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(54) **MAGNETIC RESONANCE IMAGING APPARATUS**

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(57) **ABSTRACT**

In order to reduce inaccuracy of a hemodynamic visualization image acquired when a blood flow is labeled before blood flow visualization imaging, an MRI apparatus uses a blood flow velocity to control pulse sequences including a sequence of applying a high-frequency pulse for labeling the blood flow and imaging the subsequent blood flow or display of the hemodynamic visualization image. For example, the blood flow velocity is used for controlling application positions of one or more high-frequency pulses from among a plurality of the high-frequency pulses for labeling. The MRI apparatus controls time between labeling the blood flow and starting imaging and/or the application positions of high-frequency pulses for labeling the blood flow. A threshold value for color display of a blood flow visualization image is controlled.

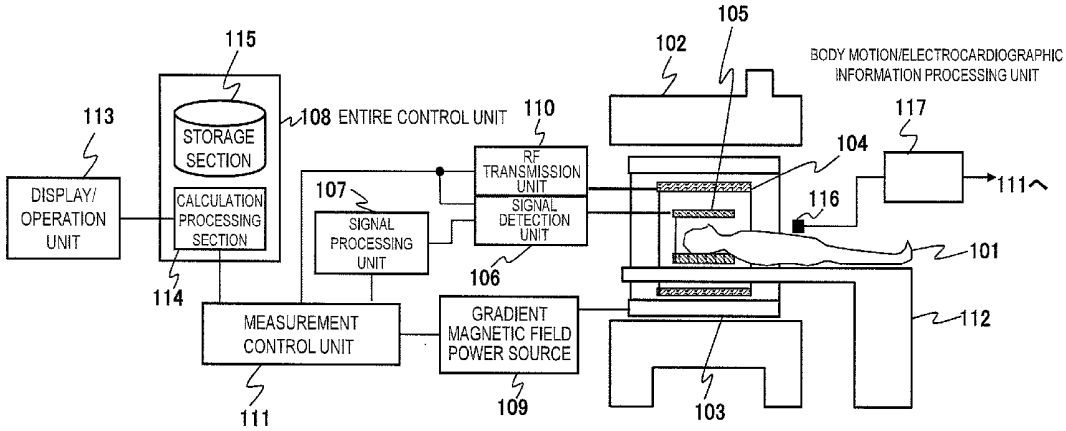


FIG.1

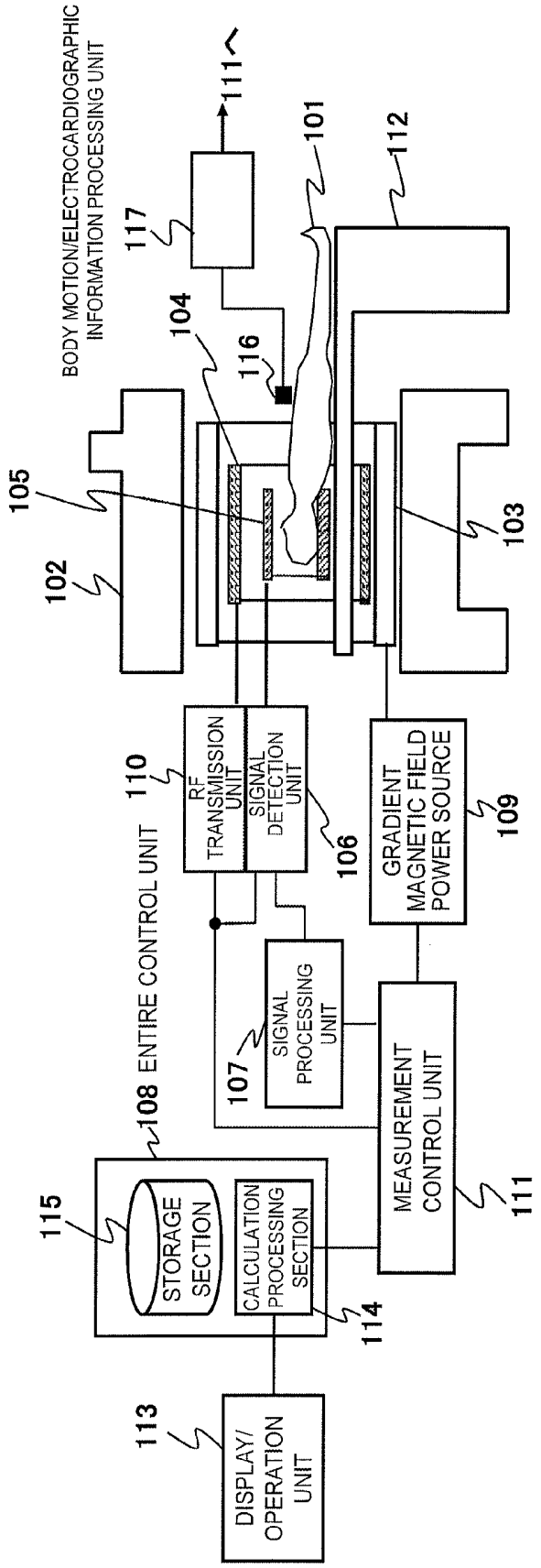

BODY MOTION/ELECTROCARDIOGRAPHIC INFORMATION PROCESSING UNIT
111
117
101
112
104
116
105
102
103
RF TRANSMISSION UNIT
SIGNAL DETECTION UNIT
110
106
GRADIENT MAGNETIC FIELD POWER SOURCE
109
SIGNAL PROCESSING UNIT
107
108 ENTIRE CONTROL UNIT
MEASUREMENT CONTROL UNIT
111
115
STORAGE SECTION
CALCULATION PROCESSING SECTION
114
113
DISPLAY/ OPERATION UNIT

FIG.2

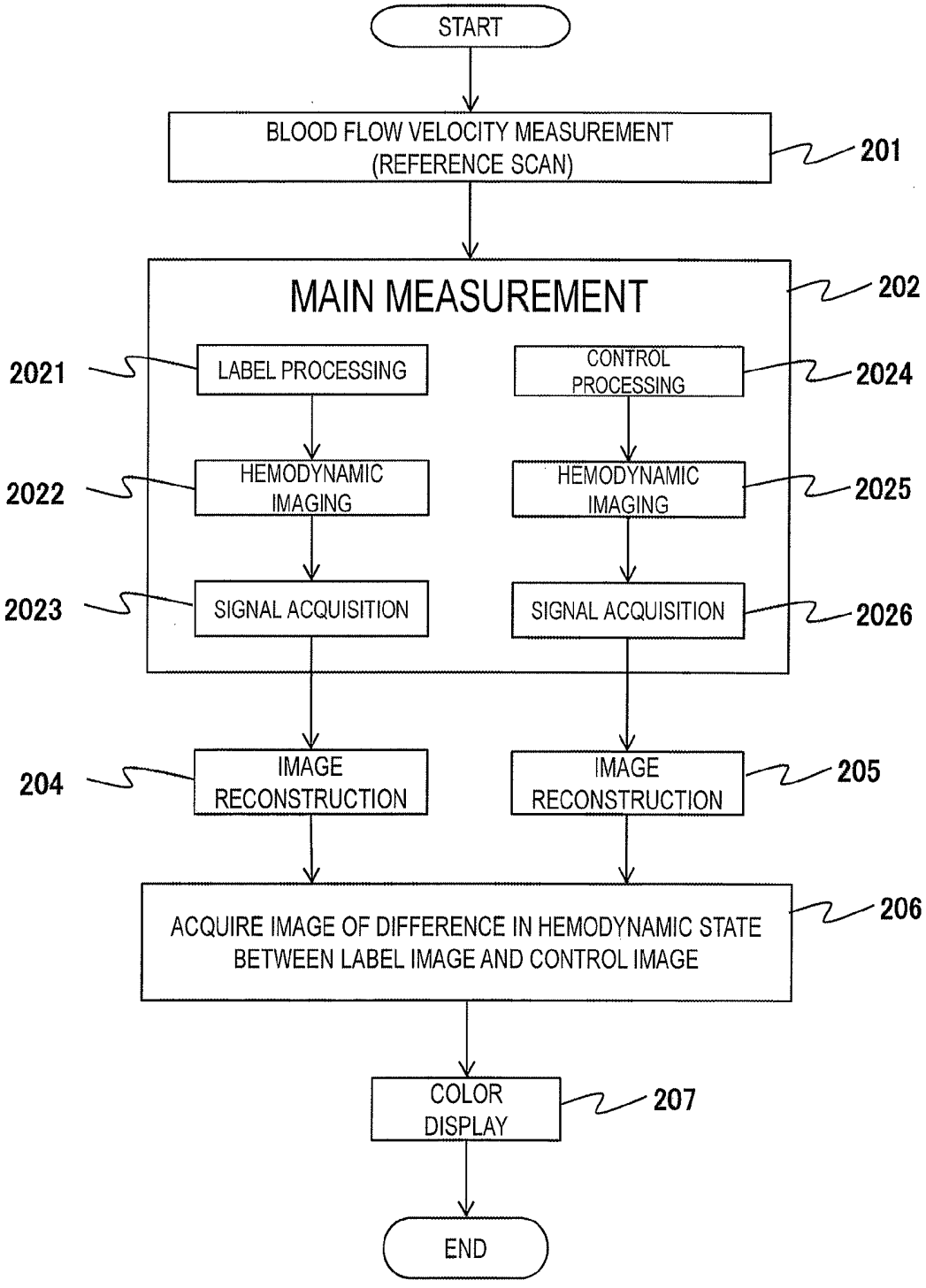

START
BLOOD FLOW VELOCITY MEASUREMENT (REFERENCE SCAN)
201
MAIN MEASUREMENT
202
2021
LABEL PROCESSING
CONTROL PROCESSING
2024
2022
HEMODYNAMIC IMAGING
HEMODYNAMIC IMAGING
2025
2023
SIGNAL ACQUISITION
SIGNAL ACQUISITION
2026
204
IMAGE RECONSTRUCTION
IMAGE RECONSTRUCTION
205
ACQUIRE IMAGE OF DIFFERENCE IN HEMODYNAMIC STATE BETWEEN LABEL IMAGE AND CONTROL IMAGE
206
COLOR DISPLAY
207
END

FIG.3

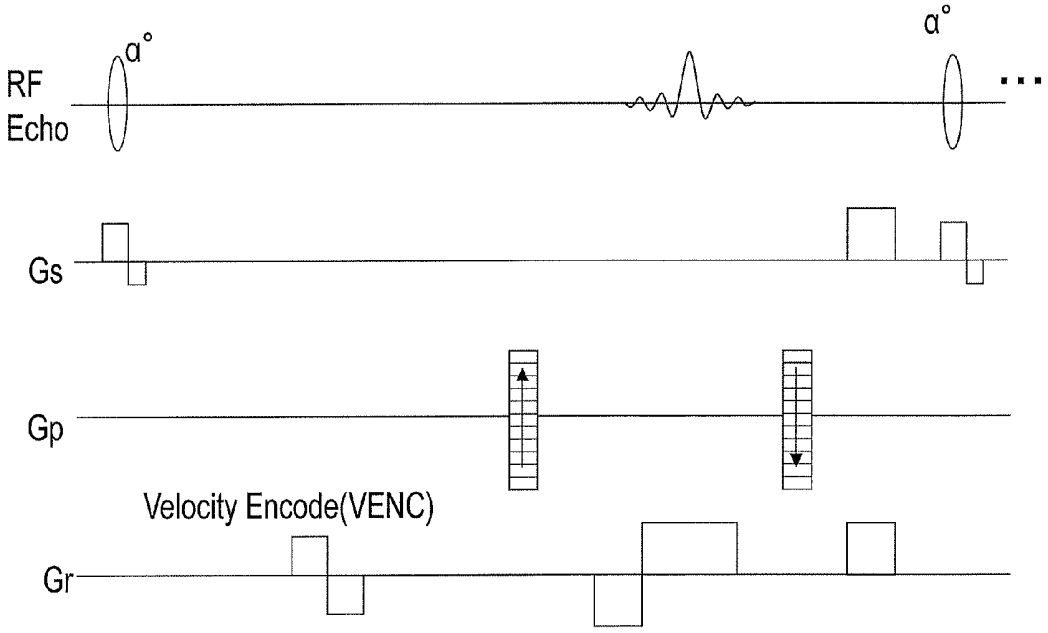


FIG.4

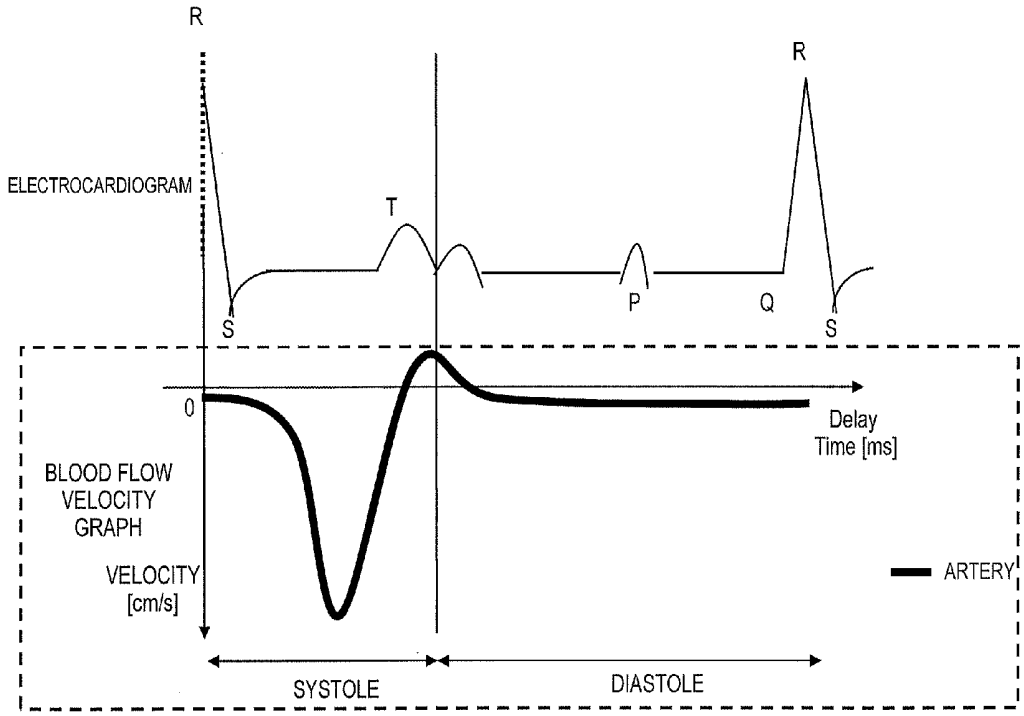

R
R
ELECTROCARDIOGRAM
T
P
Q
S
S
0
Delay
Time [ms]
BLOOD FLOW
VELOCITY
GRAPH
VELOCITY
[cm/s]
ARTERY
SYSTOLE
DIASTOLE

FIG.5

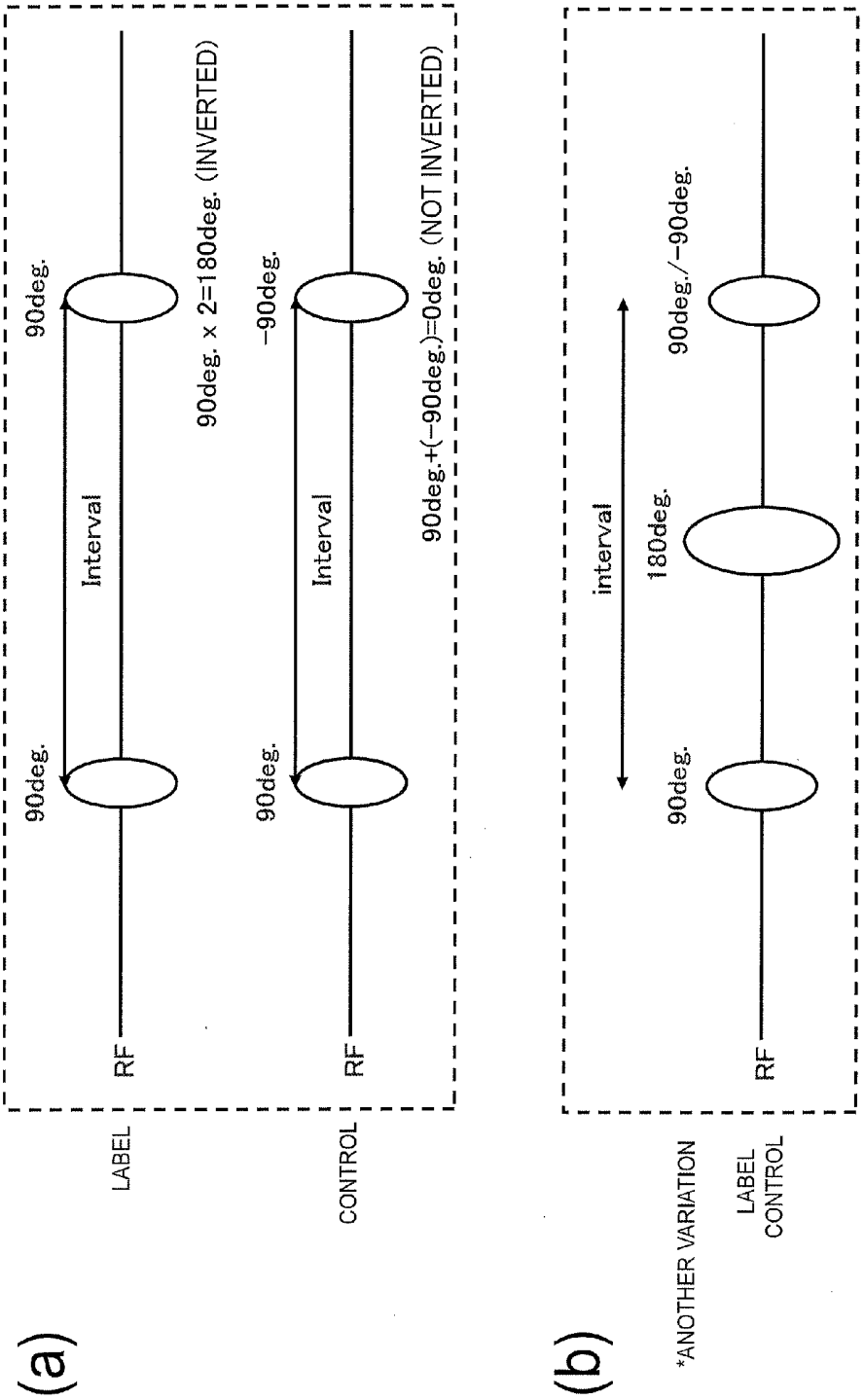

(a)
LABEL
CONTROL
RF
RF
FIRST RF PULSE
SECOND RF PULSE
90deg.
Interval
90deg.
90deg. x 2=180deg. (INVERTED)
−90deg.
Interval
90deg.
90deg.+(−90deg.)=0deg. (NOT INVERTED)
(b)
*ANOTHER VARIATION
LABEL
CONTROL
RF
90deg.
interval
180deg.
90deg./−90deg.

FIG.6

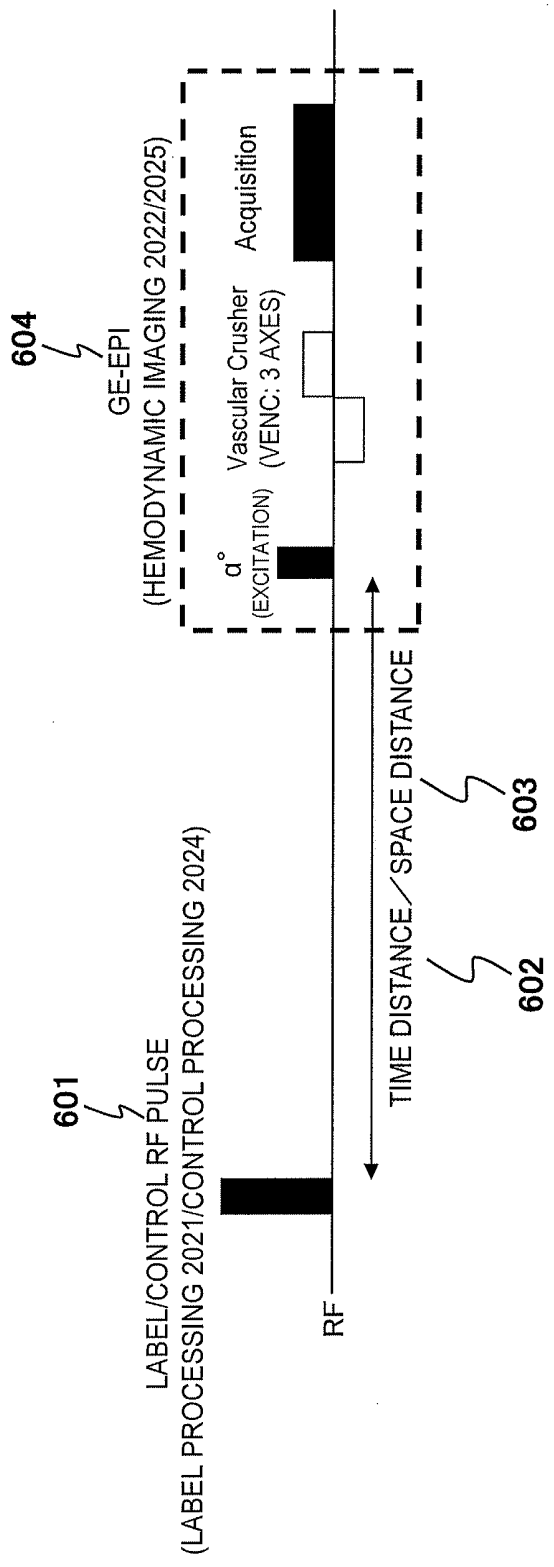

604
GE-EPI
(HEMODYNAMIC IMAGING 2022/2025)
α°
(EXCITATION)
Vascular Crusher
(VENC: 3 AXES)
Acquisition
601
LABEL/CONTROL RF PULSE
(LABEL PROCESSING 2021/CONTROL PROCESSING 2024)
TIME DISTANCE/SPACE DISTANCE
603
602
RF

FIG.7

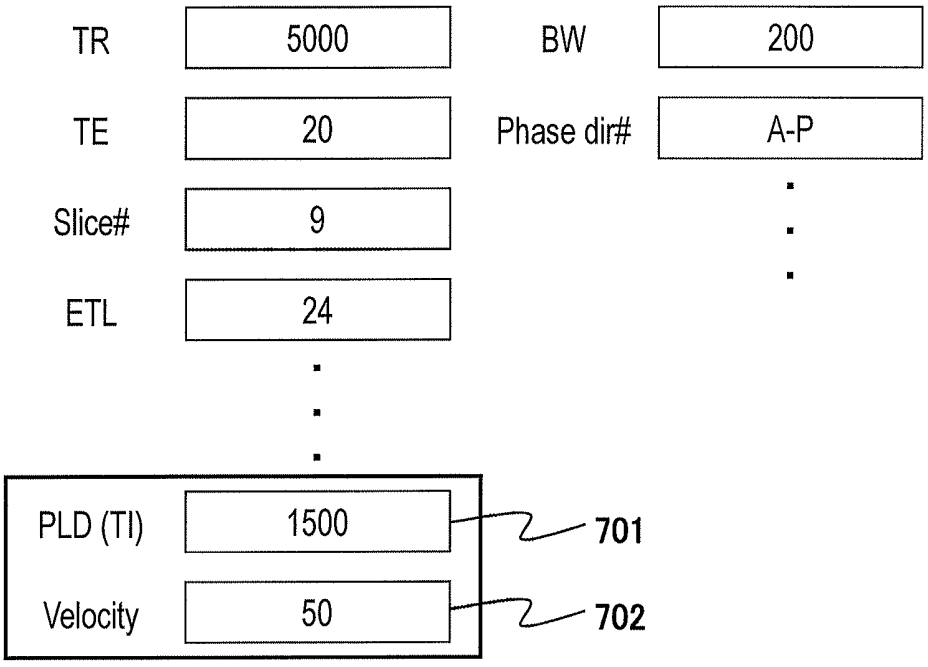

TR
5000
BW
200
TE
20
Phase dir#
A-P
Slice#
9
ETL
24
PLD (TI)
1500
701
Velocity
50
702

FIG.8

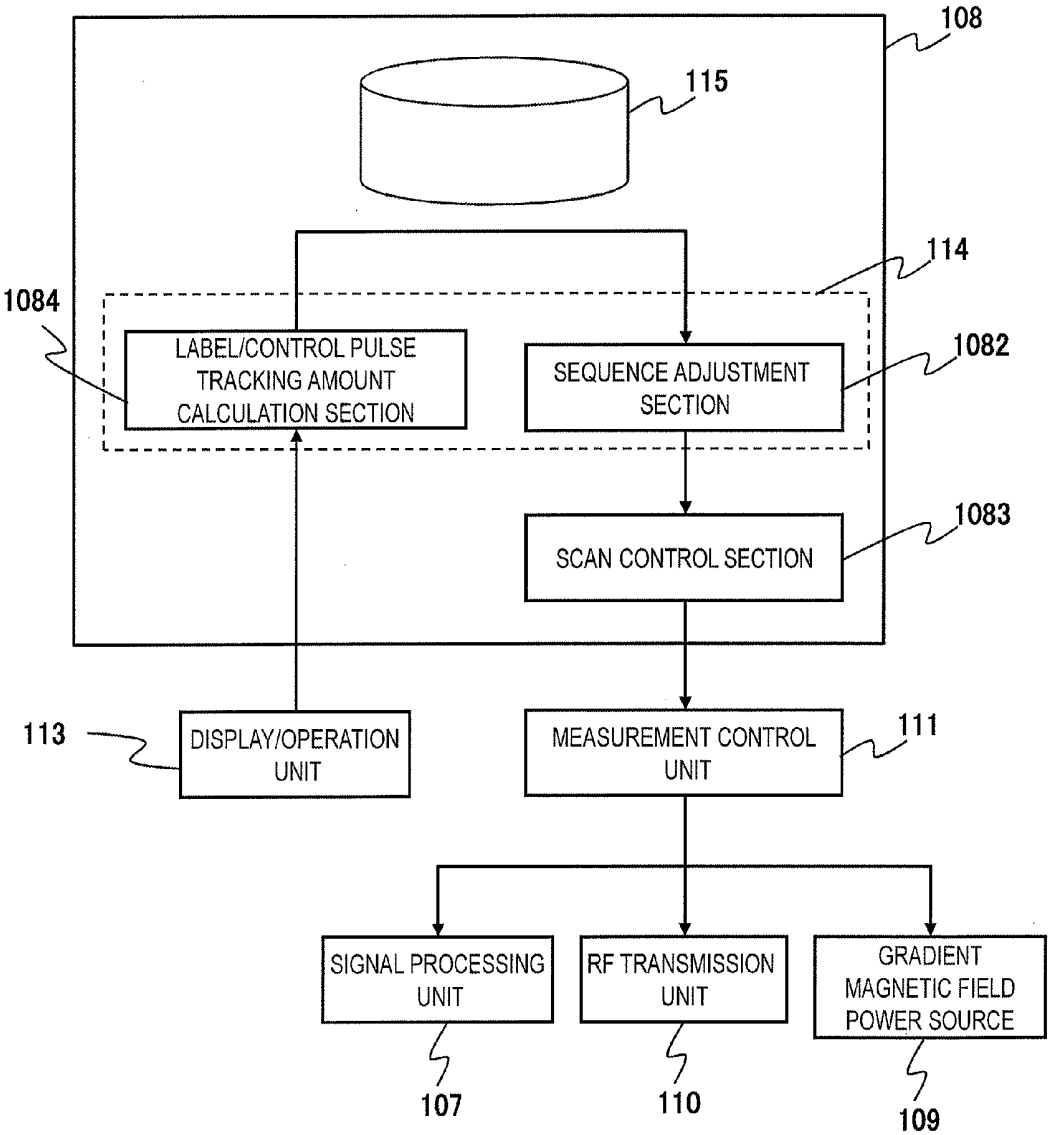

108
115
114
1084
LABEL/CONTROL PULSE TRACKING AMOUNT CALCULATION SECTION
SEQUENCE ADJUSTMENT SECTION
1082
SCAN CONTROL SECTION
1083
113
DISPLAY/OPERATION UNIT
MEASUREMENT CONTROL UNIT
111
SIGNAL PROCESSING UNIT
RF TRANSMISSION UNIT
GRADIENT MAGNETIC FIELD POWER SOURCE
107
110
109

FIG.9

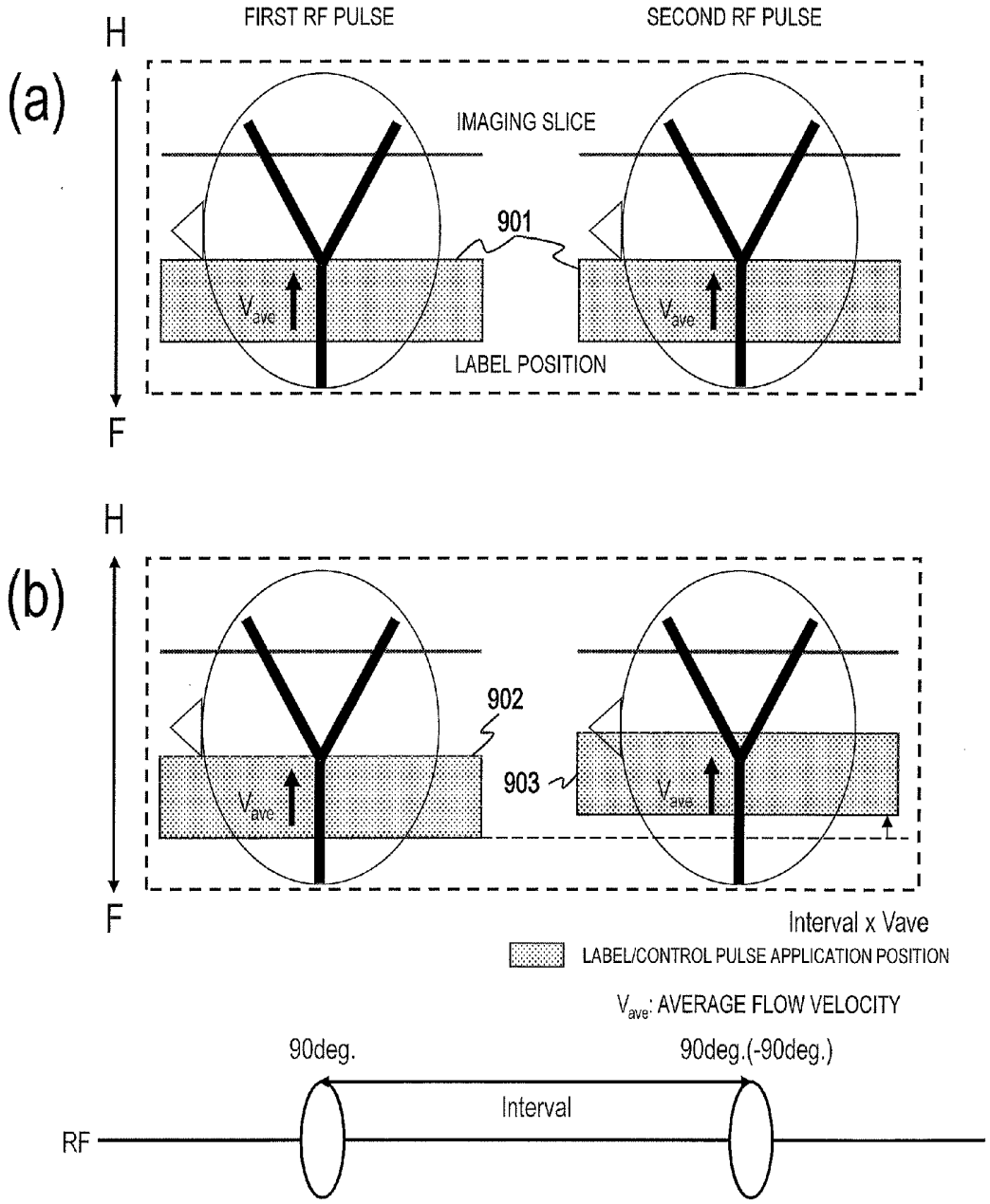

(a)
H
F
FIRST RF PULSE
SECOND RF PULSE
IMAGING SLICE
901
V_{ave}
V_{ave}
LABEL POSITION
(b)
H
F
902
903
V_{ave}
V_{ave}
Interval x Vave
LABEL/CONTROL PULSE APPLICATION POSITION
V_{ave}: AVERAGE FLOW VELOCITY
90deg.
90deg.(-90deg.)
Interval
RF

FIG.10

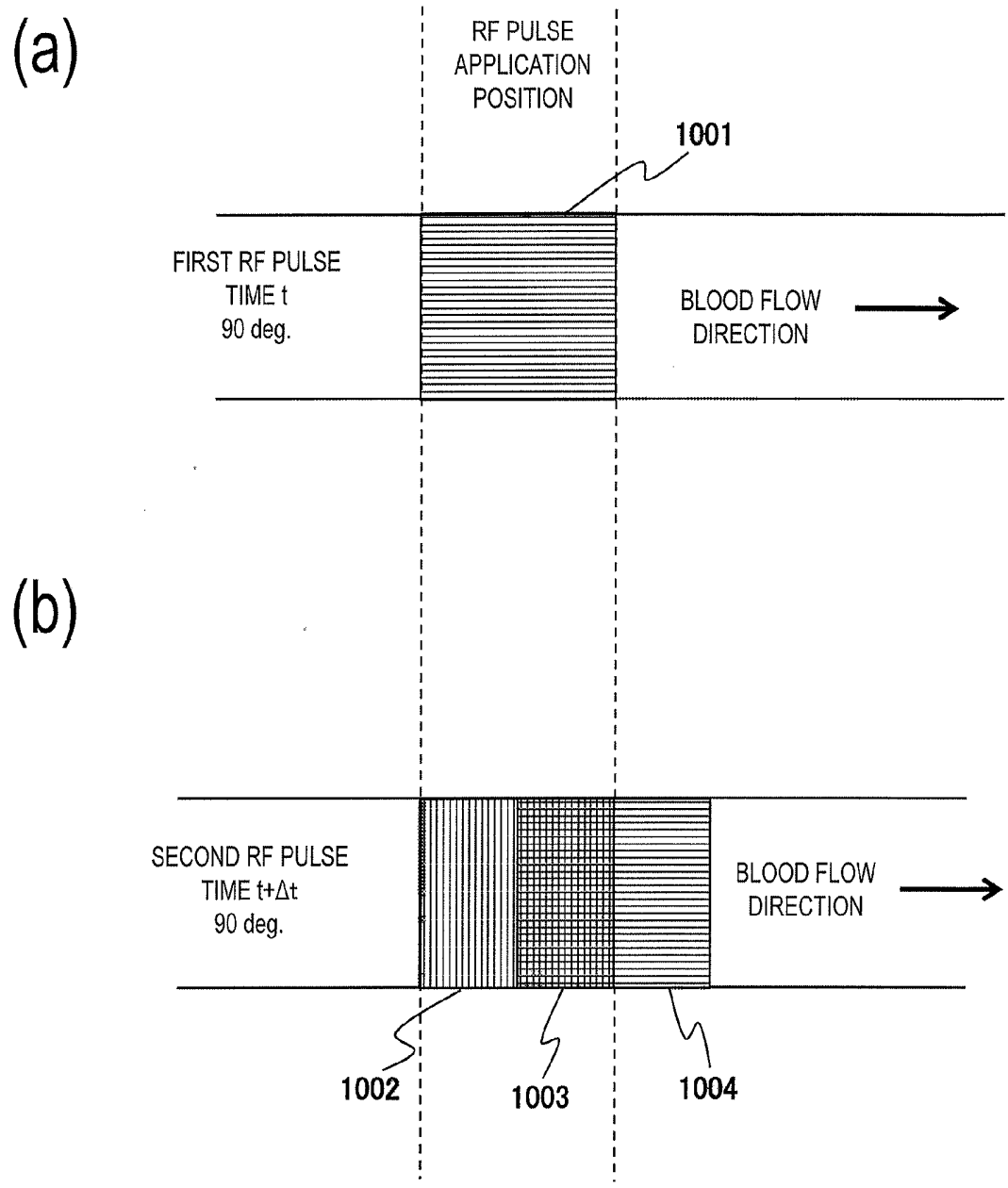

(a)
RF PULSE APPLICATION POSITION
1001
FIRST RF PULSE
TIME t
90 deg.
BLOOD FLOW DIRECTION
(b)
SECOND RF PULSE
TIME t+Δt
90 deg.
BLOOD FLOW DIRECTION
1002
1003
1004

FIG.11

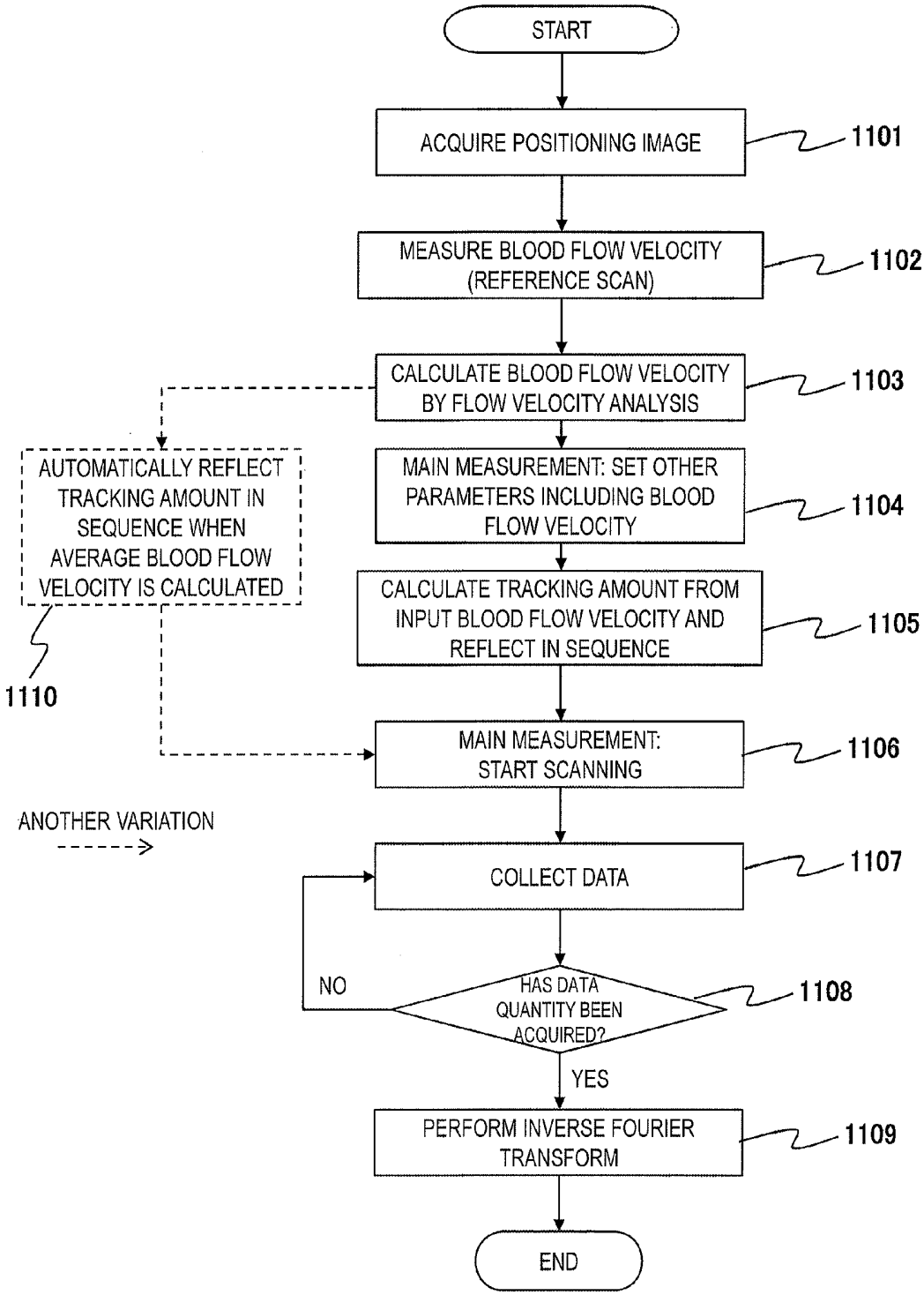

START
ACQUIRE POSITIONING IMAGE
1101
MEASURE BLOOD FLOW VELOCITY (REFERENCE SCAN)
1102
CALCULATE BLOOD FLOW VELOCITY BY FLOW VELOCITY ANALYSIS
1103
AUTOMATICALLY REFLECT TRACKING AMOUNT IN SEQUENCE WHEN AVERAGE BLOOD FLOW VELOCITY IS CALCULATED
1110
MAIN MEASUREMENT: SET OTHER PARAMETERS INCLUDING BLOOD FLOW VELOCITY
1104
CALCULATE TRACKING AMOUNT FROM INPUT BLOOD FLOW VELOCITY AND REFLECT IN SEQUENCE
1105
MAIN MEASUREMENT: START SCANNING
1106
ANOTHER VARIATION
COLLECT DATA
1107
NO
HAS DATA QUANTITY BEEN ACQUIRED?
1108
YES
PERFORM INVERSE FOURIER TRANSFORM
1109
END

FIG.12

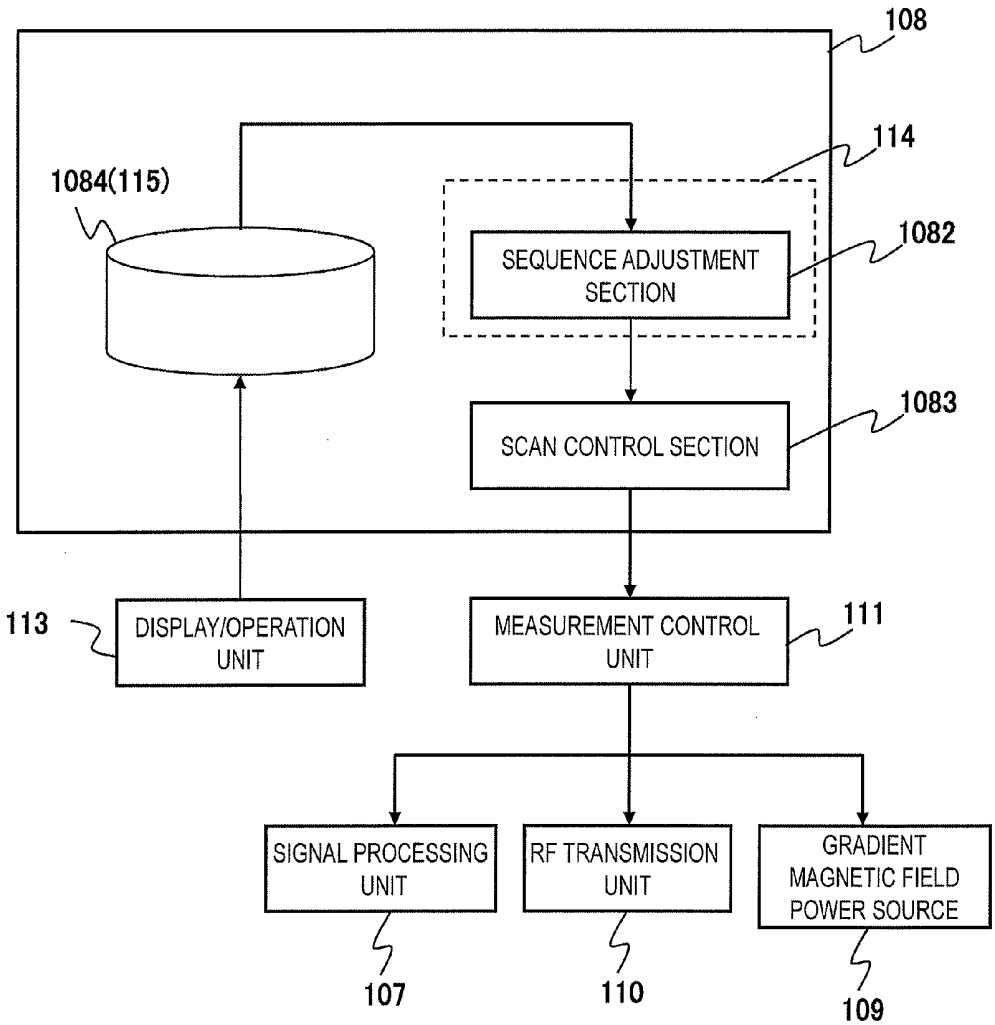
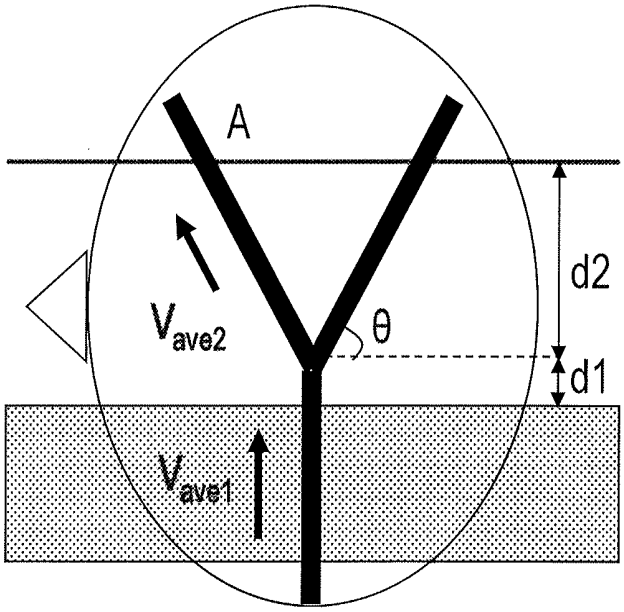

108
114
1084(115)
SEQUENCE ADJUSTMENT SECTION
1082
SCAN CONTROL SECTION
1083
113
DISPLAY/OPERATION UNIT
MEASUREMENT CONTROL UNIT
111
SIGNAL PROCESSING UNIT
RF TRANSMISSION UNIT
GRADIENT MAGNETIC FIELD POWER SOURCE
107
110
109

FIG.13



LABEL/CONTROL PULSE APPLICATION POSITION

FIG.14

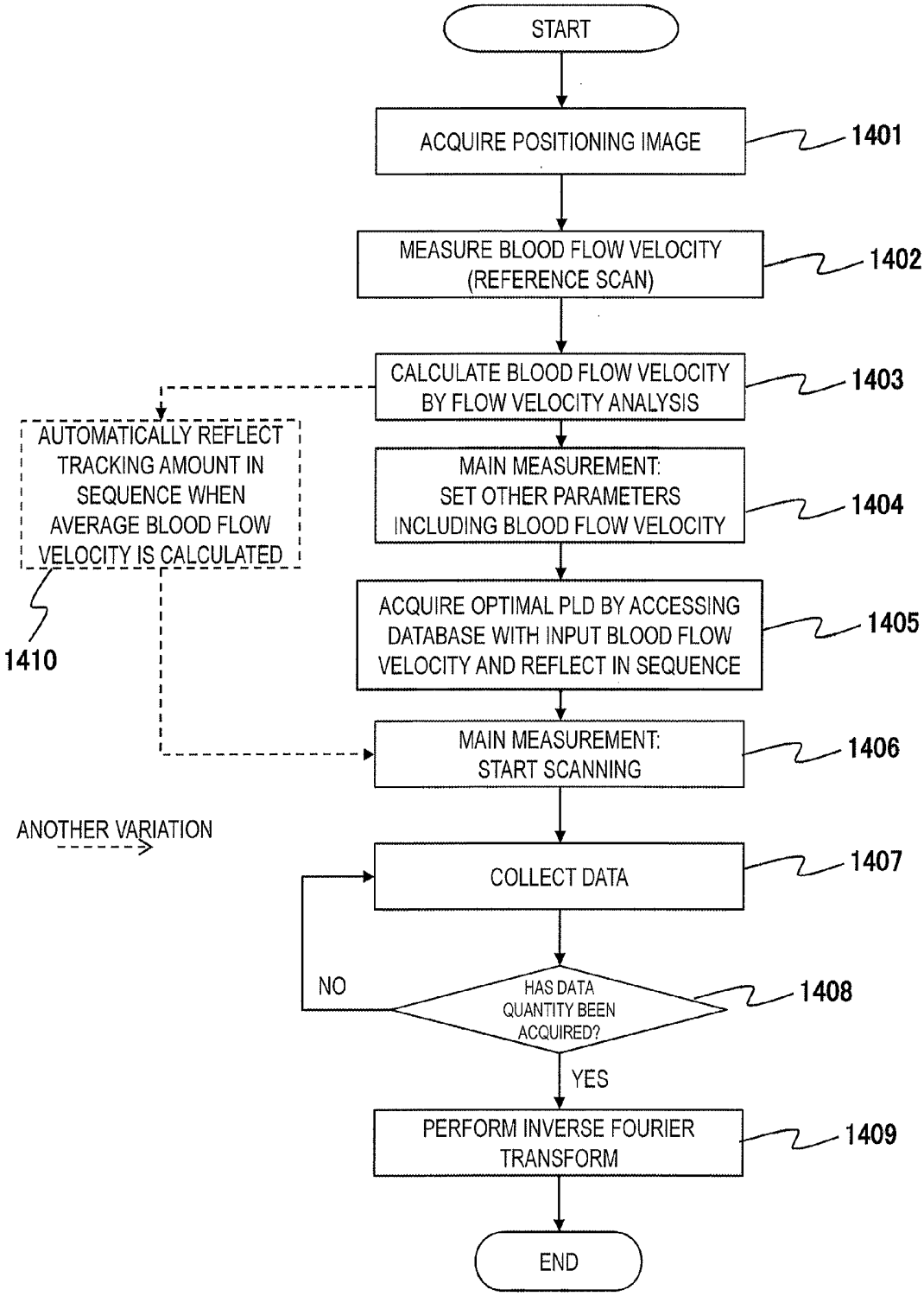

START
ACQUIRE POSITIONING IMAGE
1401
MEASURE BLOOD FLOW VELOCITY (REFERENCE SCAN)
1402
CALCULATE BLOOD FLOW VELOCITY BY FLOW VELOCITY ANALYSIS
1403
AUTOMATICALLY REFLECT TRACKING AMOUNT IN SEQUENCE WHEN AVERAGE BLOOD FLOW VELOCITY IS CALCULATED
1410
MAIN MEASUREMENT: SET OTHER PARAMETERS INCLUDING BLOOD FLOW VELOCITY
1404
ACQUIRE OPTIMAL PLD BY ACCESSING DATABASE WITH INPUT BLOOD FLOW VELOCITY AND REFLECT IN SEQUENCE
1405
MAIN MEASUREMENT: START SCANNING
1406
ANOTHER VARIATION
COLLECT DATA
1407
NO
HAS DATA QUANTITY BEEN ACQUIRED?
1408
YES
PERFORM INVERSE FOURIER TRANSFORM
1409
END

FIG.15

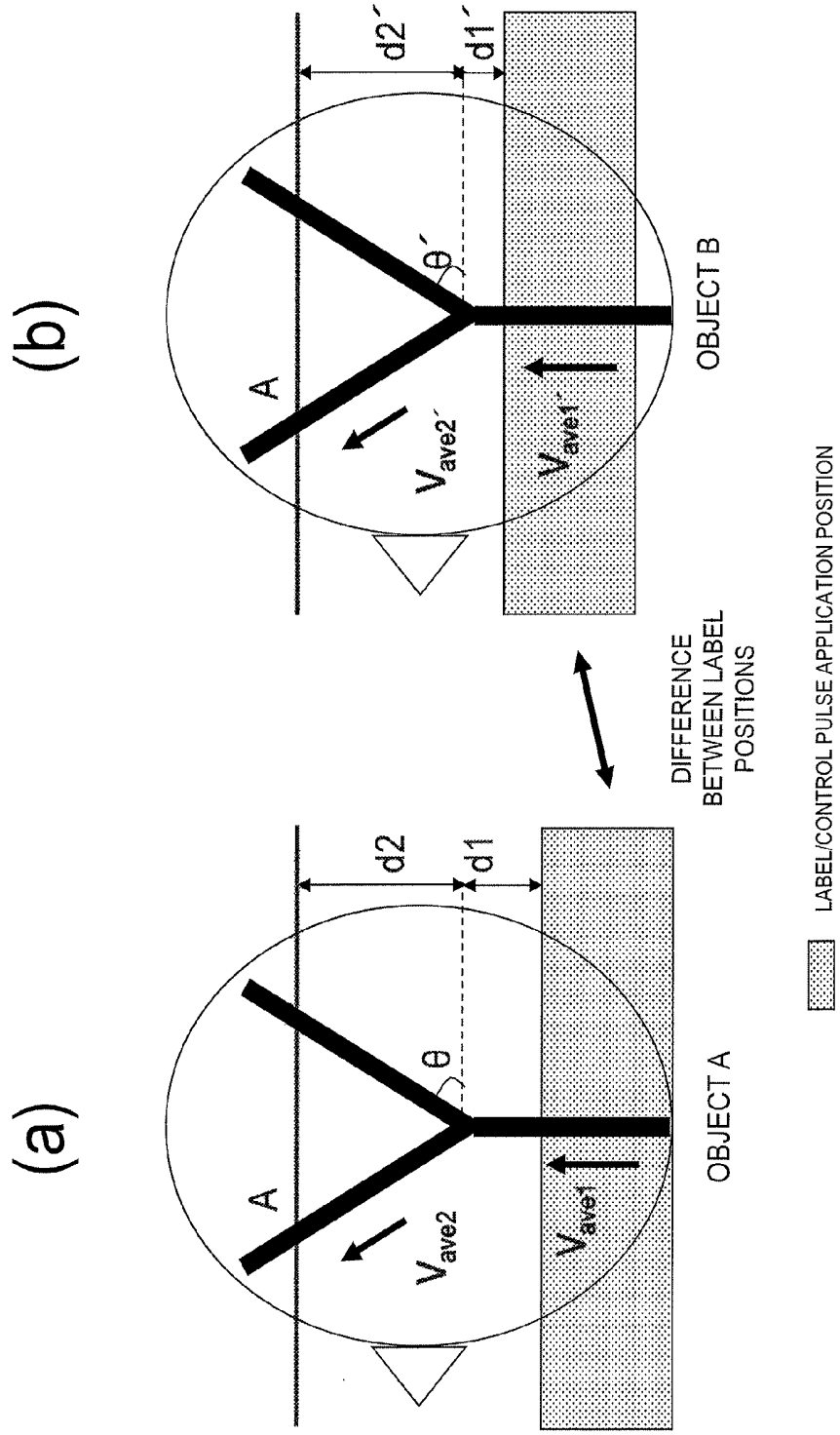

(a)
(b)
A
θ
d2
d1
V_{ave2}
V_{ave1}
θ´
d2´
d1´
V_{ave2}´
V_{ave1}´
OBJECT A
OBJECT B
DIFFERENCE BETWEEN LABEL POSITIONS
LABEL/CONTROL PULSE APPLICATION POSITION

FIG.16

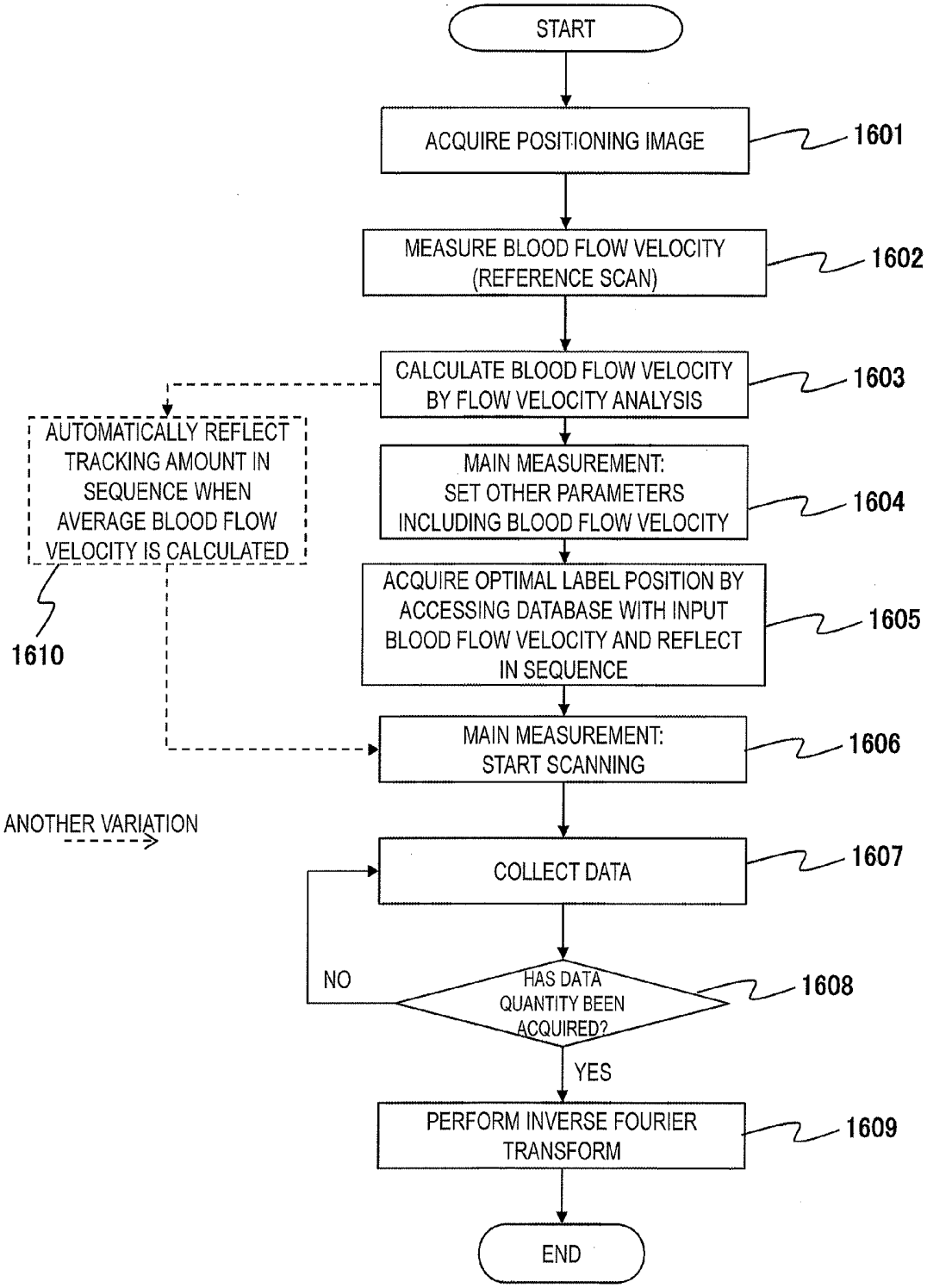

START
ACQUIRE POSITIONING IMAGE
1601
MEASURE BLOOD FLOW VELOCITY (REFERENCE SCAN)
1602
CALCULATE BLOOD FLOW VELOCITY BY FLOW VELOCITY ANALYSIS
1603
AUTOMATICALLY REFLECT TRACKING AMOUNT IN SEQUENCE WHEN AVERAGE BLOOD FLOW VELOCITY IS CALCULATED
1610
MAIN MEASUREMENT: SET OTHER PARAMETERS INCLUDING BLOOD FLOW VELOCITY
1604
ACQUIRE OPTIMAL LABEL POSITION BY ACCESSING DATABASE WITH INPUT BLOOD FLOW VELOCITY AND REFLECT IN SEQUENCE
1605
MAIN MEASUREMENT: START SCANNING
1606
ANOTHER VARIATION
COLLECT DATA
1607
NO
HAS DATA QUANTITY BEEN ACQUIRED?
1608
YES
PERFORM INVERSE FOURIER TRANSFORM
1609
END

FIG.17

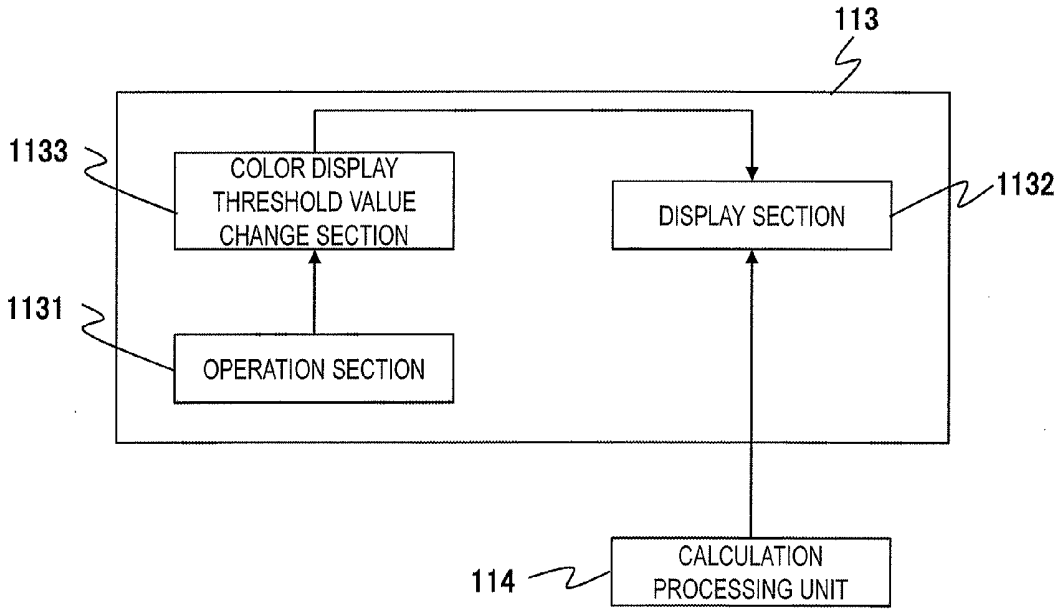
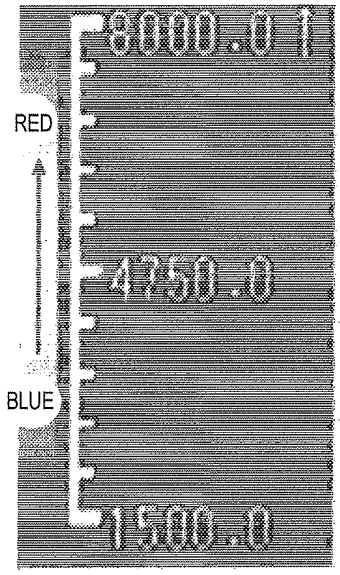

113
1133
COLOR DISPLAY THRESHOLD VALUE CHANGE SECTION
DISPLAY SECTION
1132
1131
OPERATION SECTION
114
CALCULATION PROCESSING UNIT

FIG.18

(a)


8000.0
RED
4250.0
BLUE
1500.0
COLOR
SIGNAL VALUE

(b)

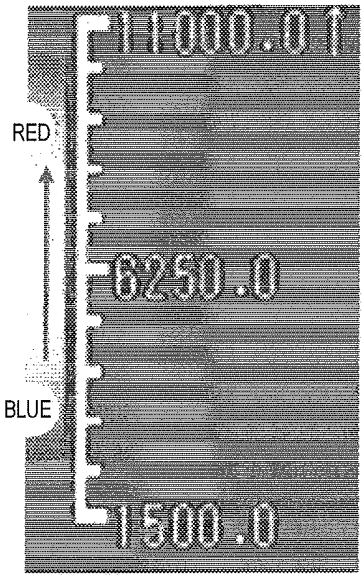

11000.0
RED
6250.0
BLUE
1500.0
COLOR
SIGNAL VALUE

FIG.19

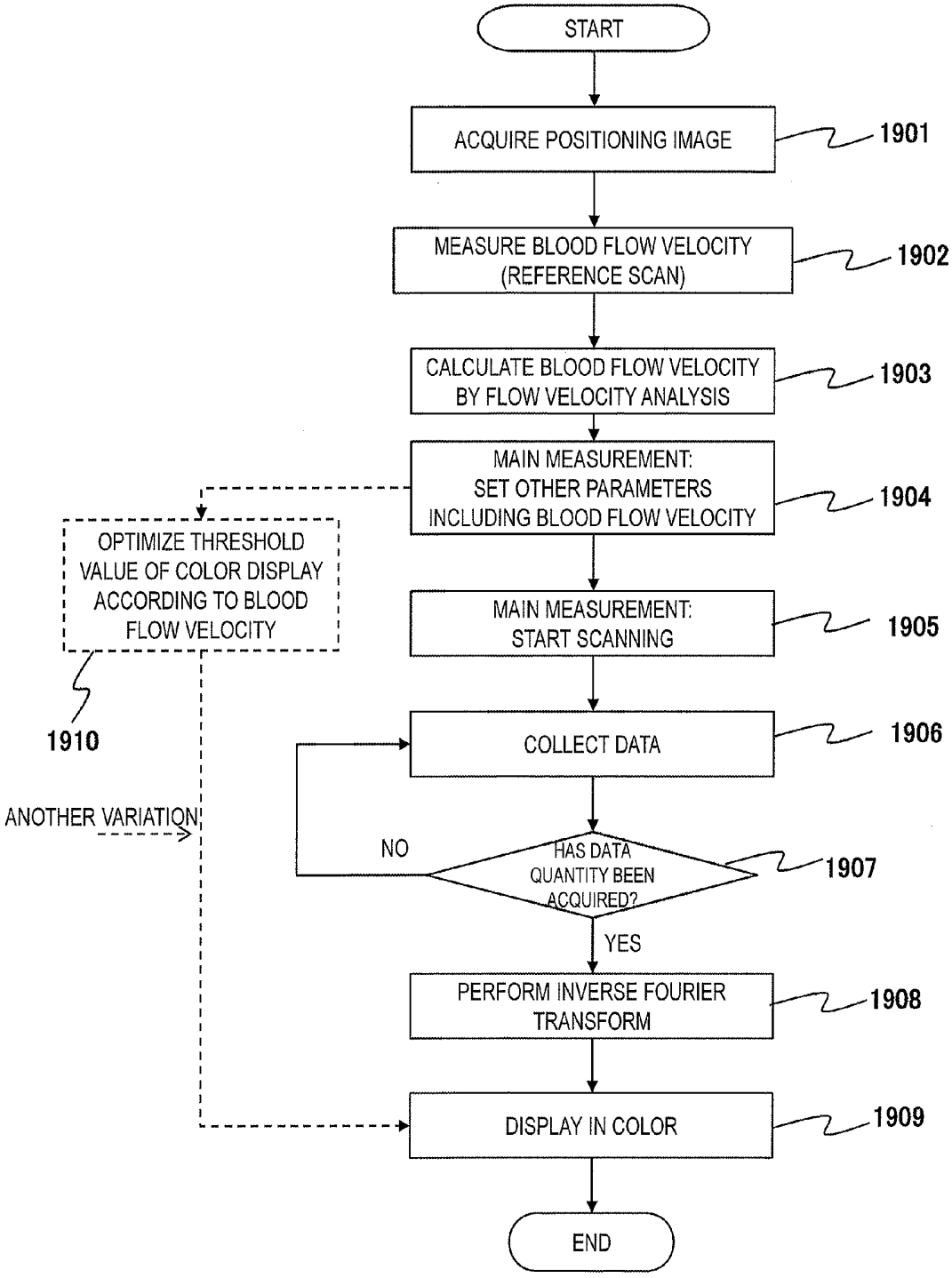
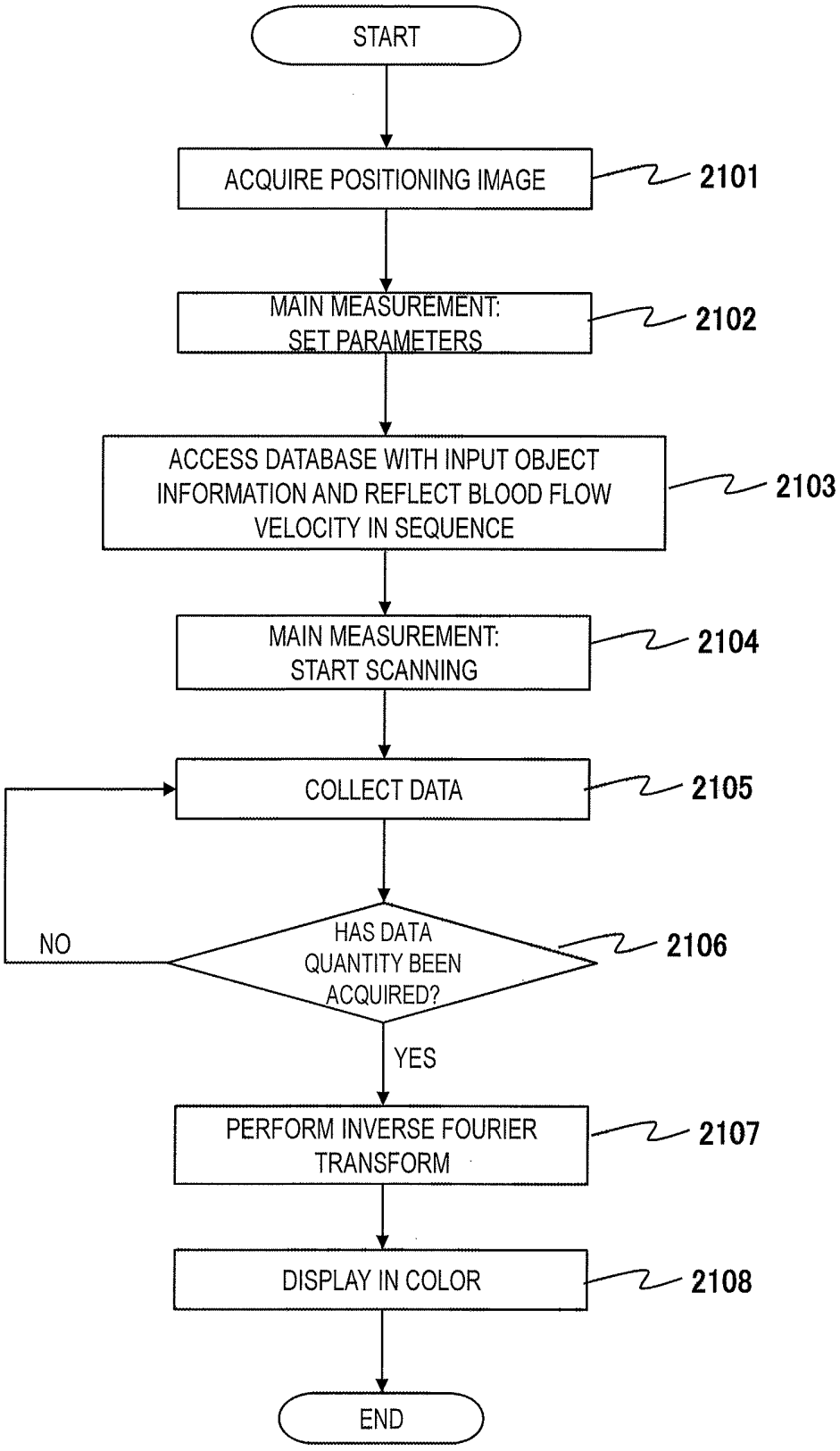

START
ACQUIRE POSITIONING IMAGE
1901
MEASURE BLOOD FLOW VELOCITY (REFERENCE SCAN)
1902
CALCULATE BLOOD FLOW VELOCITY BY FLOW VELOCITY ANALYSIS
1903
MAIN MEASUREMENT: SET OTHER PARAMETERS INCLUDING BLOOD FLOW VELOCITY
1904
OPTIMIZE THRESHOLD VALUE OF COLOR DISPLAY ACCORDING TO BLOOD FLOW VELOCITY
1910
ANOTHER VARIATION
MAIN MEASUREMENT: START SCANNING
1905
COLLECT DATA
1906
NO
HAS DATA QUANTITY BEEN ACQUIRED?
1907
YES
PERFORM INVERSE FOURIER TRANSFORM
1908
DISPLAY IN COLOR
1909
END

FIG.20

HEIGHT [CM]	AGE [YEAR]	WEIGHT [KG]	PULSE RATE	SEX	BLOOD FLOW VELOCITY	OPTIMAL PLD
LESS THAN 170 (170 OR MORE)	LESS THAN 30	LESS THAN 60	LESS THAN 75	MALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
				FEMALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
			75 OR MORE	MALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
				FEMALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
		60 OR MORE	LESS THAN 75	MALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
				FEMALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
			75 OR MORE	MALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
				FEMALE	LESS THAN 40	1700 (1500)
					40 OR MORE	1600 (1500)
	30 OR MORE	CLASSIFIED DEPENDING ON CASE SIMILARLY TO ABOVE				

FIG.21


START
ACQUIRE POSITIONING IMAGE
2101
MAIN MEASUREMENT: SET PARAMETERS
2102
ACCESS DATABASE WITH INPUT OBJECT INFORMATION AND REFLECT BLOOD FLOW VELOCITY IN SEQUENCE
2103
MAIN MEASUREMENT: START SCANNING
2104
COLLECT DATA
2105
HAS DATA QUANTITY BEEN ACQUIRED?
2106
NO
YES
PERFORM INVERSE FOURIER TRANSFORM
2107
DISPLAY IN COLOR
2108
END

MAGNETIC RESONANCE IMAGING APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a magnetic resonance imaging (hereinafter, referred to as "MRI") apparatus and, in particular, to an MRI apparatus that performs blood flow imaging.

BACKGROUND ART

[0002] An MRI apparatus is used for imaging to visualize a hemodynamic state with a difference between an image in which blood is labeled (a label image) and an image that is not labeled (a control image). In such imaging, blood vessel images and perfusion images can be acquired depending on the imaging timing. Thus acquired images are referred to as magnetic resonance (hereinafter, referred to as "MR") perfusion images. The perfusion means a blood flow passing through the capillary circulation of an organ or a tissue region.

[0003] One of the imaging methods for MR perfusion images is an Arterial Spin Labeling method (hereinafter, referred to as "ASL"). In ASL, non-contrast imaging can generate the MR perfusion images.

[0004] As an example of ASL, the methods described in Patent Literatures 1 to 3 are taken.

[0005] PTL 1 describes that one 360-degree adiabatic labeling pulse is applied in order to acquire a label image and that two 180-degree adiabatic control pulses are applied in order to acquire a control image. PTL 2 describes that hundreds of high-frequency magnetic field (hereinafter, referred to as "RE") pulses are applied in order to acquire a label or control image. PTL 3 discloses that two or three RF pulses are applied in order to acquire a label or control image.

CITATION LIST

Patent Literature

[0006] PTL 1: U.S. Patent Publication No. 5846197

[0007] PTL 2: U.S. Patent Publication No. 7545142

[0008] PTL 3: U.S. Patent Publication No. 6285900

SUMMARY OF INVENTION

Technical Problem

[0009] Although ASL has an advantage to be non-invasive because it does not use a contrast agent, there is a case where perfusion can be inaccurately evaluated in a hemodynamic visualization image acquired from ASL.

[0010] The causes of the above inaccurate evaluation are considered as follows.

[0011] 1) When blood protons are labelled and controlled using a plurality of pulses, the blood protons move, and application positions of the second and subsequent RF pulses are shifted, which makes labeling and controlling imperfect.

[0012] 2) A region of interest is imaged before the labeled and controlled blood protons are spread out in the region of interest or after the blood protons flow out of the region of interest.

[0013] 3) Longitudinal relaxation of the labelled protons proceeds before the protons spread are spread out in a region of interest after label processing, which results in reducing labeling effects.

[0014] 4) When a dynamic range of signal values is previously fixed during displaying a blood flow in a region of interest, the color display of hemodynamic images is inaccurate depending on the magnitude of an acquired signal value of a region of interest.

[0015] PTLs 1, 2, and 3 do not disclose the above problems as well as the solutions thereof.

[0016] The purpose of the present invention is to solve the above problems and reduce inaccuracy of a hemodynamic visualization image acquired from ASL. This acquires the hemodynamic visualization image in which an SNR (Signal-to-Noise Ratio) was improved or improves reliability of the hemodynamic visualization image displayed in color.

Solution to Problem

[0017] In order to achieve the above purpose, the present invention uses a blood flow velocity to control a hemodynamic imaging pulse sequence accompanying a blood flow labeling process and a threshold value of color display of a hemodynamic image.

[0018] Specifically, the MRI apparatus of the present invention is characterized by comprising a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; and a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence, that the pulse sequence includes sequences of applying a plurality of high-frequency pulses labeling blood flows (flowing bloods) and imaging the subsequent blood flows, and that the control unit uses a blood flow velocity to control application positions of one or more high-frequency pulses from among the plurality of high-frequency pulses.

[0019] Also, the MRI apparatus of the present invention is characterized by comprising a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; and a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence, that the pulse sequence includes sequences of applying a high-frequency pulse labeling a blood flow (flowing blood) and imaging the subsequent blood flow, and that the control unit uses a blood flow velocity to control time between labeling the blood flow and starting the imaging and/or application positions of a high-frequency pulse for labeling the blood flow.

[0020] Also, the MRI apparatus of the present invention is characterized by comprising a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence; and a display/operation unit displaying a blood flow visualization image, that the pulse sequence includes

sequences of applying a high-frequency pulse labeling a blood flow and imaging the subsequent blood flow, and that the display/operation unit is provided with a function of displaying in color based on a threshold value of signal strength of the blood flow visualization image to change the threshold value using a blood flow velocity.

Advantageous Effects of Invention

[0021] The present invention can reduce inaccuracy of hemodynamic visualization images acquired from ASL. This can acquire a hemodynamic image whose SNR was improved or improve reliability of the hemodynamic image displayed in color.

BRIEF DESCRIPTION OF DRAWINGS

[0022] FIG. **1** is a block diagram illustrating the overall configuration of an MRI apparatus to which the present invention is applied.

[0023] FIG. **2** is a schematic diagram of the procedure for displaying a hemodynamic image in color.

[0024] FIG. **3** is an explanatory diagram illustrating an example of a sequence used in a phase contrast method.

[0025] FIG. **4** is a graph of a blood flow velocity.

[0026] FIG. **5** is an explanatory diagram of an example of a labeling pulse or a control pulse.

[0027] FIG. **6** illustrates an example of main measurement to acquire a hemodynamic image.

[0028] FIG. **7** illustrates an example of a user interface.

[0029] FIG. **8** is a block diagram in which an entire control unit of a first embodiment is mainly illustrated.

[0030] FIG. **9** illustrates an example position of RF pulse application.

[0031] FIG. **10** illustrates a positional shift of RF pulse application caused by movement of blood protons.

[0032] FIG. **11** illustrates the procedure of the first embodiment.

[0033] FIG. **12** is a block diagram in which the entire control unit of second, third, and fifth embodiments is mainly illustrated.

[0034] FIG. **13** illustrates a relationship between a blood flow velocity and PLD.

[0035] FIG. **14** illustrates the procedure of the second embodiment.

[0036] FIG. **15** illustrates a relationship between a blood flow velocity and a label or control pulse application position.

[0037] FIG. **16** illustrates the procedure of the third embodiment.

[0038] FIG. **17** is a block diagram in which a display/operation unit of a fourth embodiment is mainly illustrated.

[0039] FIG. **18** illustrates examples of a blood flow velocity and a color bar.

[0040] FIG. **19** illustrates the procedure of the fourth embodiment.

[0041] FIG. **20** illustrates an example of a database.

[0042] FIG. **21** illustrates the procedure of the fifth embodiment.

DESCRIPTION OF EMBODIMENTS

[0043] Hereinafter, the embodiments of the present invention will be described referring to the diagrams. It is noted that the same reference signs are used for the same functions in all the diagrams for describing the embodiments of the present invention, and the repeated descriptions are omitted.

[0044] First, an example overview of an MRI apparatus to which the present invention is applied will be described based on FIG. **1**.

[0045] FIG. **1** is block diagram illustrating an overall configuration of one embodiment of the MRI apparatus related to the present invention. The MRI apparatus acquires tomographic images of an object **101** using a nuclear magnetic resonance (hereinafter, referred to as "NMR") phenomenon. As illustrated in FIG. **1**, the MRI apparatus comprises a static magnetic field generating magnet **102**, a gradient magnetic field coil **103** and a gradient magnetic field power source **109**, a transmission RF coil **104** and an RF transmission unit **110**, a reception RF coil **105** and a signal detection unit **106**, a signal processing unit **107**, a measurement control unit **111**, an entire control unit **108**, a display/operation unit **113**, and a bed **112** that places the object **101** to carry the object **101** in/from the inside of the static magnetic field generating magnet **102**.

[0046] The static magnetic field generating magnet **102** generates a homogeneous static magnetic field in each of an orthogonal direction to the body axis of the object **101** in case of the vertical magnetic field system and a body-axis direction in case of the horizontal magnetic field system, and a static magnetic field generation source of the permanent magnet system, the normal conduction system, or the superconducting system is disposed around the object **101**.

[0047] The gradient magnetic field coil **103** consists of gradient magnetic field coils of the three-axis directions X, Y, and Z, each of the gradient magnetic field coils is connected to the gradient magnetic field power source **109** to drive the coils, and the electric current is supplied. Specifically, the gradient magnetic field power source **109** of each of the gradient magnetic field coils is driven by the command from the measurement control unit **111** to be described later, and the electric current is supplied to each of the gradient magnetic field coils. This generates gradient magnetic fields Gx, Gy, and Gz in the three-axis directions X, Y, and Z. According to the way of applying the gradient magnetic fields, an imaging cross section of an object is determined in order to apply phase encoding and frequency encoding to signals.

[0048] When a two-dimensional slice plane is imaged, a slice gradient magnetic field pulse (Gs) is applied in a direction orthogonal to the slice plane (imaging cross section) to set a slice plane for the object **101**, and a phase encoding gradient magnetic field pulse (Gp) and a frequency encoding (lead-out) gradient magnetic field pulse (Gf) are applied in the remaining two directions orthogonal to the slice plane and orthogonal to each other to encode positional information in each direction for echo signals.

[0049] The transmission RF coil **104** is a coil irradiating RF pulses to the object **101** and is connected to the RF transmission unit **110** to supply a high-frequency pulse current. Hence, an NMR phenomenon is induced in atomic nucleus spin of atoms composing biological tissues of the object **101**. Specifically, the RF transmission unit **110** is driven by the command from the measurement control unit **111** to be described later, high-frequency pulses are amplitude-modulated and supplied to the transmission RF coil **104** disposed in the vicinity of the object **101** after amplification, and then RF pulses are irradiated to the object **101**.

[0050] The reception RF coil **105** is a coil receiving NMR signals (echo signals) to be emitted by the NMR phenomenon by the atomic nucleus spin of atoms composing biological tissues of the object **101** and is connected to the signal detection unit **106**. The signal detection unit **106** performs a detection process for the echo signals received by the reception RF coil **105**. Specifically, response echo signals of the object **101** induced by RF pulses irradiated from the transmission RF coil **104** are received by the reception RF coil **105** disposed in the vicinity of the object **101**, and the signal detection unit **106** amplifies the received echo signals according to the command from the measurement control unit **111** to be described later, divides the signals into orthogonal two-system signals with quadrature phase detection, respectively samples the two-system signals by the predetermined number (such as 128, 256, and 512), converts each of the sampled signals into a digital amount with A/D conversion, and then transmits the converted signals to the signal processing unit **107** to be described. Therefore, the echo signals are acquired as time-series digital data (hereinafter, referred to as echo data) consisting of the predetermined number of sampling data.

[0051] The signal processing unit **107** performs various processes on the echo data and transmits the processed echo data to the measurement control unit **111**.

[0052] The measurement control unit **111** mainly transmits various commands for data collection required to reconstruct tomographic images of the object **101** in order to control the gradient magnetic field power source **109**, the RF transmission unit **110**, and the signal detection unit **106**. Specifically, the measurement control unit **111** operates under control of the entire control unit **108** to be described later, controls the gradient magnetic field power source **109**, the RF transmission unit **110**, and the signal detection unit **106** based on a predetermined pulse sequence, repeatedly executes application of RF pulses and gradient magnetic field pulses to the object **101**and detection of echo signals from the object **101**, and then collects echo data required to reconstruct images of an imaging region of the object **101**.

[0053] As an example of a predetermined pulse sequence, given are pulse sequences for acquiring a blood flow velocity and MR perfusion images.

[0054] The entire control unit **108** controls the measurement control unit **111**, various data processes, display and storage of the process results, and the like and comprises a calculation processing section **114** including a CPU and a memory inside and a storage section **115** such as an optical disk and a magnetic disk. Specifically, the measurement control unit **111** is controlled in order to execute echo data collection. When the echo data is input from the measurement control unit **111**, the calculation processing section **114** stores the echo data in a region equivalent to k-space of the memory based on encoding information applied to the echo data. The echo data group stored in the region equivalent to k-space is referred to also as k-space data. Then, the calculation processing section **114** executes signal processing for the k-space data and processing such as image reconstruction by Fourier transform, displays images of the object **101** as the result on the display/operation unit **113** to be described later, and then records the images in the storage section **115**.

[0055] In the present description, the measurement control unit **111** and the entire control unit **108** are collectively referred to also as the control unit.

[0056] The display/operation unit **113** comprises a display unit displaying reconstructed images of the object **101** and an operation unit such as a trackball, a mouse, and a key board inputting various control information of the MRI apparatus and control information about processes to be performed by the above entire control unit **108**. The operation unit is disposed in the vicinity of the display unit and interactively controls various processes of the MRI apparatus through the operation unit while an operator is observing the display unit. The display unit has a color display function of a blood flow and can display images whose threshold values were changed for the color display.

[0057] Each part of the entire control unit **108** and each part of the display/operation unit **113** can consist of a CPU and a memory. In the memory, a program for executing each function is previously installed, and the CPU reads and executes the program in the memory. Consequently, operations of each part can be achieved. Although processing procedures of the entire control unit **108** and the display/operation unit **113** to be described later are described assuming that the processing procedures are realized as software, processes of the entire control unit **108** and the display/operation unit **113** can be realized by hardware such as ASIC and FPGA without limiting to the software in the present embodiments.

[0058] The MRI apparatus related to the present invention can be also provided with a body motion/electrocardiographic information detection unit that detects body motion/electrocardiographic information of an object as an external device. The body motion/electrocardiographic information detection unit comprises a sensor unit **116** that is mounted on the object **101** to detect the body motion/electrocardiographic information of the object and a body motion/electrocardiographic information processing unit **117** that processes signals from the sensor unit **116** and transmits the processed body motion/electrocardiographic information to the measurement control unit **111**. The sensor unit **116** is a sensor for respiratory waveform detection in a case where the body motion/electrocardiographic information detection unit detects a respiratory waveform of the object, and the sensor unit **116** is an electrocardiograph, a pulse rate meter, or the like in a case where the body motion/electrocardiographic information detection unit detects electrocardiographic information of the object. The measurement control unit **111** executes a pulse sequence by synchronizing with the body motion/electrocardiographic information of the object detected by the body motion/electrocardiographic information detection unit (synchronous imaging).

[0059] In FIG. **1**, the transmission RF coil **104** and the gradient magnetic field coil **103** on the transmission side are installed, for example, so as to be opposite to the object **101** in case of the vertical magnetic field system or so as to surround the object **101** in case of the horizontal magnetic field system in the static magnetic field space of the static magnetic field generating magnet **102** in which the object **101** is carried. The reception RF coil **105** on the reception side is also installed so as to be opposite to or so as to surround the object **101**.

[0060] Next, the operation procedure of the control unit will be mainly described based on the overall configuration of the above embodiment.

[0061] FIG. **2** illustrates the overview of the operation procedure of the present embodiments.

[0062] The control unit controls blood flow velocity measurement (reference scan) **201** for obtaining a blood flow velocity. The blood flow velocity obtained by the reference scan **201** is used for sequence control of main measurement **202** in the entire control unit **108** and color display **207** in the display/operation unit **113**.

[0063] For example, a pulse sequence of a PC (Phase Contrast) method excellent in blood flow velocity visualization can be used for the reference scan **201** for obtaining a blood flow velocity. FIG. **3** illustrates an example of a sequence diagram of the PC method using a flow encode pulse that provides a phase shift proportional to a blood flow velocity. FIG. **4** illustrates an example of a blood flow velocity graph acquired using the PC method. An average blood flow velocity of each object can be evaluated from the acquired blood flow velocity graph. Alternatively, in case of performing synchronous imaging, not the average blood flow velocity but a blood flow velocity at a desired Delay Time (delay time from the R wave) may be evaluated.

[0064] Not only the MRI apparatus but also the other devices can be used for the blood flow velocity measurement. A blood flow velocity may be obtained by storing general relationships between object information such as the height, age, weight, and sex of an object and the blood flow velocity in a database and accessing the database when a user inputs the object information instead of the blood flow velocity measurement.

[0065] Next, the control unit controls the main measurement **202** to acquire hemodynamic images. The main measurement **202** includes label processing **2021** and control processing **2024** as well as hemodynamic imaging **2022** and hemodynamic imaging **2025** to be performed after those processes. Although the hemodynamic images include both perfusion images and blood vessel images, the perfusion images will be mainly described as an example in the following description.

[0066] A known method capable of acquiring hemodynamic images in a non-contrast manner may be used for the main measurement **202**. An ASL (Arterial Spin Labeling) method is known as such a known method. Additionally, PASL (Pulsed Arterial Spin Labeling), CASL (Continuous Arterial Spin Labeling), pCASL (Pseudo-Continuous Arterial Spin Labeling), and the like are given as specific examples of the ASL method.

[0067] The label processing **2021** reverses the spin of a selected site, and the control processing **2024** makes longitudinal magnetization 0 degree of the spin of a selected site. One or more pulses of high-frequency pulses are applied in the label processing **2021** or the control processing **2024**. A known method may be used in the label processing **2021** or the control processing **2024**. A label/control RF pulse processing to be used in a known method capable of acquiring perfusion images in the above non-contrast manner is given as a known method.

[0068] FIG. **5** illustrates examples of RF pulses for the label processing **2021** and RF pulses for the control processing **2024**. FIG. **5**(*a*) illustrates examples of using two of 90-degree pulses as labeling RF pulses as well as using a 90-degree pulse and a −90-degree pulse as controlling RF pulse, and FIG. **5**(*b*) illustrates an example of using a 90-degree pulse, a 180-degree pulse, and a 90-degree pulse as the labeling RF pulses and a 90-degree pulse, a 180-degree pulse, and a −90-degree pulse as controlling RF pulses. Here, the 180-degree pulse is a pulse for re-focusing protons on which lateral magnetization was performed with the 90-degree pulse and phase dispersion was performed due to static magnetic field (B**0**) inhomogeneity (re-focusing pulse). It is noted that a flip angle and the number of applications of the RF pulses are not limited to the above.

[0069] A known imaging method capable of acquiring blood vessel images or perfusion images can be adopted for hemodynamic imaging **2022** or **2025**. The known imaging method includes a spin echo-type echo planer method (SE-EPI), a fast spin echo method (FSE), a gradient echo-type echo planer method (GE-EPI), and the like.

[0070] Referring to FIG. **6**, described is a relationship between the sites for the label processing **2021** and the control processing **2024** of FIG. **2** and the sites for both the hemodynamic imaging **2022** and **2025**. Although the label processing and the control processing are different, they are illustrated together in order to simplify the description in the diagram.

[0071] The site for performing the label processing **2021** or the control processing **2024** is set to a predetermined position on the upper flow side of a blood flow compared to a target site at which the hemodynamic imaging **2022** or **2025** is performed by considering a velocity of the blood flowing from the site to the target site at which the hemodynamic imaging **2022** or **2025** is performed and time distance **602**/space distance **603** between performing the label processing **2021** or the control processing **2024** and performing the hemodynamic imaging **2022** or **2025**.

[0072] Here, the time distance **602** is time between performing the label processing **2021** or the control processing **2024** and starting the hemodynamic imaging **2022** or **2025**. The space distance **603** is a distance between a position of the hemodynamic imaging **2022** or **2025** and a position for applying label/control processing RF pulses.

[0073] In case of performing label or control processing on a blood flow using a plurality of RF pulses, the time distance **602** may be time between first or last processing and starting imaging, and the space distance **603** may be a distance between a position of hemodynamic imaging and a first or last RF pulse application position.

[0074] The time distance **602** can be referred to as PLD (Post Label Delay). It is desired that imaging a region of interest is performed in time when label- or control-processed blood protons reach the region of interest, and the PLD is desirably time until the label- or control-processed blood is spread all over the region of interest. On the other hand, the PLD should be set shorter as possible so that longitudinal relaxation does not proceed because the longitudinal relaxation proceeds in a case where the PLD is too long. It is clinically desirable to perform imaging at a plurality of time distances (PLD) because optimal PLD differs depending on the object.

[0075] In the main measurement **202**, a site to perform the label processing **2021** is selected, a blood flow is labeled by applying RF pulses for labeling a blood flow, and then a pulse sequence for the hemodynamic imaging **2022** is executed by selecting a target site in a position separated by a predetermined time distance **602**/space distance **603** in order to acquire signals required for image reconstruction (**2023** of FIG. **2**).

[0076] Next, a site to perform the control processing **2024** is selected to apply RF pulses for control processing, the same target site is selected in a position separated by a predetermined time distance **602**/space distance **603**, and

then the same pulse sequence of the hemodynamic imaging **2025** is executed in order to acquire signals (**2026**). Images visualizing hemodynamics are acquired (**206**) by taking a difference between an image reconstructed from the signals acquired after the label processing (**204**) and an image reconstructed from the signals acquired after the control processing (**205**).

[0077] Either of the label processing **2021** or the control processing **2024** may be first performed, and signals required for image reconstruction may be finally acquired by alternately performing label processing to signal acquisition (**2021** to **2023**) and control processing to signal acquisition (**2024** to **2026**).

[0078] The acquired image, i.e. a perfusion image is displayed in color (**207**). The color display is performed by assigning colors to signal strength according to predetermined threshold values. A color bar is also displayed to indicate the threshold values of the color image display.

[0079] It is noted that scanning conditions and scan parameters required for main measurement can be input from a user interface (UI) as illustrated in FIG. **7** by a user. Information such as a blood flow velocity, PLD, a space distance (not illustrated in the diagram), and an application position of a high-frequency pulse (not illustrated in the diagram) for labeling/controlling is simultaneously input as needed.

[0080] As described above, referring to FIG. **2** and the like, the operational overview of the MRI apparatus of the present embodiments are described. The present embodiments reflect a result acquired in the blood flow velocity measurement **201** to the main measurement **202** and/or the color display **207** to be performed next and improve the accuracy to visualize perfusion, which can adopt several forms as utility forms of a blood flow velocity. Hereinafter, each embodiment having a different utility form will be described.

Embodiment 1

[0081] An MRI apparatus of Embodiment 1 is characterized by that a control unit uses a blood flow velocity in order to control application positions of high-frequency pulses after the second pulse of a plurality of the high-frequency pulses. In Embodiment 1, a blood flow velocity in a label or control region is acquired in the blood flow velocity measurement (reference scan) **201**. The sequence of the main measurement **202** is controlled using the acquired blood flow velocity in order to make the RF pulse application positions to track the blood flow in the label processing **2021** or the control processing **2024**. Specifically, the blood flow velocity is used for controlling RF pulse application positions after the second RF pulse labeling the blood flow.

[0082] FIG. **8** is a functional block diagram in which the entire control unit **108** of the present embodiment is mainly illustrated. In FIG. **8**, the same functions as FIG. **1** are indicated with the same reference signs, and the descriptions thereof are omitted.

[0083] As illustrated, the entire control unit **108** includes a label/control pulse tracking amount calculation section **1081** and a sequence adjustment section **1082**.

[0084] The label/control pulse tracking amount calculation section **1081** calculates a change amount (tracking amount) in label or control positions using a blood flow velocity in a label or control processing region as described later.

[0085] The sequence adjustment section **1082** adjusts a main measurement sequence based on the calculation result acquired by the label/control pulse tracking amount calculation section **1081**. Specifically, the sequence adjustment section **1082** adjusts at least either of a frequency or a gradient magnetic field application amount of RF pulses based on the acquired tracking amount in order to adjust application positions of the RF pulses.

[0086] A scan control section **1083** controls operations such as start and stop of scanning.

[0087] Described will be calculation to be performed by the label/control pulse tracking amount calculation section **1081**.

[0088] First, referring to FIGS. **9** and **10**, description will be made for a case where RF pulse application positions are shifted depending on the blood flow velocity. Here, as an example, described will be a case of using two RF pulses as labeling/controlling RF pulses.

[0089] The labeling RF pulses and the control processing RF pulses comprises the same number of multiple RF pulses, and the pulse intervals are set as short as possible in order to avoid B**0** inhomogeneity effects (refer to FIG. **5**).

[0090] However, even if the pulse intervals are short, the blood flow moves in the meantime. Therefore, in case of selecting the same site **901** and performing label/control processing like a conventional technique illustrated in FIG. **9**(*a*), labeling or controlling becomes incomplete because the label/control processing is not performed on the actually same blood.

[0091] Using FIG. **10**, the incompleteness of the label processing will be described specifically. FIG. **10** illustrates an example in case of using two 90-degree pulses as RF pulses. First, FIG. **10**(*a*) illustrates application of the first 90-degree RF pulse. **1001** of the diagram is a region selected by the RF pulse application.

[0092] Next, FIG. **10**(*b*) illustrates RF pulse application of the second 90-degree RF pulse after Δt hours. Because blood protons on the region **1001** move according to a blood flow velocity at this time, only a region **1003** is a region where spin is reversed (label-processed) by the second 90-degree RF pulse. It is noted that a region **1004** is a region on which the first RF pulse processing has been performed and the second RF pulse processing is not performed and that a region **1002** on which the first RF pulse processing is not performed and the second RF pulse processing has been performed on the other hand.

[0093] The present embodiment reduces the incompleteness label/control processing that depends on a blood flow speed by tracking a blood flow velocity to move a site on which label/control processing is performed.

[0094] FIG. **9**(*b*) indicates application positions of RF pulses for the label/control processing of the present embodiment. FIG. **9** illustrates an example of using two 90-degree pulses as the RF pulses for the label/control processing. In the diagram, H stands for Head, and F stands for Foot. The present embodiment allows an application position **903** of the second RF pulse to track a blood flow according to a blood flow velocity of each object after RF pulses of the label or control processing are applied in a position **902**.

[0095] Hence, the label/control pulse tracking amount calculation section **1081** calculates a label or control pulse tracking amount as follows.

[0096] V_{ave} stands for an average value of the blood flow velocity evaluated by the reference scan, and Interval stands for an RF pulse interval as follows.

$$\Delta d = V_{ave} \times \text{Interval} \quad \text{[Equation 1]}$$

[0097] The tracking amount Δd is calculated using the above equation.

[0098] In a case where the label/control RF pulses comprise three or more pulses (n pulses), an application position tracking amount may be calculated by Δd in the last RF pulse application position or may be calculated using the following equation in the first RF pulse application position.

$$\Delta di = V_{ave} \times \text{Interval} \times (i-1)_{i=3,4,\ldots n} \quad \text{[Equation 2]}$$

[0099] In a case where the label/control RF pulses comprise n pulses, application positions are tracked by m pulses (n>=m) according to a blood flow velocity and a label thickness, and it is configured that tracking from the first to m-th pulses is repeated.

[0100] A tracking amount may be also calculated from a blood flow velocity in desired Delay Time (delay time from the R-wave) in case of synchronous imaging.

[0101] The procedure for the MRI apparatus and the control unit of the present embodiment will be described using FIG. **11**.

[0102] A positioning image is imaged in order to set an imaging position (Step **1101**).

[0103] Using the positioning image imaged in Step **1101**, blood flow velocity measurement (reference scan) is performed on a region specified by an operator (Step **1102**).

[0104] A blood flow velocity graph is evaluated by a flow velocity analysis based on data acquired the reference scan in order to calculate a blood flow velocity (Step **1103**).

[0105] A display/operation unit **113** is used for setting scan parameters input for main measurement. At this time, the blood flow velocity evaluated in Step **1103** is also input as a scan parameter (Step **1104**).

[0106] The label/control pulse tracking amount calculation section **1081** calculates a tracking amount of label or control pulses according to the equation (1) or (2) using the input blood flow velocity. The sequence adjustment section **1082** adjusts a sequence based on the calculation result (Step **1105**).

[0107] Inputting the start button starts scanning for main measurement (Step **1106**). That is, performed are label processing **2021**, hemodynamic imaging **2022**, control processing **2024**, hemodynamic imaging **2025**, and the like of FIG. **2**.

[0108] The measurement control unit **111** collects data (Step **1107**).

[0109] The measurement control unit **111** judges whether or not a predetermined amount of data determined by parameters set by an operator in Step **1104** has been acquired and proceeds to Step **1107** in a case where the acquisition has not been completed or proceeds to Step **1109** in a case where the acquisition has been completed (Step **1108**).

[0110] The calculation processing section **114** reconstructs two-dimensional or three-dimensional images by performing a Fourier transform on k-space data (Step **1109**).

[0111] As illustrated in the dashed-line arrow of FIG. **11** as a variation example, it may be configured so that a tracking amount is automatically reflected to a sequence when a blood flow velocity is calculated in Step **1103** in order to start main measurement of Step **1106** (Step **1110**).

[0112] The present embodiment reflects a blood flow velocity to the main measurement sequence and makes RF pulse application positions for performing label or control processing track a blood flow, which can perform the label or control processing on the blood flow more efficiently than conventional methods. Consequently, highly reliable hemodynamic images in which the SNR was improved can be acquired.

Embodiment 2

[0113] An MRI apparatus of Embodiment 2 is characterized by that the control unit controls time from labeling a blood flow to starting imaging using a blood flow velocity. That is, although Embodiment 1 makes RF pulse application positions for performing label or control processing track a blood flow, Embodiment 2 differently uses the blood flow velocity for adjusting time from label/control processing to starting imaging (PLD) in main measurement. It is noted that the blood flow velocity includes a blood flow velocity from a label or control processing region to an imaging region but is not limited to this.

[0114] In a case where a distance from an imaging position to a position to which label or control RF pulses are applied is fixed, for example, it takes a longer time to reach a region of interest than a case of a high blood flow velocity in case of a low blood flow velocity.

[0115] It is clinically desirable to perform imaging at a plurality of time distances (PLDs) because time until labeled or controlled blood protons to reach a region of interest differs depending on the object. On the other hand, imaging at the plurality of PLDs results in extending imaging time, and there are some cases where such imaging is not accepted in the view point of examination time.

[0116] The present embodiment performs imaging at a PLD suitable for an object using a blood flow velocity obtained by a reference scan in order to acquire highly reliable hemodynamic images by performing imaging only once. That is, the start of imaging a blood flow is controlled by using the blood flow velocity to adjust the PLDs. It is noted that the PLD is time from applying the last RF pulse from among a plurality of label or control RF pulses to starting imaging in the present embodiment.

[0117] FIG. **12** is a functional block diagram in which the entire control unit **108** of the present embodiment is mainly illustrated. In FIG. **12**, the same functions as FIG. **1** are indicated with the same reference signs, and the descriptions thereof are omitted. The entire control unit **108** is characterized by comprising a database **1084** and the sequence adjustment section **1082**.

[0118] The entire control unit **108** accesses the database **1084** to acquire a PLD suitable for a blood flow velocity obtained a reference scan.

[0119] The database **1084** includes data of a relationship between a blood flow velocity and a PLD in the brain based on a standard model of humans. The equation (3) shows an example of the relationship between a blood flow velocity and a PLD.

$$PLD_A = \frac{d1}{V_{ave1}} + \frac{d2}{\sin\theta \times V_{ave2}} + \alpha \quad \text{[Equation 3]}$$

[0120] As illustrated to FIG. **13**, the equation (3) represents time until labeled or controlled blood reaches the point A in an imaging slice. However, FIG. **13** simplifies blood vessel running in the brain for easy understanding. In the diagram, V_{ave1} is an average blood flow velocity until the blood reaches a branch point of the blood vessel, V_{ave2} is an average blood flow velocity from the branch point of the blood vessel to A in the imaging slice, d**1** is a distance from an application position of a label or control RF pulse to the branch point, and d**2** is a distance from the branch point to A in the imaging slice. θ is a branching angle. Also, a indicates a fluctuation of each living body until perfusion signals are shown after labeled blood reaches a perfusion region. Equation (3) and FIG. **13** shows that a suitable PLD and a blood flow velocity are closely related to each other.

[0121] Such a relationship between the suitable PLD and the blood flow velocity is stored in the database **1084**.

[0122] The sequence adjustment section **1082** reflects a suitable PLD acquired from the above relational equation between the PLD and the blood flow velocity to a sequence.

[0123] The scan control section **1083** controls operations such as start and stop of scanning.

[0124] The procedure for the MRI apparatus and the control unit of the present embodiment will be described using FIG. **14**.

[0125] A positioning image for setting a imaging position is imaged (Step **1401**).

[0126] Using the positioning image imaged in Step **1401**, the blood flow velocity measurement (reference scan) is performed on a region specified by an operator (Step **1402**).

[0127] A blood flow velocity graph is evaluated by the flow velocity analysis based on data acquired the reference scan in order to calculate a blood flow velocity (Step **1403**).

[0128] The display/operation unit **113** is used for setting scan parameters input for main measurement. At this time, the blood flow velocity evaluated in Step **1403** is also input as a scan parameter (Step **1404**).

[0129] The entire control unit **108** accesses the database **1084** to acquire a PLD suitable for the input blood flow velocity. The sequence adjustment section **1082** reflects the suitable PLD to a sequence (Step **1405**).

[0130] Pressing the start button starts scanning for main measurement (Step **1406**). That is, performed are the label processing **2021**, the hemodynamic imaging **2022**, the control processing **2024**, the hemodynamic imaging **2025**, and the like of FIG. **2**.

[0131] The measurement control unit **111** collects data (Step **1407**).

[0132] The measurement control unit **111** judges whether or not a predetermined amount of data determined by parameters set by an operator in Step **1404** has been acquired and proceeds to Step **1407** in a case where the acquisition has not been completed or proceeds to Step **1409** in a case where the acquisition has been completed (Step **1408**).

[0133] The calculation processing section **114** reconstructs two-dimensional or three-dimensional images by performing a Fourier transform on k-space data (Step **1409**).

[0134] As illustrated in the dashed-line arrow of FIG. **14** as a variation example, it may be configured so that a suitable PLD is automatically reflected to a sequence when a blood flow velocity is calculated in Step **1403** in order to start the scanning for main measurement of Step **1406** (Step **1410**).

[0135] The present embodiment performs imaging at a PLD suitable for each object using a blood flow velocity of the object, which can acquire highly reliable hemodynamic images without being affected by the blood flow velocity by performing imaging only once.

Embodiment 3

[0136] An MRI apparatus of Embodiment 3 is characterized a control unit uses a blood flow velocity in order to control application positions of high-frequency pulses for labeling a blood flow. That is, although Embodiment 2 is a case of changing a PLD according to the blood flow velocity, Embodiment 3 uses the blood flow velocity in order to adjust application positions of label or control processing RF pulses (the space distance **603** of FIG. **6**) differently from Embodiment 2.

[0137] It is noted that the blood flow velocity includes a blood flow velocity from a label or control processing region to an imaging region but is not limited to this.

[0138] In a case where the PLD is too long, longitudinal relaxation of label-processed blood protons proceeds, which results in reducing labeling effects. On the other hand, in case of setting the PLD shorter in light of the longitudinal relaxation, there can be a case where blood protons with a low flow velocity have not reached a region of interest.

[0139] The present invention performs imaging at an optimal space distance using a blood flow velocity obtained by a reference scan, which acquires highly reliable hemodynamic images in which the SNR was improved without prolonging a PLD (by preventing labeling effect reduction due to longitudinal relaxation).

[0140] Specifically, the blood flow velocity obtained by a reference scan is used for controlling positions to which label or control RF pulses are applied (hereinafter, referred to as "label or control positions").

[0141] FIG. **12** is a functional block diagram in which the entire control unit **108** of the present embodiment is mainly illustrated. In FIG. **12**, the same functions as FIG. **1** are indicated with the same reference signs, and the descriptions thereof are omitted. The entire control unit **108** is characterized by including the database **1084** and the sequence adjustment section **1082**.

[0142] The database **1084** includes data related to a relationship between a blood flow velocity and optimal label or control positions based on a standard model of humans. Equations (4) and (5) show examples of relationships between the blood flow velocity and the optimal label or control positions. It is noted that a described in Equations (4) and (5) is similar to a described in Equation (3).

$$PLD1000\ [\mathrm{ms}] = \frac{d1}{V_{ave1}} + \frac{d2}{\sin\theta \times V_{ave2}} + \alpha \qquad \text{[Equation 4]}$$

$$PLD1000\ [\mathrm{ms}] = \frac{d1'}{V'_{ave1}} + \frac{d2'}{\sin\theta' \times V'_{ave2}} + \alpha \qquad \text{[Equation 5]}$$

[0143] Although both of Equations (4) and (5) represent relationships between a blood flow velocity and optimal label or control positions in case of performing imaging at a predetermined PLD1000ms, different are objects and average blood flow velocities V_{ave1} and V_{ave2} to a branch point of a blood vessel. Therefore, a difference occurs between distances d**1** and d**1'** from application positions of label or

control RF pulses optimal for a set PLD to the branch point as illustrated in FIGS. **15**(*a*) and **15**(*b*) (in which blood vessel running in the brain is simplified for easy understanding). There can be a difference between distances d**2** and d**2'** from the branch point to the point A in the imaging slice and between the branching angles θ. FIG. **16**(*a*) represents Equation (4), and FIG. **16**(*b*) represents Equation (5).

[0144] In other words, the optimal label or control positions are different depending on in case of performing imaging at a certain PLD set by a user (refer to the label positions A and B). The database **1084** stores such a relationship between a blood flow velocity and optimal label or control positions.

[0145] The sequence adjustment section **1082** adjusts application positions of RF pulses based on the optimal label or control positions acquired from the database **1084**.

[0146] The scan control section **1083** performs control similarly to the description of Embodiment 2.

[0147] FIG. **16** illustrates operations the MRI apparatus and the control unit of the present embodiment.

[0148] Steps **1601** to **1604** are similar to Steps **1401** to **1404** of Embodiment 2.

[0149] In Step **1605**, the entire control unit **108** accesses the database **1084** in order to acquire label or control positions optimal for an input blood flow velocity, and the sequence adjustment section **1082** reflects the optimal label or control positions to a sequence.

[0150] Steps **1606** to **1609** are similar to Steps **1406** to **1409** of Embodiment 2.

[0151] As a variation example illustrated in the dashed-line arrow of FIG. **16**, it may be configured so that optimal label or control positions are automatically reflected to a sequence when a blood flow velocity is calculated in Step **1603** (Step **1610**).

[0152] The present invention adjusts application positions of label or control pulses using a blood flow velocity, which can acquire highly reliable hemodynamic images in which the SNR was improved without being affected by the blood flow velocity at a PLD set by a user.

[0153] Although the case where either of the time distance or the space distance is adjusted is described in Embodiments 2 and 3, Embodiments 2 and 3 may be combined. That is, a PLD and application positions of label or control pulses may be controlled so as to spread out label- or control-processed blood protons in the entire region of interest and prevent longitudinal relaxation of the label- or control-processed blood protons from proceeding as possible.

Embodiment 4

[0154] An MRI apparatus of Embodiment 4 is characterized by that a display/operation unit includes a function of displaying in color based on a threshold value of signal strength of a blood flow visualization image and changes the threshold value using a blood flow velocity. That is, Embodiment 4 uses the blood flow velocity as the threshold value for the color image display when an image of a region of interest is displayed (refer to the color display **207** of FIG. **2**). It is noted that the blood flow velocity includes a blood flow velocity from a label or control processing region to an imaging region but is not limited to this.

[0155] Time until label- or control-processed blood reaches a region of interest varies depending on the object. Therefore, in case of performing imaging at the same PLD, a signal value of a result image varies depending on the object.

[0156] In case of displaying such a result image in color, the color display is generally performed based on a correspondence table (LUT) between signal values and colors (for example, a red color is changed to a blue one), and a color bar indicating the correspondence between the signal values and the colors is displayed together with an image to which the colors were assigned. For example, the color becomes red as the signal value increases, and the color becomes blue as the signal value decreases.

[0157] As described above, because the signal value varies depending on the blood flow velocity, whether or not there are many areas in an ischemia state and whether or not there are many areas displayed in blue due to the blood flow velocity cannot be determined in a case where a dynamic range (a threshold value of the signal value) to which a color is assigned, for example, when there are many areas in which the signal value is low (areas displayed in blue), which results in reducing an ability of perfusion visualization.

[0158] The present embodiment changes a threshold value of a signal value according to the blood flow velocity in order to improve the ability of perfusion visualization without depending on the blood flow velocity. Specifically, the blood flow velocity is used for optimizing color image display of a result image for each object. For example, the threshold value is reduced in a case where the blood flow velocity is low (the signal value is relatively low), and the threshold value is increased in a case where the blood flow velocity is high (the signal value is relatively high).

[0159] FIG. **17** is a functional block diagram in which the display/operation unit **113** of the present embodiment is mainly illustrated. The display/operation unit **113** includes an operation section **1131**, a color display threshold value change section **1133**, and a display section **1132**. A measured blood flow velocity is input through the operation section **1131**. The color display threshold value change section **1133** optimizes and sets a threshold value of a color bar based on the input blood flow velocity.

[0160] FIG. **18** shows an example of changing a threshold value according to the blood flow velocity. FIGS. **18**(*a*) and **18**(*b*) illustrates color bars in cases of the blood flow velocity 30 cm/s and lk 50 cm/s respectively, and the scales displayed on the color bars indicates signals values, in which red and blue areas are assigned to the upper and lower sides respectively.

[0161] For example, in a case where there are many areas displayed in blue because a blood flow velocity is low (30 cm/s) and the signal value is low, the upper limit value and the lower limit value of the signal value are set to 8,000 and 1,500 respectively in FIG. **18**(*a*). By thus narrowing a dynamic range, a perfusion image can be displayed not only in the blue area but also in the red area even if signal strength is small. In other words, signal strength variation can be visualized in a more satisfactory manner.

[0162] On the other hand, for example, in a case where the signal value exceeds the color bar because the blood flow velocity is high (50 cm/s) and the signal value is high, the upper limit value and the lower limit value of the signal value are set to 11,000 and 1,500 respectively. By thus expanding the dynamic range, a perfusion image can be visualized more accurately in the color bar.

[0163] The display section **1132** displays hemodynamic images based on the set threshold value of the color bar.

[0164] Processing procedures of the MRI apparatus, the control unit, and the display/operation unit of the present embodiment will be described using FIG. **19**.

[0165] A positioning image for setting an imaging position is imaged (Step **1901**).

[0166] Using the positioning image imaged in Step **1901**, blood flow velocity measurement (reference scan) is performed on a region specified by an operator (Step **1902**).

[0167] Based on the data acquired by the reference scan, a blood flow velocity graph is evaluated by the flow velocity analysis in order to calculate a blood flow velocity (Step **1903**).

[0168] Set are scan parameters for main measurement input through the display/operation unit **113**. At this time, the blood flow velocity evaluated in Step **1903** is also input as a scan parameter (Step **1904**).

[0169] Pressing the start button starts scanning for main measurement (Step **1905**). That is, performed are the label processing **2021**, the hemodynamic imaging **2022**, the control processing **2024**, the hemodynamic imaging **2025**, and the like of FIG. **2**.

[0170] The measurement control unit **111** collects data (Step **1906**).

[0171] The measurement control unit **111** judges whether or not an amount of data set by an operator in Step **1904** has been acquired and proceeds to Step **19006** in a case where the acquisition has not been completed or proceeds to Step **1908** in a case where the acquisition has been completed (Step **1907**).

[0172] The calculation processing section **114** reconstructs two-dimensional or three-dimensional images by performing a Fourier transform on k-space data (Step **1908**).

[0173] When the display/operation unit **113** displays a reconstructed image in color, the color display threshold value change section **1133** sets an optimal threshold value according to the blood flow velocity calculated in Step **1903** (Step **1910**). Then, the display section **1132** performs color display using the threshold value (Step **1909**).

[0174] It may be configured the optimal threshold value for color display is automatically reflected when the blood flow velocity is calculated in Step **1903** (not illustrated in the diagram).

[0175] The present embodiment can improve the reliability of the hemodynamic images displayed in color by changing a threshold value for the color display using the blood flow velocity.

[0176] Each the above-described Embodiments 1 to 4 may be performed alone, or one or more embodiments selected from Embodiments 1 to 4 may be combined and performed. In particular, it is desirable to combine Embodiments 1 and 4 in a case where Embodiments 2 and 3 are not performed.

Embodiment 5

[0177] Although a blood flow velocity is acquired from the reference scan in Embodiments 1 to 4 (refer to **201** of FIG. **2**), Embodiment 5 describes that it can be applied also to a case where the blood flow velocity is acquired from a database.

[0178] That is, an MRI apparatus of Embodiment 5 is characterized by that a control unit acquires a blood flow velocity by accessing the database that retains the standard blood flow velocity information. Although the step of the reference scan is not necessary in Embodiment 5, main measurement for acquiring hemodynamic images is similar to Embodiments 1 to 4.

[0179] FIG. **12** is a functional block diagram in which the entire control unit **108** of the present embodiment is mainly illustrated. In FIG. **12**, the same functions as FIG. **1** are indicated with the same reference signs, and the descriptions thereof are omitted. The entire control unit **108** is characterized by including the database **1084** and the sequence adjustment section **1082**.

[0180] The database **1084** retains a general relationship between the height, age, weight, sex, pulse rate, and blood flow velocity of an object. An example of the database is indicated in FIG. **20**. The information indicated in FIG. **20** is just an example, and more detailed information may be listed.

[0181] The entire control unit **108** accesses the database **1084** in order to acquire a blood flow velocity corresponding to object information input in the display/operation unit **113**. The sequence adjustment section **1082** uses the acquired blood flow velocity in order to adjust a sequence as described in Embodiments 1 to 3. Although not illustrated in the diagram, the acquired blood flow velocity may be used for changing a threshold value for color display of Embodiment 4.

[0182] Processing procedures of the MRI apparatus, the control unit, and the display/operation unit of the present embodiment will be described using FIG. **21**.

[0183] A positioning image for setting an imaging position is imaged (Step **2101**).

[0184] Set are scan parameters for main measurement (Step **2102**).

[0185] The entire control unit **108** accesses the database **1084** in order to acquire a blood flow velocity corresponding to the input object information. The sequence adjustment section **1082** uses the acquired blood flow velocity in order to adjust a sequence as described in Embodiments 1 to 3 (Step **2103**).

[0186] Steps **2104** to **2107** are similar to those of Embodiments 1 to 4.

[0187] The color display in Step **2108** is similar to the color display **207** and can be processed similarly to Embodiment 4.

[0188] The same effect as Embodiments 1 to 4 can be acquired also in case of acquiring a blood flow velocity from a database in the present embodiment.

[0189] As described in each embodiment of the present invention, the present invention can be applied to any of two-dimensional and three-dimensional imaging methods in case of the acquisition method for non-contrast MR perfusion images, and a known pulse sequence may be adopted, including a spin echo-type echo planer method (SE-EPI), a fast spin echo method (FSE), a gradient echo-type echo planer method (GE-EPI), and the like.

[0190] The present invention can be applied to not only the head but also the entire body including the heart, kidney, liver, arms, and legs.

[0191] As described above in several embodiments of the present invention, the present invention can reduce the inaccuracy of non-contrast perfusion images, which can acquire hemodynamic images whose SNR is stably high. The reliability of hemodynamic images displayed in color can be also improved.

REFERENCE SIGNS LIST

[0192] **102**: static magnetic field generating magnet, **103**: gradient magnetic field coil, **109**: gradient magnetic field power source, **104**: transmission RF coil, **110**: RF transmission unit, **105**: reception RF coil, **106**: signal detection unit, **111**: measurement control unit (control unit), **108**: entire control unit (control unit), **113**: display/operation unit

1. A magnetic resonance imaging apparatus comprising:

a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; and a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence,

wherein the pulse sequence includes sequences of applying a plurality of high-frequency pulses labeling a blood flow and imaging the blood flow, and

the control unit uses a blood flow velocity to control application positions of one or more high-frequency pulses from among the plurality of high-frequency pulses.

2. The magnetic resonance imaging apparatus according to claim **1**,

wherein the control unit is provided with a label/control pulse tracking amount calculation section that calculates a correction amount of application positions of the second and subsequent high-frequency pulses compared with an application position of the first high-frequency pulse.

3. The magnetic resonance imaging apparatus according to claim **2**,

wherein the control unit adjusts at least either of a frequency of high-frequency pulses or a gradient magnetic field application amount to control application positions of the second and subsequent high-frequency pulses.

4. The magnetic resonance imaging apparatus according to claim **1**,

wherein the control unit further controls time between labeling the blood flow and starting the imaging and/or the application positions of high-frequency pulses for labeling the blood flow.

5. The magnetic resonance imaging apparatus according to claim **4**,

wherein the time is between applying the last high-frequency pulse from among the plurality of high-frequency pulses and starting the imaging.

6. The magnetic resonance imaging apparatus according to claim **1**, further comprising:

a display/operation unit that displays a blood flow visualization image in color based on a threshold value of the signal strength thereof,

wherein the display/operation unit changes the threshold value using a blood flow velocity.

7. The magnetic resonance imaging apparatus according to claim **1**,

wherein the control unit performs measurement using a phase contrast method or accesses a database that retains standard blood flow velocity information in order to acquire the blood flow velocity.

8. The magnetic resonance imaging apparatus according to claim **1**, further comprising:

the display/operation unit that displays a blood flow visualization image,

wherein the display/operation unit displays at least any of the blood flow velocity, the time between labeling the blood flow and starting the imaging, and the application positions of high-frequency pulses for labeling the blood flow.

9. The magnetic resonance imaging apparatus according to claim **1**,

wherein the pulse sequence is selected from a group comprising PASL (Pulsed Arterial Spin Labeling), CASL (Continuous Arterial Spin Labeling), and pCASL (Pseudo-Continuous Arterial Spin Labeling).

10. A magnetic resonance imaging apparatus comprising:

a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; and a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence,

wherein the pulse sequence includes sequences of applying high-frequency pulses labeling a blood flow and imaging the blood flow, and

the control unit uses a blood flow velocity to control time between labeling the blood flow and starting the imaging and/or the application positions of high-frequency pulses for labeling the blood flow.

11. A magnetic resonance imaging apparatus comprising:

a static magnetic field generating magnet; a high-frequency magnetic field generation unit; a gradient magnetic field generation unit; a reception unit that receives nuclear magnetic resonance signals; a control unit that controls the high-frequency magnetic field generation unit; the gradient magnetic field generation unit; and the reception unit according to a predetermined pulse sequence, and a display/operation unit that displays a blood flow visualization image,

wherein the pulse sequence includes sequences of applying high-frequency pulses labeling a blood flow and imaging the blood flow, and

the display/operation unit is provided with a function of displaying in color based on a threshold value of signal strength of the blood flow visualization image to change the threshold value using a blood flow velocity.

12. The magnetic resonance imaging apparatus according to claim **11**,

wherein the display/operation unit further displays at least one of the blood flow velocity, the time between labeling the blood flow and starting the imaging, and the application positions of high-frequency pulses for labeling the blood flow.

* * * * *

专利名称(译)	磁共振成像设备		
公开(公告)号	US20170196475A1	公开(公告)日	2017-07-13
申请号	US15/326263	申请日	2015-07-28
[标]申请(专利权)人(译)	株式会社日立制作所		
申请(专利权)人(译)	HITACHI，LTD.		
当前申请(专利权)人(译)	HITACHI，LTD.		
[标]发明人	YOSHIZAWA NOBUYUKI		
发明人	YOSHIZAWA, NOBUYUKI		
IPC分类号	A61B5/055 A61B5/00 G01R33/563 A61B5/026		
CPC分类号	A61B5/055 G01R33/56366 A61B5/742 A61B5/026 A61B5/0263 G01R33/56554		
优先权	2014162909 2014-08-08 JP		
外部链接	Espacenet USPTO		

摘要(译)

为了减少在血流可视化成像之前标记血流时获取的血液动力学可视化图像的不准确性，MRI设备使用血流速度来控制脉冲序列，该脉冲序列包括应用高频脉冲以标记血流的序列。并对随后的血流或血液动力学可视化图像的显示进行成像。例如，血流速度用于控制多个高频脉冲中的一个或多个高频脉冲的施加位置以进行标记。MRI设备控制标记血流和开始成像之间的时间和/或用于标记血流的高频脉冲的施加位置。控制血流可视化图像的颜色显示的阈值。