horizontal direction along the one or more rails.

17. The imaging system of claim 11, wherein the gantry is rotatable with respect to the at least one support member to an angle with respect to a tilted axis, and the gantry is displaced both vertically and horizontally to perform an imaging scan along the tilted axis.

18. The imaging system 17, wherein the angle of the gantry with respect to the titled axis remains fixed during the imaging scan.

19. The imaging system of claim 18, wherein the gantry is perpendicular to the tilted axis.

20. The imaging system of claim 17, further comprising a control system that coordinates the respective vertical and horizontal displacement of the gantry to provide the imaging scan along the tilted axis.

21. The imaging system of claim 17, further comprising a support structure for supporting the object being imaged at the tilt angle.

22. A method of imaging an object, comprising:

positioning an object within a central imaging bore of a gantry comprising at least one imaging component for obtaining images of the object, the gantry having an imaging axis extending through the bore in a generally vertical orientation;

displacing the gantry in a generally vertical direction with respect to the object; and

obtaining image data of the object using the at least one imaging component.

23. The method of claim 22, wherein the object is a human or animal patient.

24. The method of claim 23, wherein the patient is positioned in a weight-bearing position within the bore.

25. The method of claim 24, wherein obtaining image data comprises obtaining imaging data of one or more of a foot, a limb, a joint, and an angiogram of a patient in a weight-bearing position.

26. The method of claim 22, wherein the imaging data comprises x-ray imaging data.

27. The method of claim 22, wherein the imaging data comprises magnetic resonance imaging data.

28. The method of claim 22, further comprising:

rotating the gantry from a generally vertical orientation to a generally horizontal orientation; and

displacing the gantry in a relatively horizontal direction relative to the object to perform an imaging scan.

29. The method of claim 22, further comprising:

rotating the gantry to an angle with respect to a tilted axis; and

displacing the gantry in both horizontal and vertical directions to perform an imaging scan along the tilted axis.

30. The method of claim 29, wherein the horizontal and vertical displacements occur substantially simultaneously.

31. An imaging system comprising a gantry having at least one imaging component for obtaining images of an object positioned within a bore of the gantry, the gantry having an imaging axis extending through the bore, the imaging system comprising:

means for tilting the gantry to change an orientation of the imaging axis;

means for displacing the gantry in a generally vertical direction with respect to the object; and

means for obtaining image data of the object using the at least one imaging component.

32. The imaging system of claim 31, the system further comprising:

means for displacing the gantry in a generally horizontal direction with respect to the object.

33. The imaging system of claim 32, the system further comprising:

means for controlling the displacement of the gantry in both horizontal and vertical directions to perform an imaging scan along a tilted imaging axis.

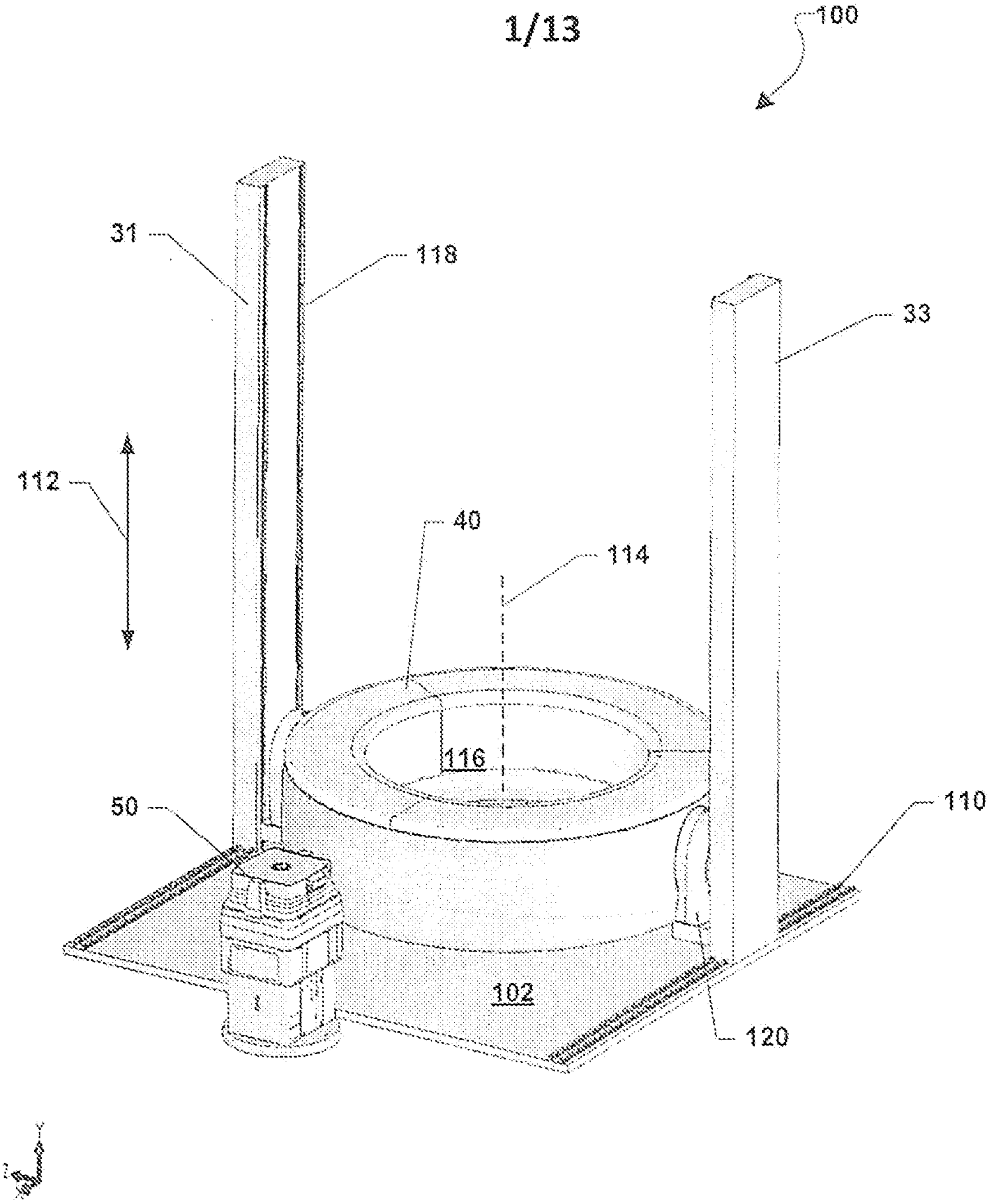

FIG. 1A

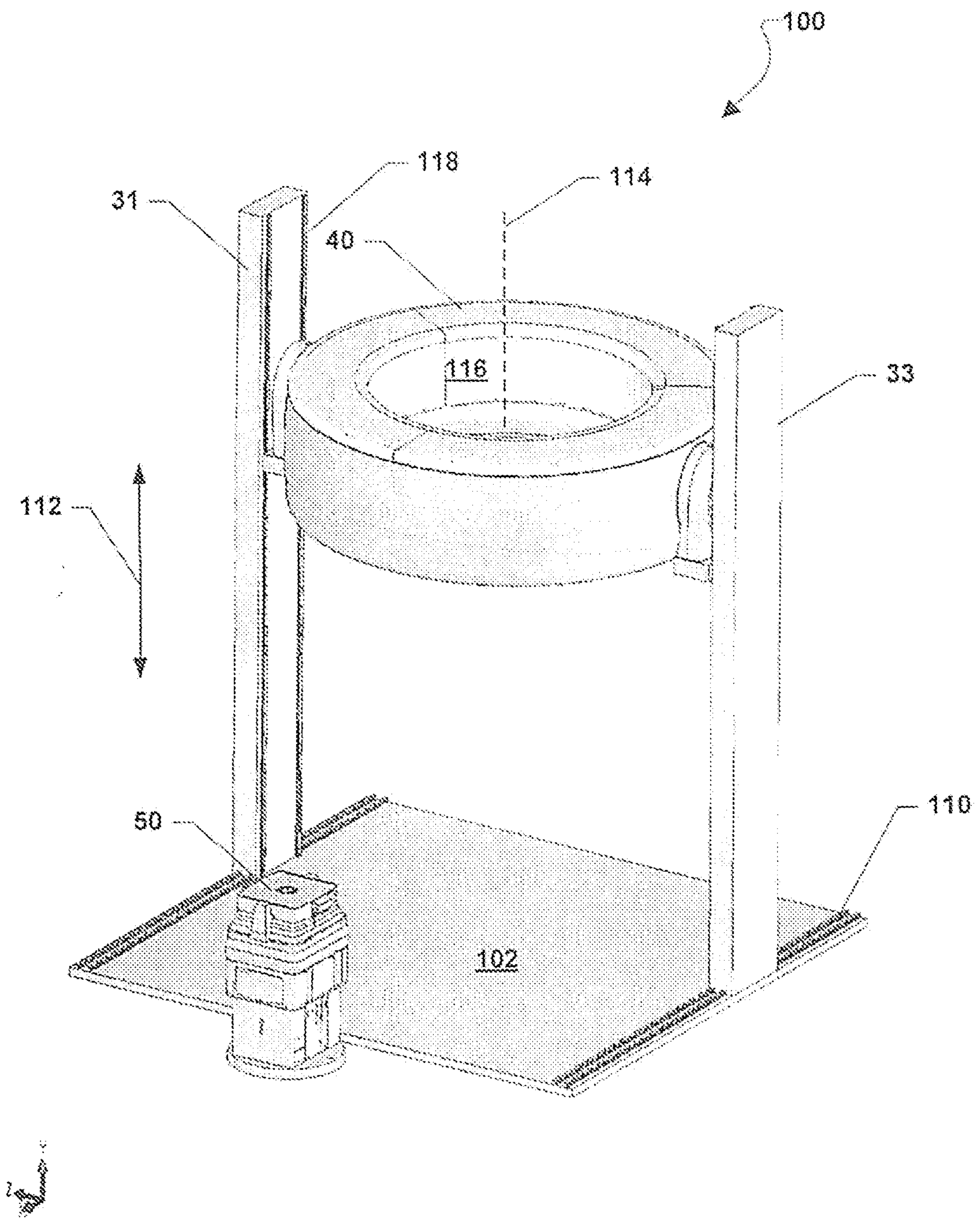

FIG. 1B

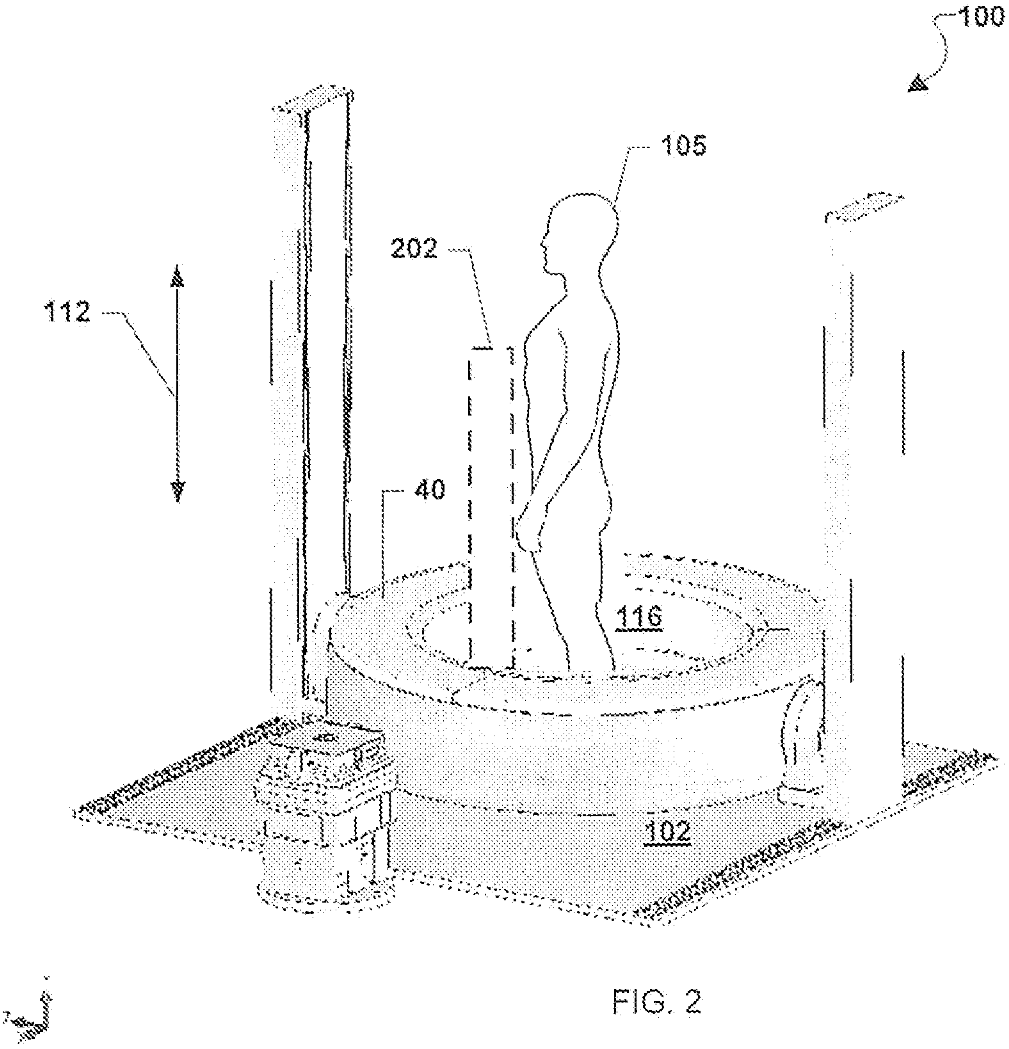

FIG. 2

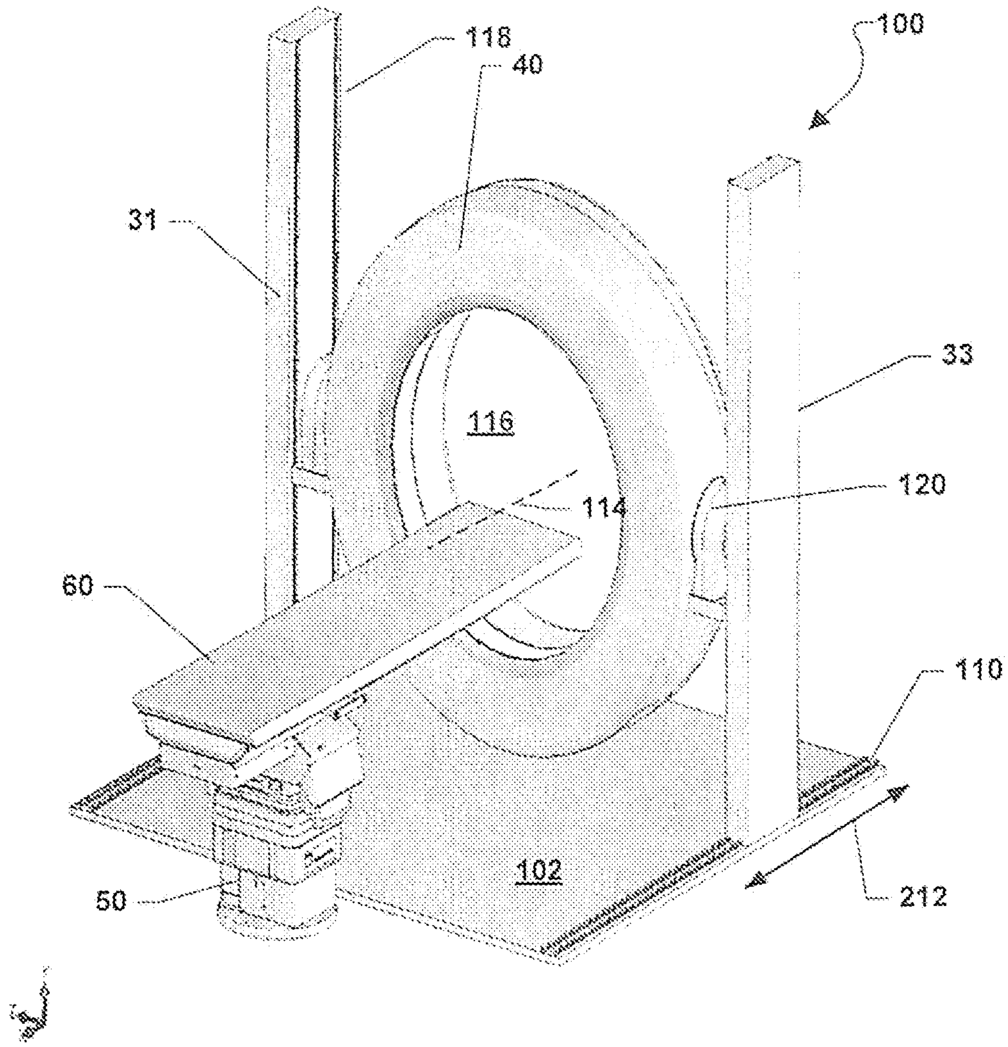

FIG. 3A

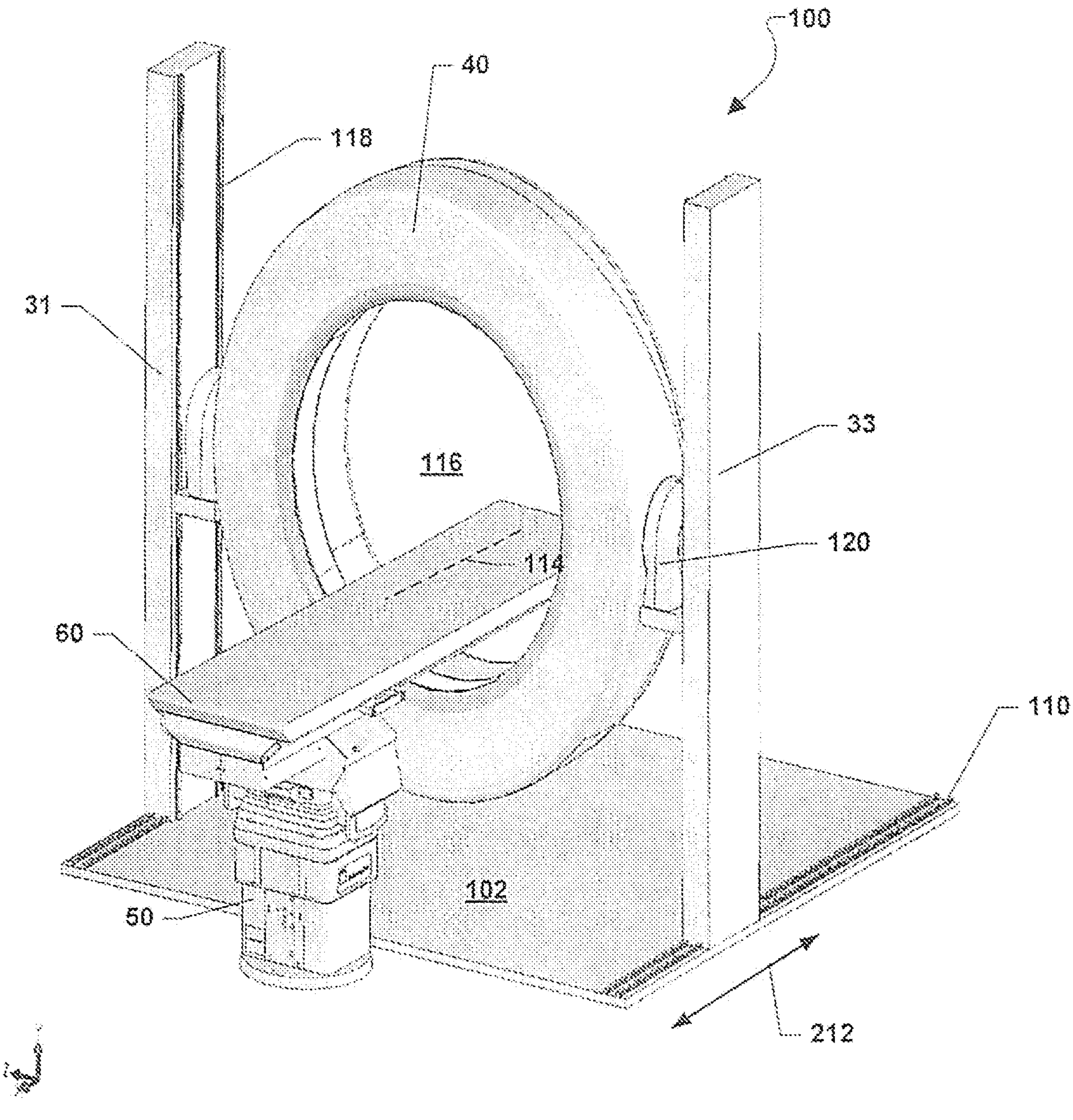

FIG. 3B

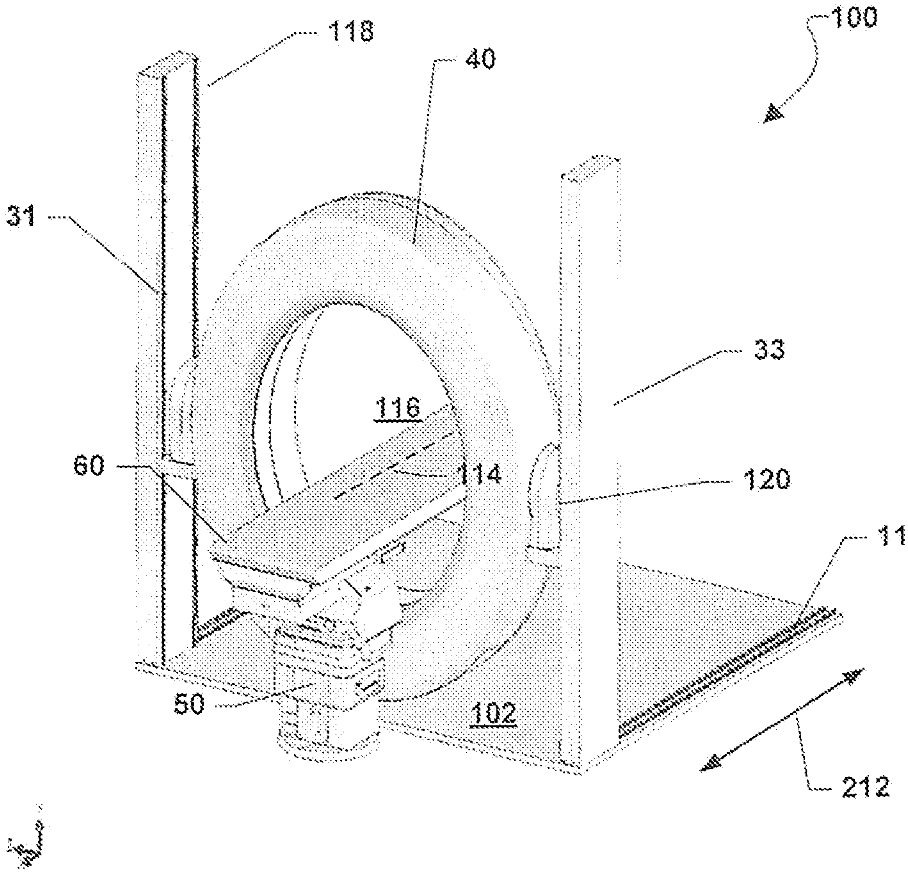

FIG. 3C

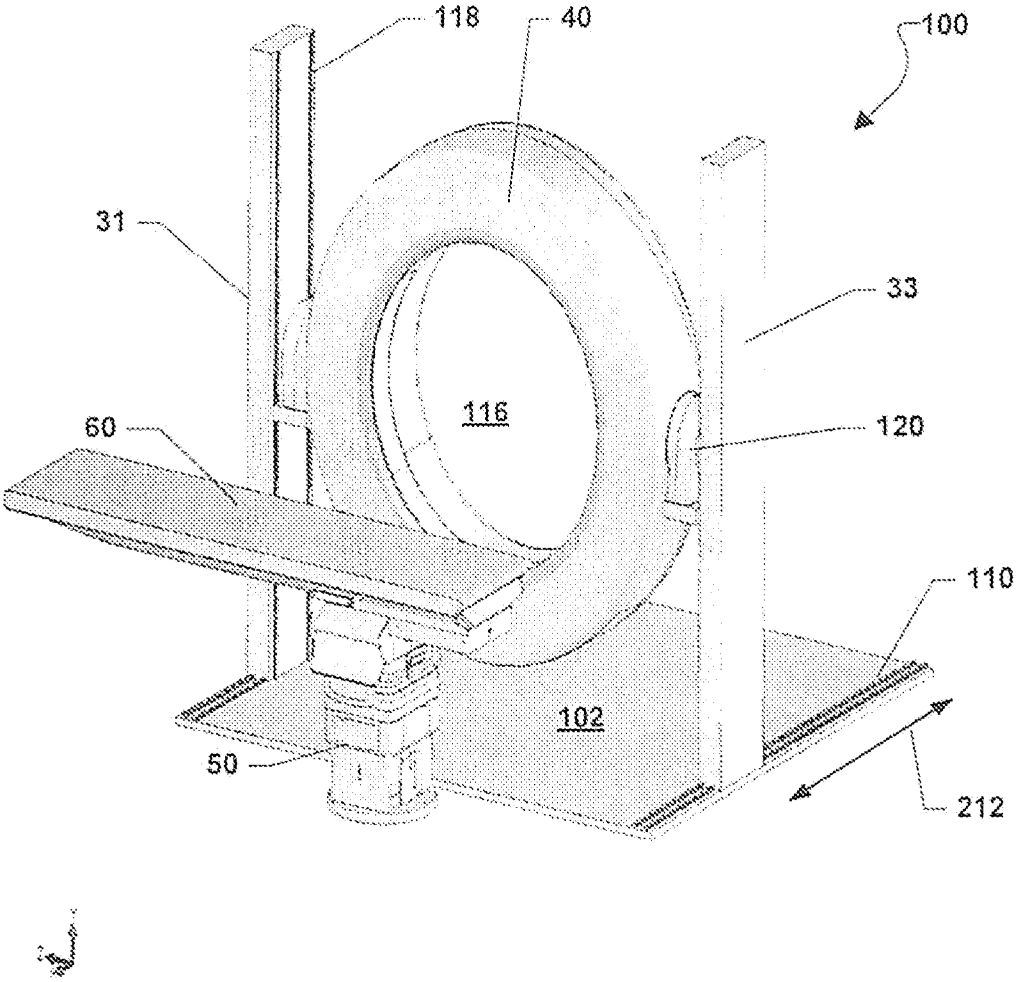

FIG. 4

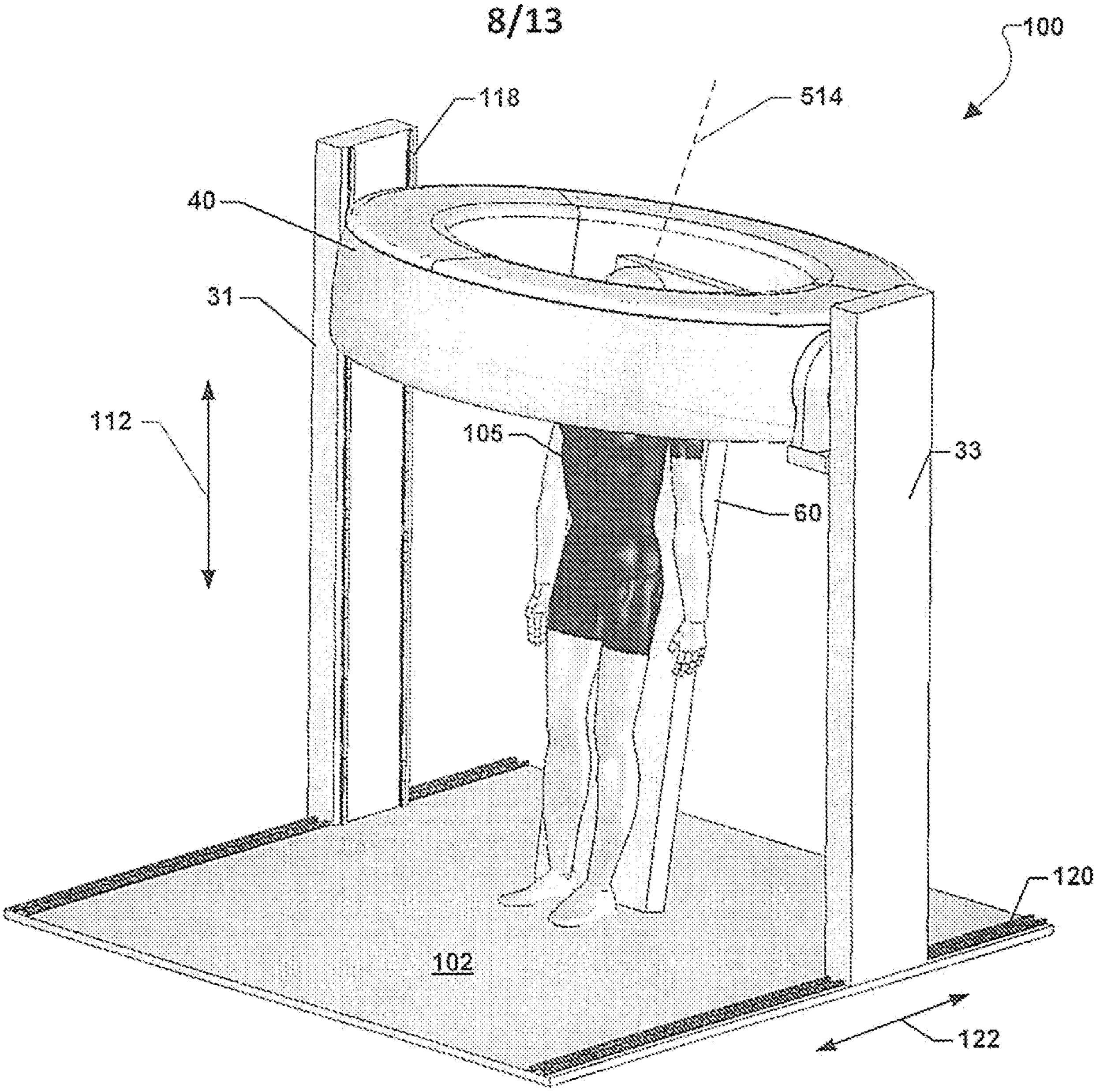

FIG. 5A

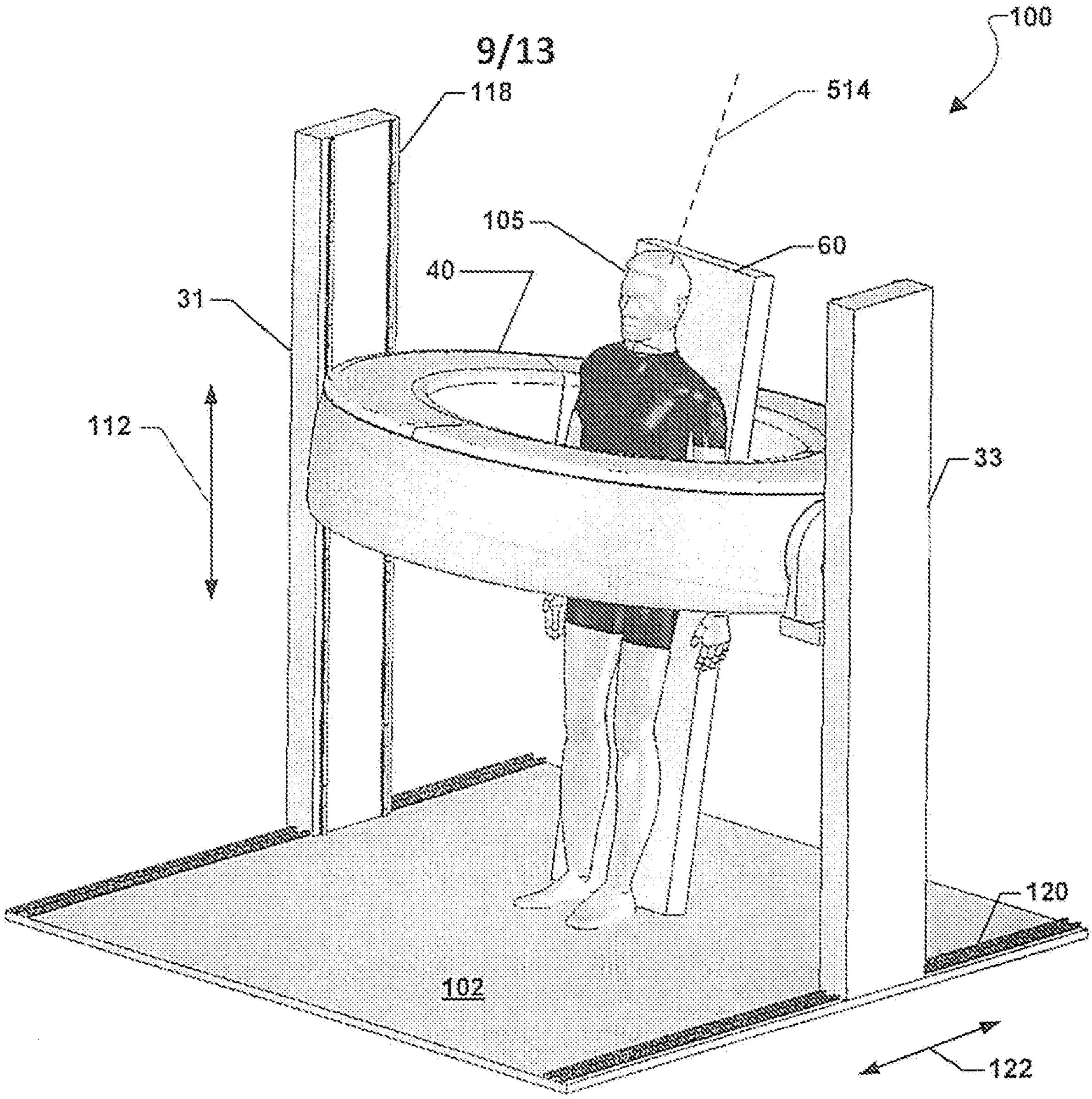

FIG. 5B

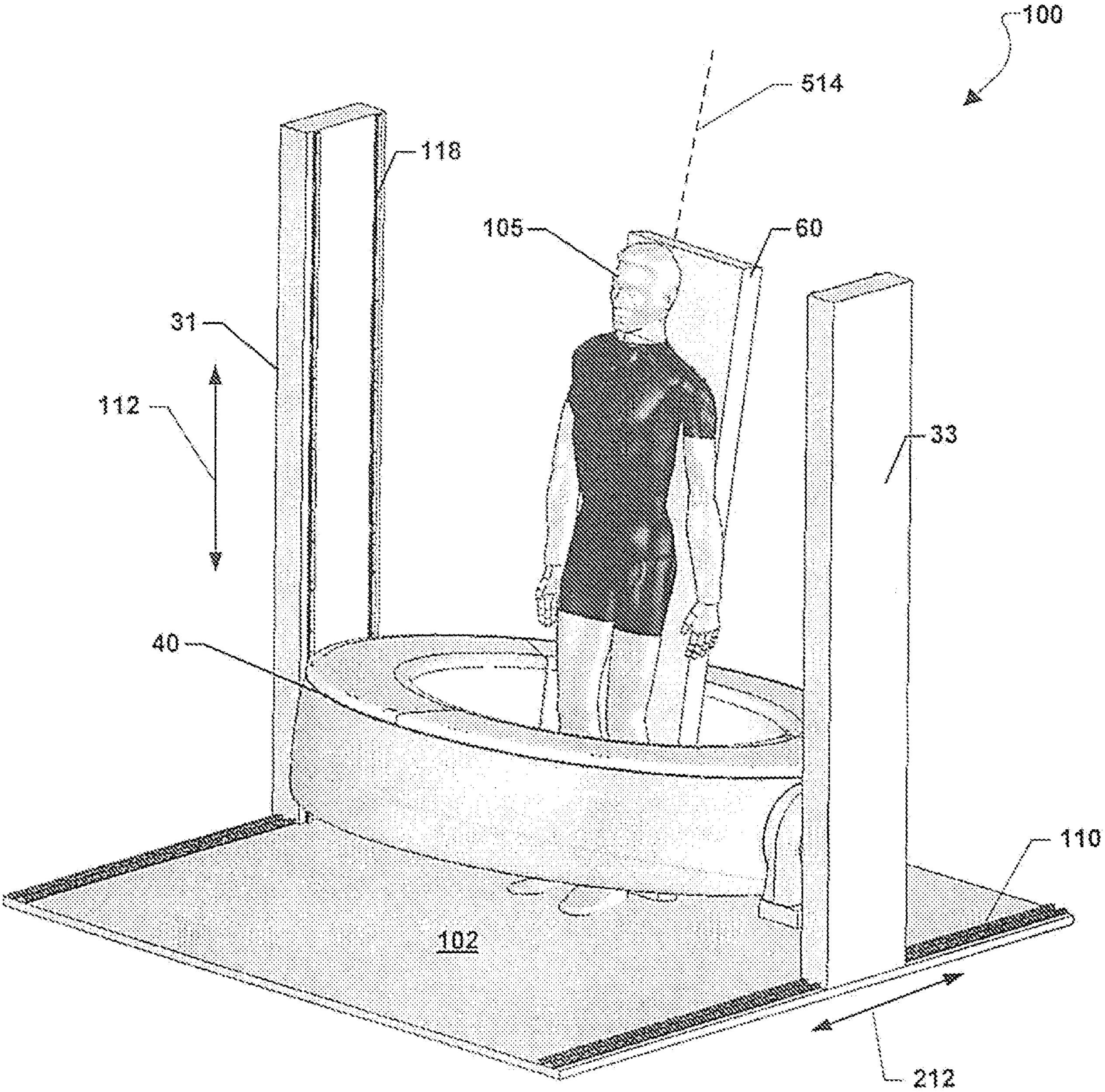

FIG. 5C

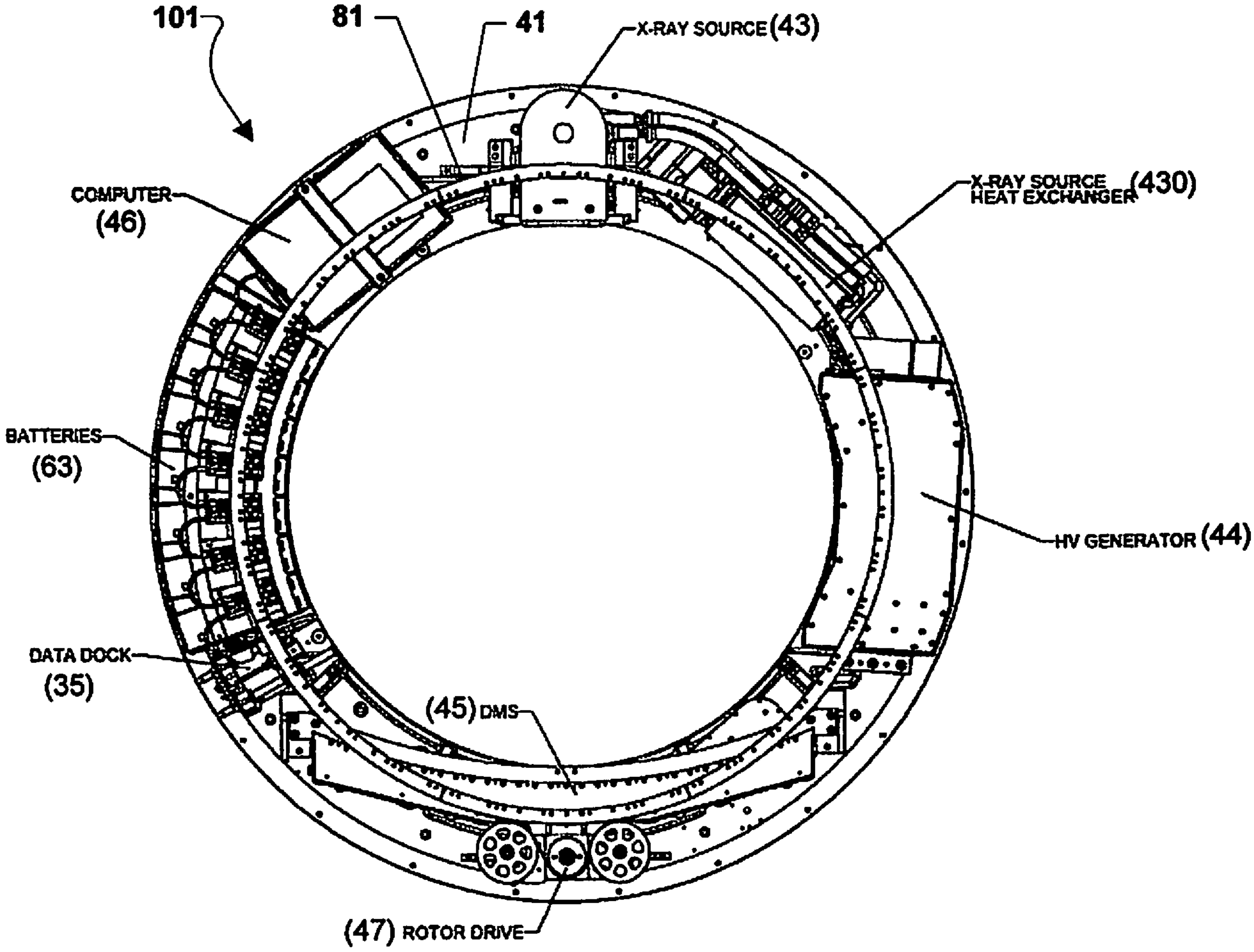
101
81
41
X-RAY SOURCE (43)
X-RAY SOURCE HEAT EXCHANGER (430)
COMPUTER (46)
BATTERIES (63)
HV GENERATOR (44)
DATA DOCK (35)
(45) DMS
(47) ROTOR DRIVE

FIG. 6

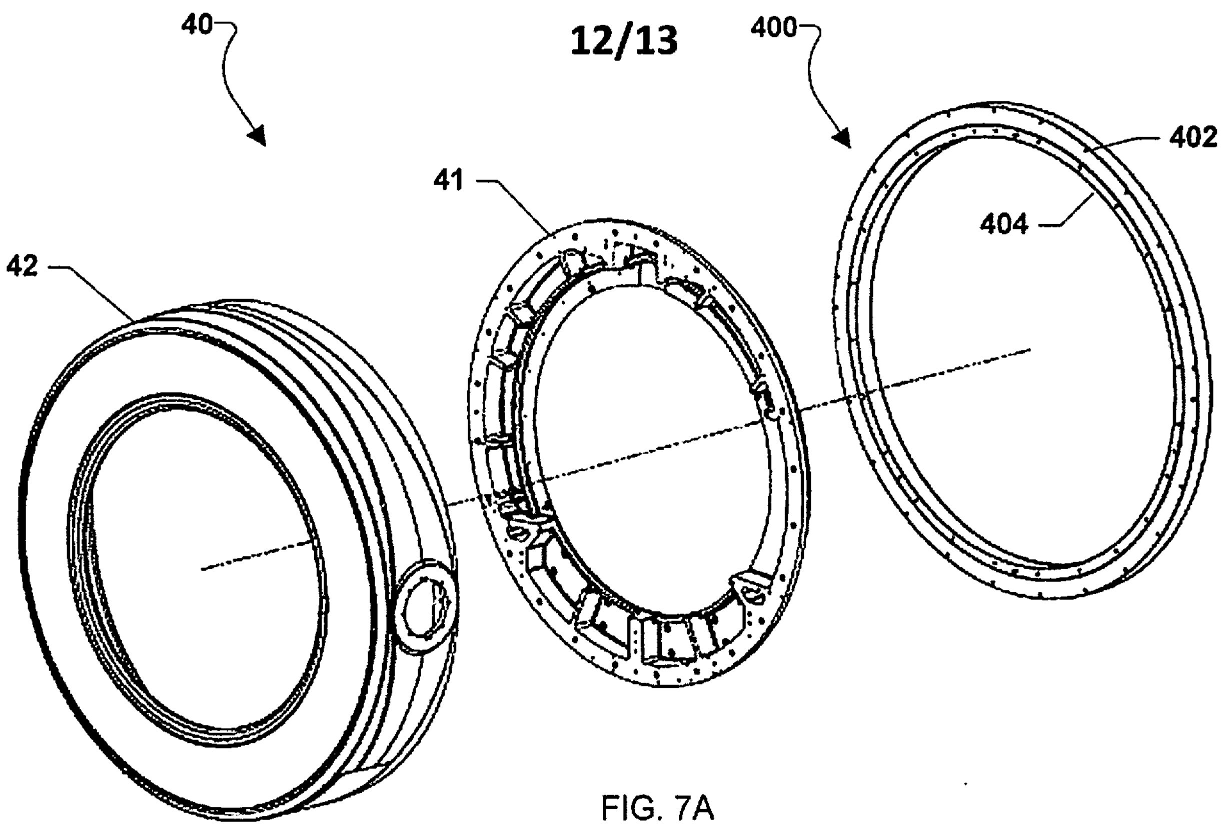

FIG. 7A

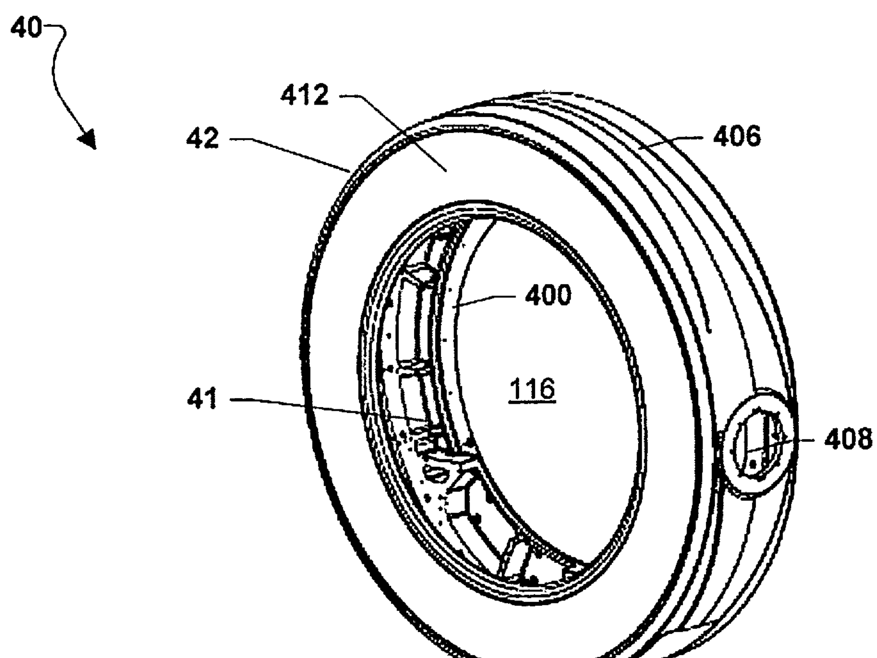

FIG. 7B

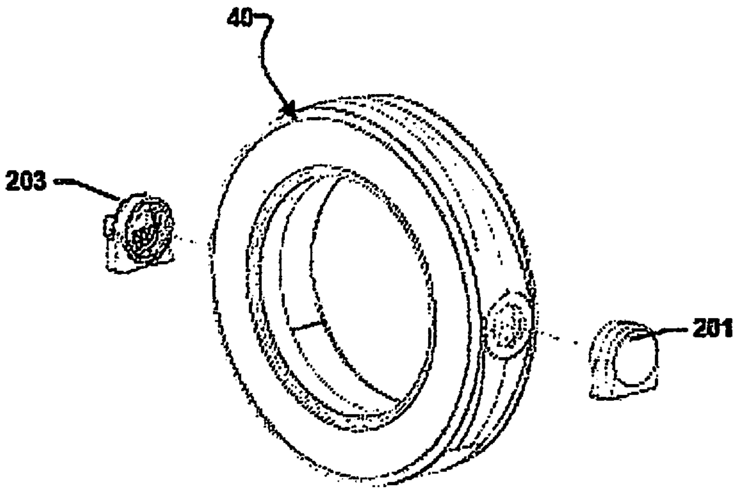

FIG. 7C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/045563

A. CLASSIFICATION OF SUBJECT MATTER

A61B 6/03(2006.01)i, A61B 6/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B 6/03; A61B 6/04; H05G 1/02; H05G 1/00; G01T 1/166

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: gantry, bore, support member, vertical scan

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 06102567 A (RICHARD E. CABRAL et al.) 15 August 2000 See abstract, column 3, line 38-column 5, line 53, claims 1, 3, 9-10, 30, 34 and figure 1.	22,26
Y		1-21,23-25,27-33
Y	US 8118488 B2 (EUGENE A. GREGERSON) 21 February 2012 See abstract, column 3, line 34-column 8, line 44, claims 1, 49, 56 and figures 3, 17.	1-21,23-25,27-33
A	US 7456407 B2 (IAIN STARK) 25 November 2008 See abstract, column 2, line 62-column 5, line 64, claim 1 and figure 1.	1-33
A	US 05448607 A (GILBERT W. MCKENNA) 05 September 1995 See abstract, column 5, line 61-column 10, line 35 and figure 1.	1-33
A	US 7806589 B2 (SCOTT TASHMAN et al.) 05 October 2010 See abstract, column 4, line 47-column 9, line 5, claims 1, 19 and figure 1.	1-33

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 2013 (13.09.2013)	**16 September 2013 (16.09.2013)**

Name and mailing address of the ISA/KR	Authorized officer
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Facsimile No. +82-42-472-7140	Telephone No. +82-42-481-8407

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/045563

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