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(71) Applicant: KOREA RESEARCH INSTITUTE OF
STANDARDS AND SCIENCE [KR/KR]; 267 Ga-
jeong-ro, Yuseong-gu, Daejeon 305-340 (KR).

(72) Inventors: SEO, Young Seob; 59, Jeonpo-daero 20beon-
gil, Nam-gu, Busan 608-824 (KR). AHN, Bong Young;
103-2504 55, Gyeryong-ro, Yuseong-gu, Daejeon 305-301
(KR).

(74) Agents: IPUS PATENT & LAW FIRM et al.; 2F, 11, Te-
heran-ro 13-gil, Gangnam-Gu, Seoul 135-080 (KR).

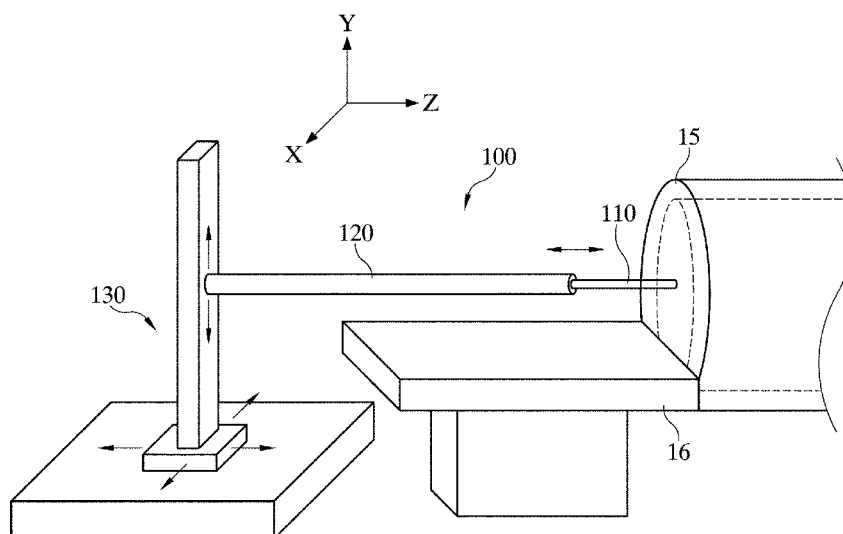
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(54) Title: APPARATUS, METHOD, AND SYSTEM FOR MEASURING UNIFORMITY OF MAIN MAGNETIC FIELD IN
MAGNETIC RESONANCE IMAGING SYSTEM AND RECORDING METHOD THEREFOR



(57) Abstract: Disclosed herein are an apparatus, method, and system for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system and a recording medium thereof and, more particularly, to a method of obtaining quantitative information using measurement equipment that may be implemented in response to automatic and semi-automatic type user-selective movements so as to measure a magnetic field within a three-dimensional (3D) space using a gauss meter and a flux meter and of automatically inputting and displaying the obtained quantitative information through software in order to measure the uniformity of a main magnetic field in a magnetic resonance imaging system which greatly influences the picture quality of a magnetic resonance medical image, thereby enabling efficient performance tests, follow-up management, and establishment of a measurement standard for a magnetic resonance imaging system.

Description

Title of Invention: APPARATUS, METHOD, AND SYSTEM FOR MEASURING UNIFORMITY OF MAIN MAGNETIC FIELD IN MAGNETIC RESONANCE IMAGING SYSTEM AND RECORDING METHOD THEREFOR

Technical Field

- [1] The present invention relates to an apparatus, method, and system for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system and a recording medium thereof and, more particularly, to a method of obtaining quantitative information using measurement equipment that may be implemented in response to automatic and semi-automatic type user-selective movements so as to measure a magnetic field within a three-dimensional (3D) space using a gauss meter and a flux meter and of automatically inputting and displaying the obtained quantitative information through software in order to measure the uniformity of a main magnetic field in a magnetic resonance imaging system which greatly influences the picture quality of a magnetic resonance medical image, thereby enabling efficient performance tests, follow-up management, and establishment of a measurement standard for a magnetic resonance imaging system.

Background Art

- [2] A superconducting magnetic resonance imaging system is widely used for disease diagnosis purposes in the medical field. The acquisition of images using the superconducting magnetic resonance imaging system has been settled as an essential factor for providing patients or doctors with precise information about diseases. Recently, the superconducting magnetic resonance imaging system has been in the spotlight as an excellent medical imaging system for presenting an anatomically accurate guideline through convergence with several medical imaging apparatuses based on the diagnostic field using a magnetic resonance imaging system that has been continuously developed. Accordingly, the excellence of the original image in a qualitative aspect has been highlighted, and the importance of a scheme for securing clinical significance by preventing the aging of a system and providing follow-up management is increased.
- [3] FIG. 1 is a diagrammatic block diagram showing the construction of a known magnetic resonance imaging system 10. As shown in FIG. 1, the magnetic resonance imaging system 10 is configured to include a workstation unit 1, a pulse sequence control unit 2, a gradient magnetic field control unit 4, a radio frequency (RF) pulse driving unit 8, a data reconfiguration unit 13, a display unit 14, etc.

- [4] The workstation unit 1 is implemented using a computer, including the pulse sequence control unit 2, the gradient magnetic field control unit 4, the RF pulse driving unit 8, the data reconfiguration unit 13, and the display unit 13 required to obtain a magnetic resonance image and a pulse sequence memory 3 necessary for corresponding control and operation.
- [5] The pulse sequence control unit 2 drives the gradient magnetic field control unit 4 and the RF pulse driving unit 8, controls the output of a pulse sequence required to obtain a magnetic resonance image, and includes the pulse sequence memory 3 for pulse sequences.
- [6] The gradient magnetic field control unit 4 controls the driving of an X-axis gradient magnetic field driving unit 5, a Y-axis gradient magnetic field driving unit 6, and a Z-axis gradient magnetic field driving unit 7. The driving units 5, 6, and 7 generate three vertical gradient magnetic fields in the X axis, the Y axis, and the Z axis in a 3D space. To this end, the driving units 5, 6, and 7 include three gradient coils corresponding to the respective axes. The gradient coils are classified into a slice selection gradient magnetic field, a phase encoding gradient, and a frequency encoding gradient magnetic field depending on the cross section of an image that is obtained in a process of obtaining a magnetic resonance image.
- [7] The RF pulse driving unit 8 controls an RF pulse transmission unit 9 configured to excite the spin of an area to be imaged in order to obtain a magnetic resonance image and an RF pulse reception unit 11 configured to receive a signal generated by the excited spin. The RF pulse reception unit 11 includes an input/output (I/O) data storage unit 12 for storing images in a digital data form.
- [8] The data reconfiguration unit 13 obtains a magnetic resonance image by performing operation, that is, two-dimensional (2D) and 3D Fourier transform, on digital data stored in the memory.
- [9] The display unit 14 sends reconfigured data so that the data is displayed through an imaging and output device.
- [10] The acquisition of the uniformity of a main magnetic field, that is, one of the most important factors in order to obtain an image using such a magnetic resonance imaging system, is directly related to the qualitative aspect of an obtained image, and the uniformity of a main magnetic field needs to be managed. A non-uniform main magnetic field results in problems, such as the distortion of a magnetic resonance image, artifacts, and low contrast resolution.
- [11] In general, after a magnetic resonance imaging system is initially installed, the uniformity of a main magnetic field in the magnetic resonance imaging system is not minutely checked. Corresponding problems overlapped with the aging of the system become causes to generate problems in obtaining an image of a diagnostic object. Ac-

cordingly, a method for measuring the aging of a magnetic resonance imaging system and the non-uniformity of a main magnetic field and precisely measuring the uniformity of a main magnetic field for solving the aging and non-uniformity is very important.

Disclosure of Invention

Technical Problem

- [12] Accordingly, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a method for the follow-up management and magnetic resonance image quality management of a magnetic resonance imaging system through the measurement of the uniformity of a main magnetic field by providing a scheme for designing equipment for measuring the uniformity of a main magnetic field of the magnetic resonance imaging system and a method of configuring environments for elements and association software.
- [13] Another object of the present invention is to provide a method capable of measuring a magnetic field in order to measure the uniformity of a main magnetic field of a magnetic resonance imaging system. To this end, the present invention provides a method for measuring a distribution of magnetic fields within a 3D space using a gauss meter and a flux meter capable of measuring the magnetic fields.
- [14] Yet another object of the present invention is to provide a measurement method through association with automatic and semi-automatic type-selective 3-axis movement equipment in order to efficiently measure a quantitative distribution and the degree of a change of magnetic fields within a 3D space. Furthermore, the present invention may provide user convenience through an association process with software for the operation and display of measured information.
- [15] Furthermore, an embodiment of the present invention provides a method of improving the quality of a medical image and proposing the degree of follow-up management, which is capable of securing a diagnostic significance by measuring the uniformity and degree of a change of magnetic fields in the 3D space distribution of a main magnetic field of the magnetic resonance imaging system.

Solution to Problem

- [16] In accordance with an aspect of the present invention, there is provided an apparatus for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system including a gantry and a patient table moving in the internal space of the gantry, including a probe configured to measure a magnetic field at each of a plurality of specific points in the internal space of the gantry; a driving unit configured to move the probe in a multi-axis direction in the internal space of the gantry; a bar disposed in a central axis in the length direction of the gantry; and a measurement plate

configured to have the bar inserted into the center of the measurement plate and reciprocally moved in the length direction of the bar, a plurality of measurement holes into each of which the probe is inserted being formed in the measurement plate, wherein the probe measures the uniformity of the magnetic fields in the internal space of the gantry by.

[17] The bar may be placed at the center of the magnetic fields within the gantry.

[18] The driving unit may include a Z-axis driving unit configured to reciprocally move the probe in a Z axis parallel to the length direction of the gantry; an X-axis driving unit configured to reciprocally move the probe in an X axis vertical to the Z axis; and a Y-axis driving unit configured to reciprocally move the probe in the Z axis and a Y axis vertical to the Z axis.

[19] The apparatus may further include a probe holder provided between the driving unit and the probe and configured to fix the probe.

[20] The measurement plate may be configured in a circular plate form having a specific thickness, the center hole into which the bar is inserted may be formed at the center of the measurement plate, and a plurality of the measurement holes may be arranged around the center hole in a radial form.

[21] The apparatus may further include a plate driving unit configured to move the measurement plate based on an axis in the length direction of the bar.

[22] The apparatus may further include a phantom plate disposed in the rear of the measurement plate and configured in a circular plate form, wherein the center hole into which the bar is inserted is formed at the center of the phantom plate, and an inside of the phantom plate is filled with a phantom solution.

[23] The apparatus may further include a driving control unit configured to control the location of the probe by controlling the driving unit and to control the location of the measurement plate by controlling the plate driving unit.

[24] The probe may include at least one of a flux meter and a gauss meter.

[25] A plurality of the probes may be disposed in a radial form.

[26] The measurement plate may be formed by combining a plurality of separated members, and the members may be assembled and disassembled.

[27] In accordance with another aspect of the present invention, there is provided a method for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system including a gantry and a patient table moving in the internal space of the gantry, including entering, by a driving unit, a probe configured to measure a magnetic field in the internal space of the gantry into the internal space of the gantry; moving, by the driving unit, the probe and inserting the probe into at least one of a plurality of measurement holes formed in a measurement plate of a circular plate form which has been inserted into a bar disposed in a central axis in the length direction of

the gantry; and measuring, by the probe, a magnetic field in the measurement hole.

[28] The method may further include inserting, by the driving unit, the probe into the measurement hole at a different location and measuring a magnetic field, after measuring, by the probe, the magnetic field in the measurement hole and moving, by a plate driving unit, the measurement plate in an axis in the length direction of the bar.

[29] In accordance with yet another aspect of the present invention, there is provided a computer-readable recording medium on which program code capable of executing the aforementioned method for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system has been recorded.

[30] In accordance with yet another aspect of the present invention, there is provided a system for analyzing the uniformity of a main magnetic field in a magnetic resonance imaging system including a gantry and a patient table moving in the internal space of the gantry and, including the aforementioned apparatus configured to measure the uniformity of a main magnetic field in the magnetic resonance imaging system; a data reception and storage unit configured to receive and store magnetic field data measured in a plurality of respective measurement holes formed in a measurement plate of the apparatus; display means configured to display the density of magnetic fields in the internal space of the gantry in a 3D image data form based on the received magnetic field data measured in the plurality of measurement holes; and analysis means configured to analyze the uniformity of a main magnetic field within the gantry based on the received magnetic field data measured in the plurality of measurement holes.

[31] In accordance with further yet another aspect of the present invention, there is provided a method for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system including a gantry and a patient table moving in the internal space of the gantry, including a first step of entering, by a driving unit, a probe configured to measure a magnetic field in the internal space of the gantry into the internal space of the gantry; a second step of moving, by the driving unit, the probe and inserting the probe into at least one of a plurality of measurement holes formed in a measurement plate of a circular plate form which has been inserted into a bar disposed in a central axis in the length direction of the gantry; a third step of measuring, by the probe, a magnetic field in the measurement hole; a fourth step of inserting, by the driving unit, the probe into the measurement hole at a different location and measuring a magnetic field in the measurement hole; a fifth step of repeating the fourth step; a sixth step of moving, by a plate driving unit, the measurement plate in an axis in the length direction of the bar; a seventh step of repeating the third step and the fourth step; an eighth step of receiving and storing, by a data reception and storage unit, magnetic field data measured in a plurality of respective measurement holes; a ninth step of displaying, by display means, the density of the magnetic fields in the internal

space of the gantry in a 3D image data form based on the received magnetic field data measured in the plurality of measurement holes; and a tenth step of analyzing, by analysis means, the uniformity of a main magnetic field within the gantry based on the received magnetic field data measured in the plurality of measurement holes.

- [32] In accordance with further yet another aspect of the present invention, there is provided the aforementioned computer-readable recording medium on which program code capable of executing a method of analyzing the uniformity of a main magnetic field in a magnetic resonance imaging system has been recorded.

Advantageous Effects of Invention

- [33] In accordance with the present invention, a method for measuring the uniformity of a main magnetic field in obtaining an image using a magnetic resonance imaging system is an important part in determining the picture quality of an obtained image, which corresponds to an important factor directly related to the aspects of image quality management and system management. In accordance with an embodiment of the present invention, quantitative information about a 3D space distribution of a main magnetic field can be measured more precisely. Accordingly, there is an advantage from a viewpoint of the management of the magnetic resonance imaging system or from a viewpoint of quality management in a qualitative aspect in obtaining a magnetic resonance image using the magnetic resonance imaging system.
- [34] Furthermore, the present invention for measuring the uniformity and degree of a change of a main magnetic field from a viewpoint of quality management in obtaining an image using the magnetic resonance imaging system and from a viewpoint of securing clinical significance and reliability needs to be essentially used in clinical/research centers where magnetic resonance medical imaging equipment is widely used, and thus the present invention is very useful.
- [35] Furthermore, follow-up management through the precise and systematic measurement of the uniformity of a main magnetic field in accordance with an embodiment of the present invention has an advantage in that the hardware/software performance of a magnetic resonance imaging system can be improved.

Brief Description of Drawings

- [36] FIG. 1 is a diagrammatic block diagram showing the construction of a known magnetic resonance imaging system;
- [37] FIG. 2 is a partial perspective view showing the front part of an apparatus for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system in accordance with an embodiment of the present invention;
- [38] FIG. 3 is a partial perspective view showing the rear part of the apparatus for measuring the uniformity of a main magnetic field in a magnetic resonance imaging

system in accordance with an embodiment of the present invention;

[39] FIG. 4 is a perspective view of a probe in accordance with an embodiment of the present invention;

[40] FIG. 5 is a partial perspective view of the apparatus for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system in the state in which measurement plates and phantom plates have been inserted into a bar in accordance with an embodiment of the present invention;

[41] FIG. 6 is a partial front view of the apparatus for measuring the uniformity of a main magnetic field in a magnetic resonance imaging system in the state in which the measurement plates and the phantom plates have been inserted into the bar in accordance with an embodiment of the present invention;

[42] FIG. 7 is a front view of the measurement plate in accordance with an embodiment of the present invention;

[43] FIG. 8 is a perspective view of the measurement plate in accordance with an embodiment of the present invention;

[44] FIG. 9 is an exploded front view of the measurement plate in accordance with an embodiment of the present invention;

[45] FIG. 10 is a front view of the phantom plate in accordance with an embodiment of the present invention;

[46] FIG. 11 is a perspective view of the phantom plate in accordance with an embodiment of the present invention; and

[47] FIG. 12 is an exploded front view of the phantom plate in accordance with an embodiment of the present invention.

Best Mode for Carrying out the Invention

[48] Hereinafter, the constructions and functions of an apparatus 100 and system for measuring the uniformity of a main magnetic field in the magnetic resonance imaging system 10 (refer to FIG. 1) in accordance with embodiments of the present invention are described in detail. First, the construction of an apparatus 100 for measuring the uniformity of a main magnetic field in the magnetic resonance imaging system 10 is described.

[49] First, FIG. 2 is a partial perspective view showing the front part of the apparatus 100 for measuring the uniformity of a main magnetic field in the magnetic resonance imaging system 10 in accordance with an embodiment of the present invention. The apparatus 100 measures the uniformity of a main magnetic field within a gantry 15, that is, a part along which a patient table 16 connected to the magnetic resonance imaging system 10 moves.

[50] From FIG. 2, it can be seen that a 3D space distribution of a main magnetic field is

measured using a driving apparatus that gradually moves to a specific distance from the entrance in the internal space of the gantry 15 of the magnetic resonance imaging system 10.

- [51] As shown in FIG. 2, it can be seen that a probe 110 in accordance with an embodiment of the present invention enters the internal space of the gantry 15 and the probe 110 may be moved in a 3-axis direction by means of a driving unit 130. Furthermore, a probe holder 120 is provided between the driving unit 130 and the probe 110. The driving unit 130 is configured to integrally move the probe 110 and the probe holder 120 in the 3-axis direction.
- [52] More particularly, the driving unit 130 in accordance with an embodiment of the present invention may be configured to include an X-axis driving unit, a Y-axis driving unit, and a Z-axis driving unit. The Z-axis driving unit is configured to reciprocally move the probe 110 in the Z axis, that is, an axis in the length direction (i.e., front and rear directions) of the gantry 15. The X-axis driving unit is configured to move the probe 110 in the left and right direction that is vertical to the Z axis. Furthermore, the Y-axis driving unit is configured to move the probe 110 in the up and down direction that is vertical to the Z axis and the X axis.
- [53] Accordingly, the probe 110 may be moved in a 3D way in the internal space of the gantry 15 by means of the driving unit 130. The driving unit 130 of FIG. 2 is only an embodiment, and the scope of the present invention should not be interpreted as being limited to the driving unit 130 of FIG. 2. It should be understood that the scope of the present invention may include any construction that may move the probe 110 in the 3D space.
- [54] The probe 110 of FIG. 2 in accordance with an embodiment of the present invention is configured to include a gauss meter or a flux meter and to measure a magnetic field value within the gantry 15. As described above, it can be seen that the probe holder 120 is connected to the driving unit 130 configured to move in the 3-axis directions (i.e., up/down, left/right, and front/rear) in order to measure a 3D space distribution so that it may move the probe 110 to a specific distance.
- [55] In another embodiment, instead of the single semi-automatic probe 110, equipment in which multiple probes 110 (i.e., non-magnetic optical fiber probes) placed in a radial form are stretched out in a radial form at specific intervals and configured to rapidly measure a 3D space distribution may be used to form a full automatic type measurement system 10.
- [56] All the elements of the apparatus for measuring the uniformity of a main magnetic field shown in FIG. 2 in accordance with an embodiment of the present invention may be configured in a form using magnetic materials so that there is no change in the main magnetic field. The 3-direction driving unit 130 configured to move the probe holder

120 of FIG. 2 in the 3-axis direction needs to be placed in a gauss line in which the influence of a main magnetic field is minimized.

[57] FIG. 3 is a partial perspective view showing the rear part of the apparatus 100 for measuring the uniformity of a main magnetic field in the magnetic resonance imaging system 10 in accordance with an embodiment of the present invention. As shown in FIG. 3, the apparatus includes a data reception and storage unit 180 configured to collect signal information measured by the probe 110. The collected signals and data are moved to the data reception and storage unit 180 (e.g., a workstation) through cables 181 and automatically inputted to software. In order to minimize the influence of a signal loss and noise when collecting signal information in each section, the cable 181 made of an optical fiber is used to connect the sections.

[58] FIG. 4 is a perspective view of the probe 110 in accordance with an embodiment of the present invention. As shown in FIG. 4, the probe 110 is basically classified into a detector 111 for detecting a signal, a body 112, and a cable connector 113. The detector 111 installed at the front of the probe 110 is used to measure a gauss or flux. All of the detector 111, the body 112, and the cable connector 113 are made of non-magnetic materials in order to prevent a change in the quantitative measurement of a main magnetic field. The cable connector 112 is made of an optical fiber in order to minimize a loss of a transfer signal and noise.

[59] FIG. 5 is a partial perspective view of the apparatus 100 for measuring the uniformity of a main magnetic field in the magnetic resonance imaging system 10 in the state in which measurement plates 150 and phantom plates 160 have been inserted into bars 140 in accordance with an embodiment of the present invention. That is, FIG. 5 shows the main magnet and the outside of the gantry 15 of the magnetic resonance imaging system 10. In general, the gantry 15 is configured to have a cylindrical form and to include a space therein in which the patient table 16 may move. Furthermore, a shroud 17 is provided on the outside surface of the gantry 15, and a magnet bore 18 is provided on the inside surface of the gantry 15.

[60] The apparatus 100 for measuring the uniformity of a main magnetic field in accordance with an embodiment of the present invention includes the measurement plates 150 and the phantom plates 160 provided in the internal space of the gantry 15. As shown in FIG. 5, center holes 151 and 161 are formed at the center of the measurement plate 150 and the phantom plate 160, and the measurement plate 150 and the phantom plate 160 are inserted into and connected to the bar 140. The central axis of the bar 140 is placed at the center of a magnetic field within a magnet, and the bar 140 is configured to pass through the gantry 15 from the entrance of the gantry 15 to the exit. The measurement plate 150 and the phantom plate 160 are connected to the bar 140 by means of the center holes 151 and 161 and are moved in an arrow direction

from the entrance of the gantry 15 to the exit by means of the plate driving unit 130.

[61] Furthermore, the measurement plate 150 includes a plurality of measurement holes 152 (refer to FIG. 7) configured to have the respective probes 110 placed therein and arranged around the center hole 151 in a radial form. The inside of the phantom plate 160 is filled with a phantom solution for obtaining a magnetic resonance image. The phantom plate 160 functions to measure the uniformity of a main magnetic field, obtain a magnetic resonance image, and show a correlation relationship between the uniformity of the main magnetic fields and an actual magnetic resonance image. For example, the phantom plate 160 may be configured to visually display the low signal to noise ratio, contrast to noise ratio, and distortion of an actually obtained magnetic resonance image in the form of an actual image when main magnetic fields measured out of the center are not uniform.

[62] FIG. 6 shows the gantry 15 of the magnetic resonance imaging system 10 at the front part. The bar 140 is placed on the basis of the center hole, that is, the center of a main magnetic field. Bar fixtures 141 are fixed to the shroud 17 on the outside surface of the gantry 15 and are configured to fix the bar 140 so that the bar 140 may be fixed to the central location of magnetic fields.

[63] FIG. 7 is a front view of the measurement plate 150 in accordance with an embodiment of the present invention, and FIG. 8 is a perspective view of the measurement plate 150 (the measurement holes 152 are not shown) in accordance with an embodiment of the present invention. That is, as shown in FIG. 7, the plurality of measurement holes 152 that become points where the probes 110 may be placed is diagrammatically shown in the measurement plate 150. The bar 140 placed from the entrance of the gantry 15 to the exit is placed in the center hole 151, and the measurement plate 150 has a diameter $2r'$ in which the measurement plate 150 may move within the gantry 15.

[64] A greater number of measurement holes 152 are distributed outward around the center of the measurement plate 150. A space distribution of uniformity from the center of a main magnetic field to the outside may be measured by the measurement holes 152. The measurement plate 150 is configured to have a specific thickness ' t_1 ' by taking the disposition of the probes 110 and a movement at specific intervals within the gantry 15 into consideration. The measurement plate 150 may have a thickness of about 10 ~ 20 mm, and the circular plate itself of the measurement plate 150 is made of non-magnetic materials. Measurement may be performed using a single probe 10 in relation to the measurement hole 152 for measuring a magnetic field, the plurality of probes 110 is disposed around the center hole and stretched out in a radial form, and measurement in a 3D space distribution may be automatically performed rapidly.

[65] FIG. 9 is an exploded front view of the measurement plate 150 in accordance with an

embodiment of the present invention. As shown in FIG. 9, the measurement plate 150 including measurement holes 152 where the probes 110 may be placed may be separated and assembled. The measurement plate 150 in accordance with an embodiment of the present invention may be configured to be separated into four and assembled. As shown in FIG. 9, the circular plate is configured to be separated and assembled for convenience of portability and easiness of coupling, and matching parts between the separated plates are configured to be detachable in the form of a block structure. Projections 153 or insertion grooves 154 are formed in the side of each of the blocks such that the insertion grooves 154 and the projections 153 belonging to different blocks may be assembled and disassembled.

[66] FIG. 10 is a front view of the phantom plate 160 in accordance with an embodiment of the present invention, and FIG. 11 is a perspective view of the phantom plate 160 in accordance with an embodiment of the present invention. That is, FIGS. 10 and 11 show the phantom plate 160 placed in the rear, belonging to the two circular plates placed within the gantry 15 of the magnetic resonance imaging system 10 and show a phantom form for obtaining a magnetic resonance image. The bar 140 placed from the entrance of the gantry 15 to the exit may be placed in the center hole 161 of the phantom plate 160, and the phantom plate 160 has a diameter in which the phantom plate 160 may move within the gantry 15. The inside of the phantom plate 160 is configured to be filled with a phantom solution so that a magnetic resonance image may be obtained. The phantom plate 160 is configured to have a specific thickness t_2 so that it may move at a specific interval within the gantry 15 and may have a thickness of about 5 ~ 10 mm. The phantom plate 160 itself may be made of non-magnetic materials.

[67] FIG. 12 is an exploded front view of the phantom plate 160 in accordance with an embodiment of the present invention. As shown in FIG. 12, the circular plate of the phantom plate 160 in accordance with an embodiment of the present invention is filled with a phantom solution and may be configured to be separated and assembled. The circular plate is configured to be separated and assembled for convenience of portability and easiness of coupling, and matching parts between the separated plates are configured to be detachable in the form of a block structure. Projections 162 or insertion grooves 163 are formed in the side of each of the blocks such that the insertion grooves 162 and the projections 163 belonging to different blocks may be assembled and disassembled.

Mode for the Invention

[68] Hereinafter, a system and method for analyzing the uniformity of a main magnetic field using the apparatus 100 for measuring the uniformity of a main magnetic field of

the magnetic resonance imaging system 10 are described. The system for analyzing the uniformity of a main magnetic field in accordance with an embodiment of the present invention is configured to include the apparatus 100 for measuring the uniformity of a main magnetic field, the data reception and storage unit 180 for receiving and storing magnetic field data measured in the plurality of measurement holes 152 formed in the measurement plate 150 of the apparatus 100 for measuring the uniformity of a main magnetic field, display means for displaying the density of magnetic fields in the internal space of the gantry 15 in the form of 3D image data based on the magnetic field data measured in the plurality of measurement holes 152, and analysis means for analyzing the uniformity of a main magnetic field within the gantry 15 based on the magnetic field data measured in the plurality of measurement holes 152.

[69] That is, the data reception and storage unit 180 receives magnetic field data, measured by the probes 110 placed in the respective measurement holes 152, in real time and stores the received magnetic field data. Furthermore, the display means is connected to the data reception and storage unit 180 which has received the magnetic field data measured in the plurality of measurement holes 152, synthesizes the magnetic field data at the respective points, and displays the density of the magnetic fields in the internal space of the gantry 15 in the form of 3D image data.

[70] The analysis means analyzes the uniformity of a main magnetic field within the gantry 15 based on the magnetic field data at the respective points and the displayed 3D image data.

[71] In a method of analyzing the uniformity of a main magnetic field, first, the driving unit 130 is driven to enter the probes 110 into the internal space of the gantry 15. Furthermore, the X-axis driving unit, the Y-axis driving unit, and the Z-axis driving unit of the driving unit 130 are driven so that the probes 110 are inserted into specific measurement holes of the plurality of measurement holes 152. Furthermore, the probes 110 measure magnetic fields in the respective measurement holes, and the measured signals are transmitted to and stored in the data reception and storage unit 180 in real time. Thereafter, the driving unit 130 is driven so that the probes 110 are inserted into the measurement holes at different locations, the probes 110 measure magnetic fields in the respective measurement holes, and the measured magnetic field data are transmitted to and stored in the data reception and storage unit 180. After obtaining a plurality of magnetic field data through the repetition of the above process, the plate driving unit 130 moves the measurement plate 150 to a specific distance in the length direction of the bar 140.

[72] After moving the measurement plate 150, the driving unit 130 is driven again so that the probes 110 are inserted into the respective measurement holes 152 formed in the measurement plate 150 that has been moved. Thereafter, as described above, the

probes 110 measure magnetic fields in specific measurement holes 152, and the measured magnetic field data is transmitted to and stored in the data reception and storage unit 180. Through such a process, the data reception and storage unit 180 obtains the magnetic field data of the entire 3D space in the internal space of the gantry 15.

[73] Furthermore, the display means displays the density of the magnetic fields in the internal space of the gantry 15 in the form of 3D image data based on the magnetic field data measured in the plurality of measurement holes 152.

[74] Furthermore, the analysis means analyzes the uniformity of a main magnetic field within the gantry 15 based on the magnetic field data measured in the plurality of measurement holes 152 and the displayed 3D image data.

Claims

- [Claim 1] An apparatus for measuring a uniformity of a main magnetic field in a magnetic resonance imaging system comprising a gantry and a patient table moving in an internal space of the gantry, the apparatus comprising:
- a probe configured to measure a magnetic field at each of a plurality of specific points in the internal space of the gantry;
 - a driving unit configured to move the probe in a multi-axis direction in the internal space of the gantry;
 - a bar disposed in a central axis in a length direction of the gantry; and
 - a measurement plate configured to have the bar inserted into a center of the measurement plate and reciprocally moved in a length direction of the bar, a plurality of measurement holes into each of which the probe is inserted being formed in the measurement plate,
- wherein the probe measures the uniformity of the magnetic fields in the internal space of the gantry by measuring the magnetic field in each of the measurement holes.
- [Claim 2] The apparatus of claim 1, wherein the bar is placed at a center of the magnetic fields within the gantry.
- [Claim 3] The apparatus of claim 1, wherein the driving unit comprises:
- a Z-axis driving unit configured to reciprocally move the probe in a Z axis parallel to the length direction of the gantry;
 - an X-axis driving unit configured to reciprocally move the probe in an X axis vertical to the Z axis; and
 - a Y-axis driving unit configured to reciprocally move the probe in the Z axis and a Y axis vertical to the Z axis.
- [Claim 4] The apparatus of claim 1, further comprising a probe holder provided between the driving unit and the probe and configured to fix the probe.
- [Claim 5] The apparatus of claim 1, wherein:
- the measurement plate is configured in a circular plate form having a specific thickness,
 - a center hole into which the bar is inserted is formed at a center of the measurement plate, and
 - a plurality of the measurement holes is arranged around the center hole in a radial form.
- [Claim 6] The apparatus of claim 5, further comprising a plate driving unit configured to move the measurement plate based on an axis in the

- length direction of the bar.
- [Claim 7] The apparatus of claim 5, further comprising a phantom plate disposed in a rear of the measurement plate and configured in a circular plate form, wherein a center hole into which the bar is inserted is formed at a center of the phantom plate, and an inside of the phantom plate is filled with a phantom solution.
- [Claim 8] The apparatus of claim 6, further comprising a driving control unit configured to control a location of the probe by controlling the driving unit and to control a location of the measurement plate by controlling the plate driving unit.
- [Claim 9] The apparatus of claim 1, wherein the probe comprises at least one of a flux meter and a gauss meter.
- [Claim 10] The apparatus of claim 1, wherein a plurality of the probes is disposed in a radial form.
- [Claim 11] The apparatus of claim 5, wherein:
the measurement plate is formed by combining a plurality of separated members, and
the members are capable of being assembled and disassembled.
- [Claim 12] A method for measuring a uniformity of a main magnetic field in a magnetic resonance imaging system comprising a gantry and a patient table moving in an internal space of the gantry, the method comprising:
entering, by a driving unit, a probe configured to measure a magnetic field in the internal space of the gantry into the internal space of the gantry;
moving, by the driving unit, the probe and inserting the probe into at least one of a plurality of measurement holes formed in a measurement plate of a circular plate form which has been inserted into a bar disposed in a central axis in a length direction of the gantry; and
measuring, by the probe, a magnetic field in the measurement hole.
- [Claim 13] The method of claim 12, further comprising:
inserting, by the driving unit, the probe into the measurement hole at a different location and measuring a magnetic field, after measuring, by the probe, the magnetic field in the measurement hole; and
moving, by a plate driving unit, the measurement plate in an axis in a length direction of the bar.
- [Claim 14] A computer-readable recording medium on which program code capable of executing a method for measuring a uniformity of a main magnetic field in a magnetic resonance imaging system according to

claim 12 or 13 has been recorded.

[Claim 15]

A system for analyzing a uniformity of a main magnetic field in a magnetic resonance imaging system comprising a gantry and a patient table moving in an internal space of the gantry, the system comprising: an apparatus configured to measure the uniformity of a main magnetic field in the magnetic resonance imaging system according to claims 1 to 11;

a data reception and storage unit configured to receive and store magnetic field data measured in a plurality of respective measurement holes formed in a measurement plate of the apparatus;

display means configured to display a density of magnetic fields in the internal space of the gantry in a 3D image data form based on the received magnetic field data measured in the plurality of measurement holes; and

analysis means configured to analyze a uniformity of a main magnetic field within the gantry based on the received magnetic field data measured in the plurality of measurement holes.

[Claim 16]

A method for measuring a uniformity of a main magnetic field in a magnetic resonance imaging system comprising a gantry and a patient table moving in an internal space of the gantry and, the method comprising:

a first step of entering, by a driving unit, a probe configured to measure a magnetic field in the internal space of the gantry into the internal space of the gantry;

a second step of moving, by the driving unit, the probe and inserting the probe into at least one of a plurality of measurement holes formed in a measurement plate of a circular plate form which has been inserted into a bar disposed in a central axis in a length direction of the gantry;

a third step of measuring, by the probe, a magnetic field in the measurement hole;

a fourth step of inserting, by the driving unit, the probe into the measurement hole at a different location and measuring a magnetic field in the measurement hole;

a fifth step of repeating the fourth step;

a sixth step of moving, by a plate driving unit, the measurement plate in an axis in a length direction of the bar;

a seventh step of repeating the third step and the fourth step;

an eighth step of receiving and storing, by a data reception and storage

unit, magnetic field data measured in a plurality of respective measurement holes;

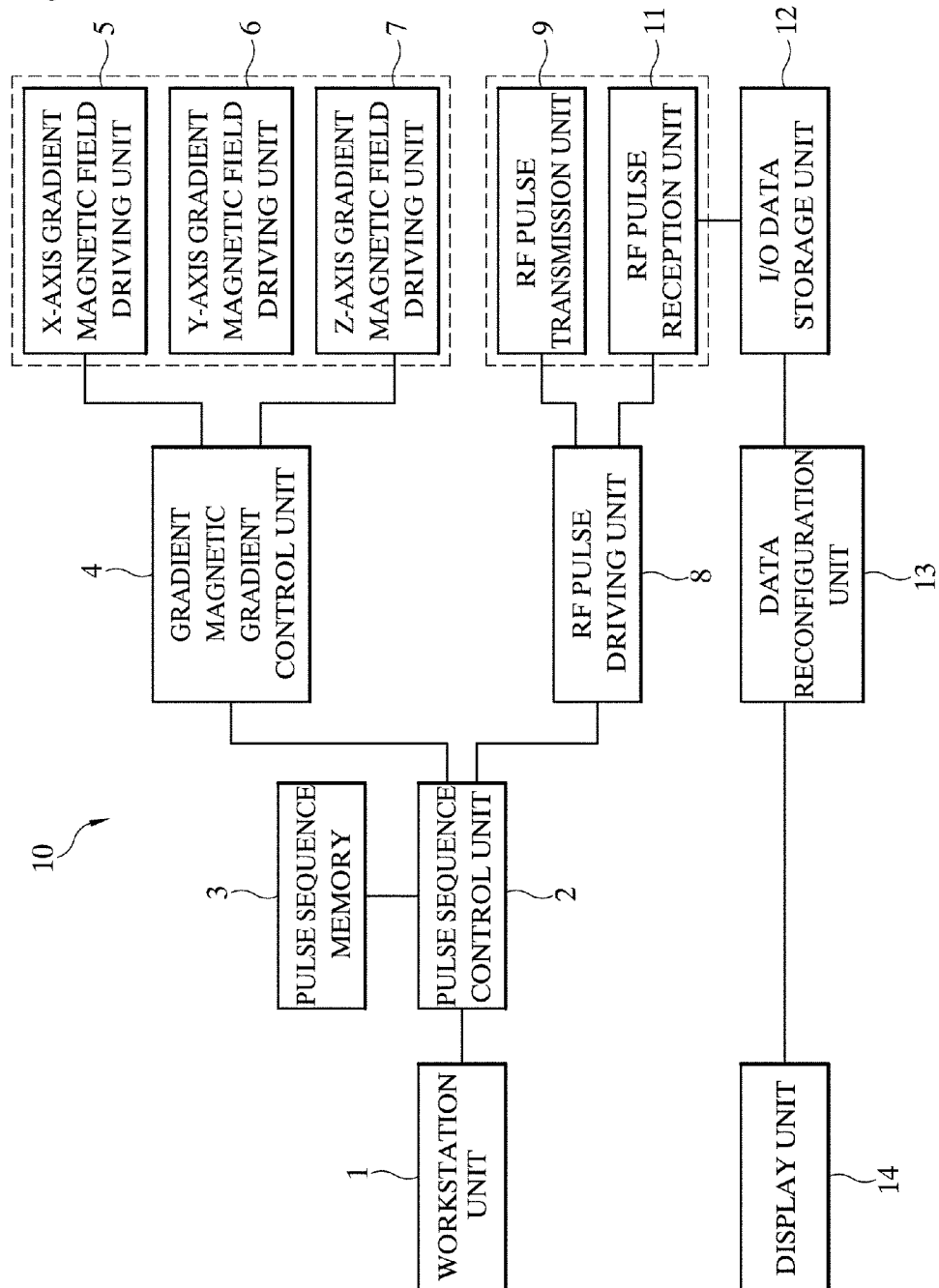
a ninth step of displaying, by display means, a density of the magnetic fields in the internal space of the gantry in a 3D image data form based on the received magnetic field data measured in the plurality of measurement holes; and

a tenth step of analyzing, by analysis means, a uniformity of a main magnetic field within the gantry based on the received magnetic field data measured in the plurality of measurement holes.

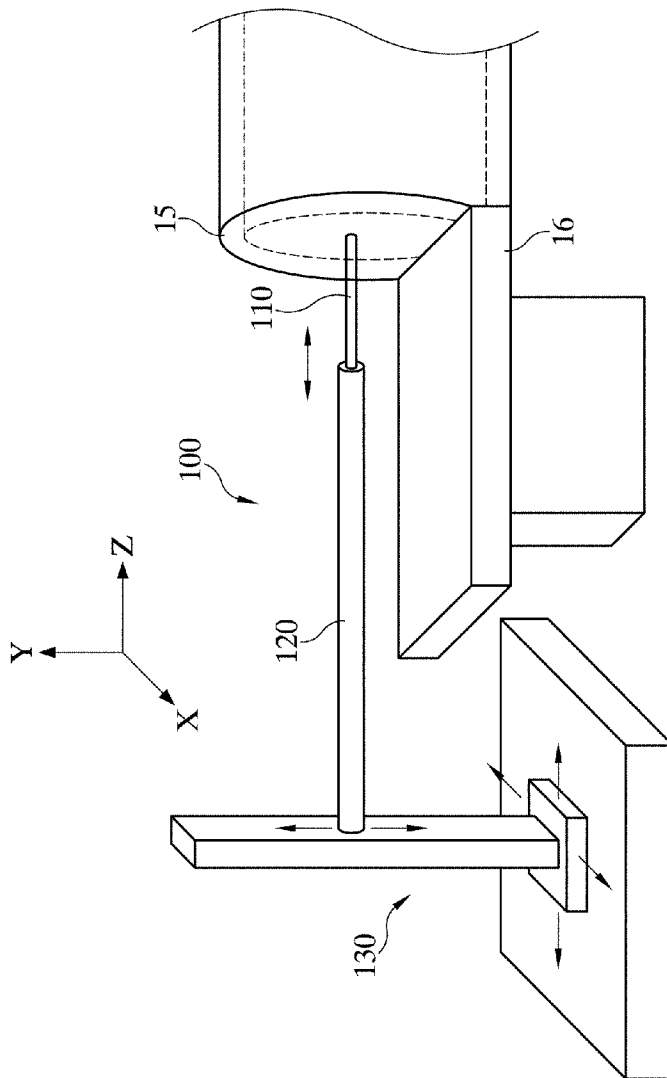
[Claim 17]

A computer-readable recording medium on which program code capable of executing a method of analyzing a uniformity of a main magnetic field in a magnetic resonance imaging system according to claim 16 has been recorded.

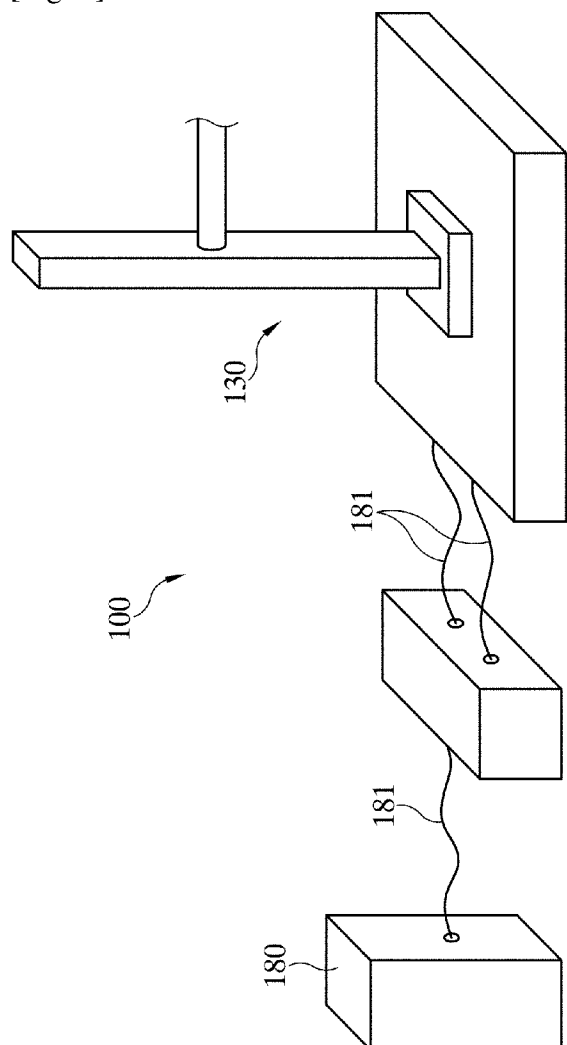
[Fig. 1]



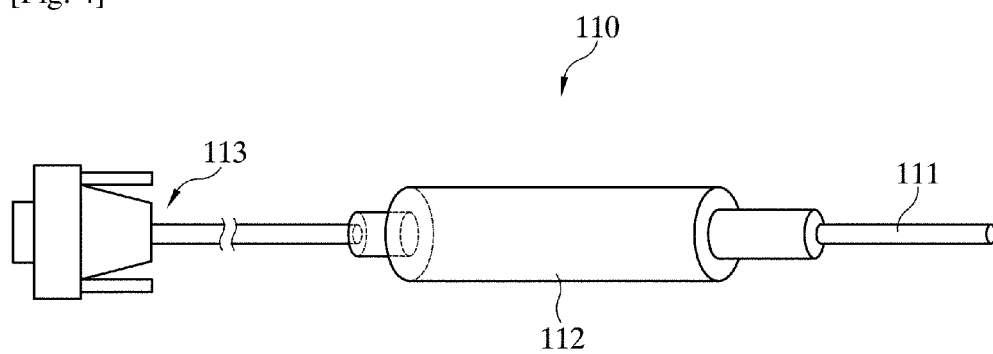
[Fig. 2]



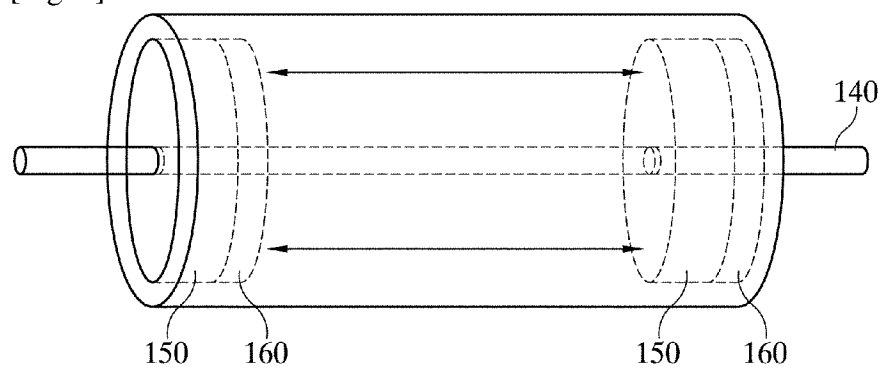
[Fig. 3]



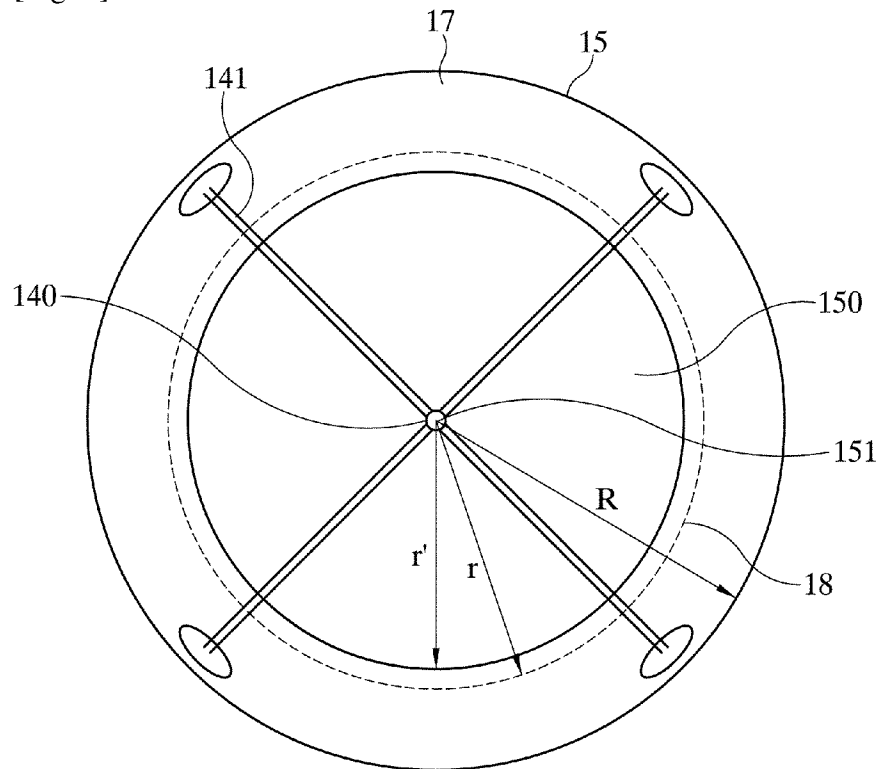
[Fig. 4]



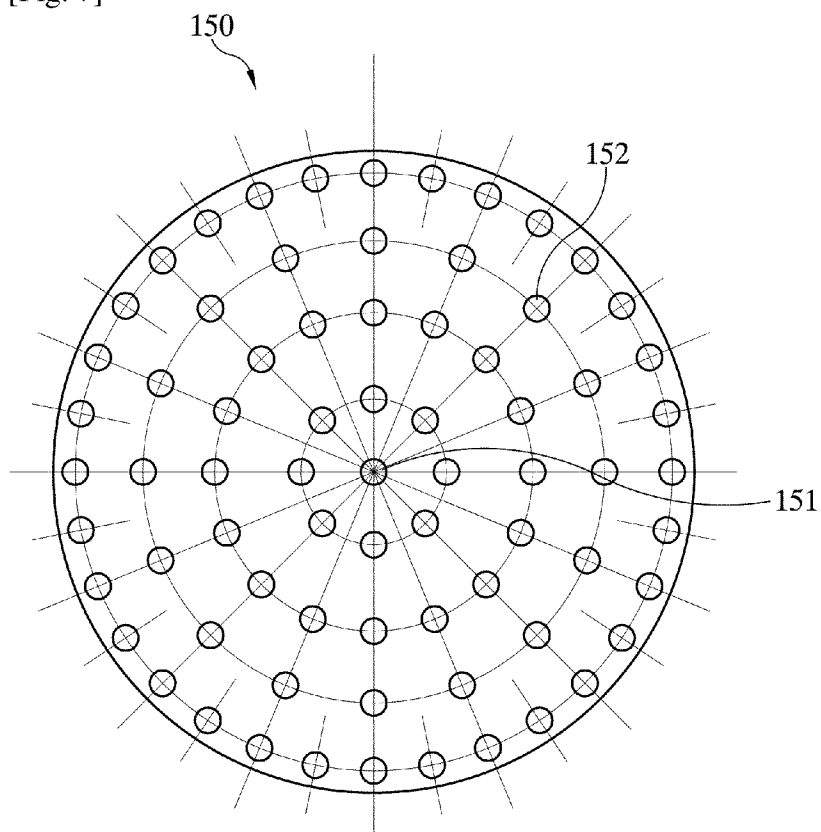
[Fig. 5]



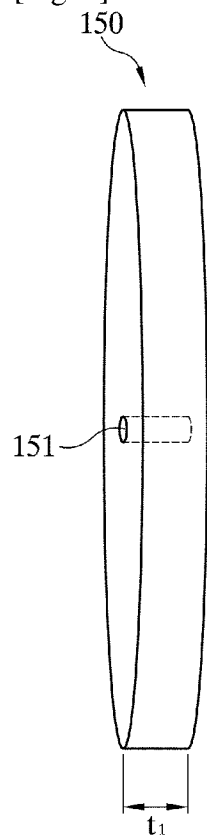
[Fig. 6]



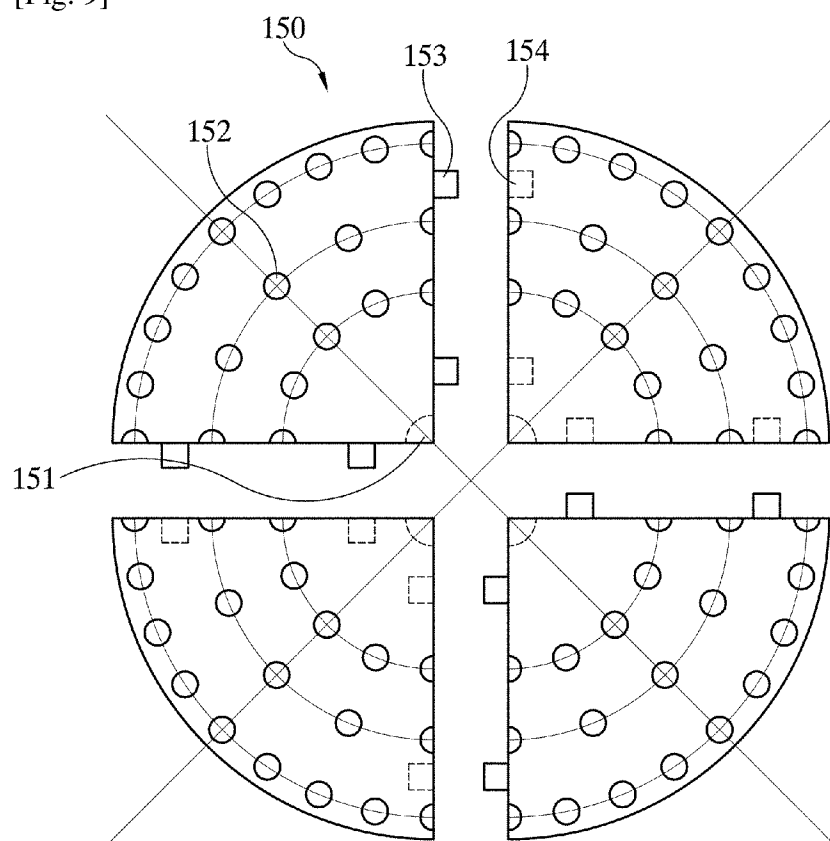
[Fig. 7]



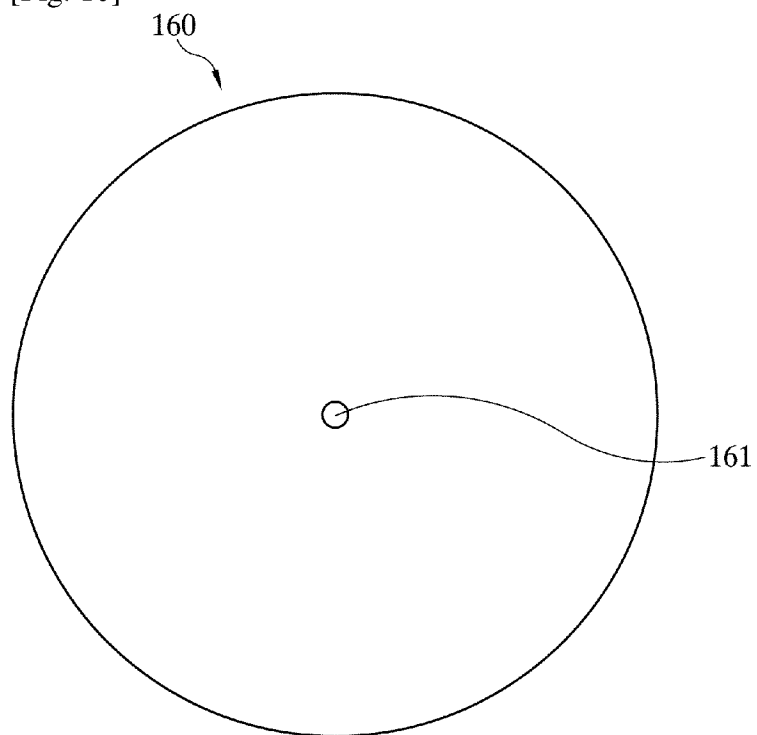
[Fig. 8]



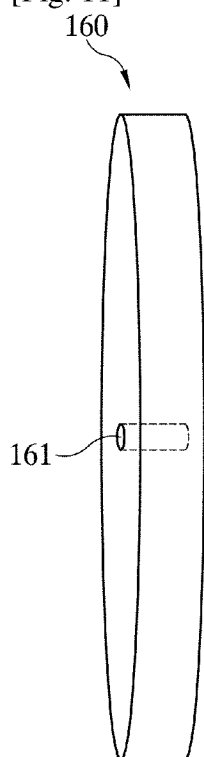
[Fig. 9]



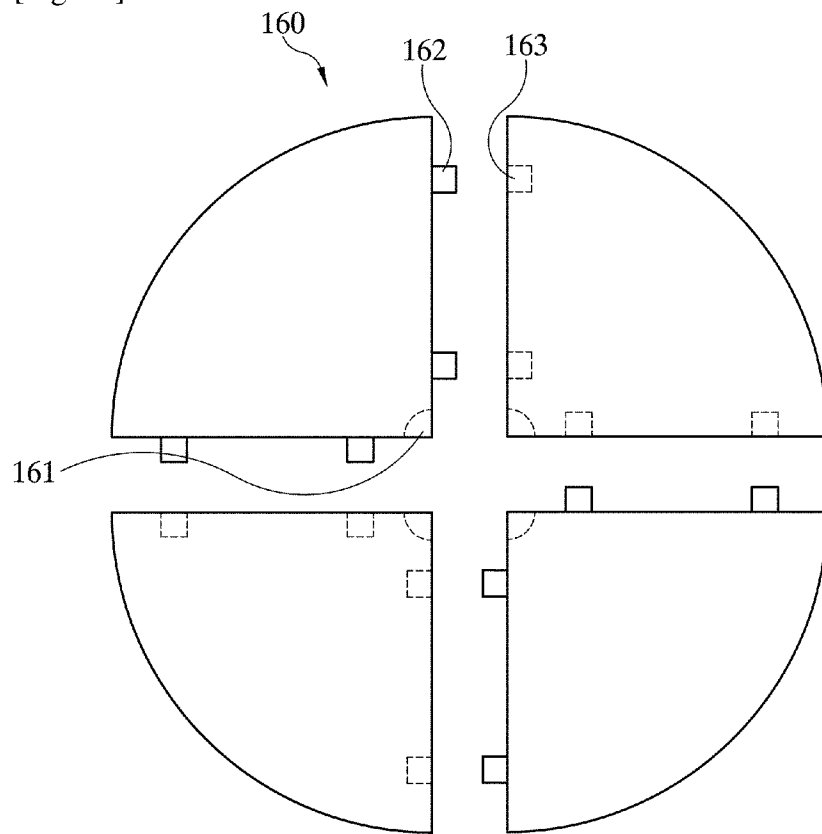
[Fig. 10]



[Fig. 11]



[Fig. 12]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/002947**A. CLASSIFICATION OF SUBJECT MATTER****G01R 33/38(2006.01)i, G01R 33/20(2006.01)i, A61B 5/055(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)

G01R 33/38; G01R 33/32; A61B 5/055; G01R 33/09; G01R 33/10; G01R 33/20

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: MRI , measurement , uniformity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-017706 A (HITACHI MEDICAL CORP) 22 January 2002 See paragraphs [0024], [0026]; figure 2.	1-14, 16, 17
Y	JP 06-070911A (TOSHIBA CORP) 15 March 1994 See paragraphs [0010], [0018].	1-14, 16, 17
A	KR 10-0738321 B1 (KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE) 12 July 2007 See abstract; claims 1-3, 6.	1, 12, 14, 16, 17
A	KR 10-0936497 B1 (ULVAC KOREA) 13 January 2010 See abstract; claims 1, 7.	1, 12, 14, 16, 17



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 another 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

10 July 2014 (10.07.2014)

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

YANG, Chan Ho

Telephone No. +82-42-481-5689



INTERNATIONAL SEARCH REPORTInternational application No.
PCT/KR2014/002947**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 15
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2014/002947

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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JP 06-070911A	15/03/1994	JP 3359938 B2	24/12/2002
KR 10-0738321 B1	12/07/2007	None	
KR 10-0936497 B1	13/01/2010	KR 10-2009-44170 A	07/05/2009