(54) **MAGNETIC RESONANCE SIGNAL ACQUIRING METHOD AND APPARATUS, RECORDING MEDIUM AND MAGNETIC RESONANCE IMAGING APPARATUS**

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(57)   **ABSTRACT**

For the purpose of increasing the time available for performing a calculation on a navigator echo, the sampling frequency for a navigator echo is made higher than the sampling frequency for an imaging echo, or the number of sampling points for the navigator echo is made fewer than the number of sampling points for the imaging echo, or both measures are implemented in combination.
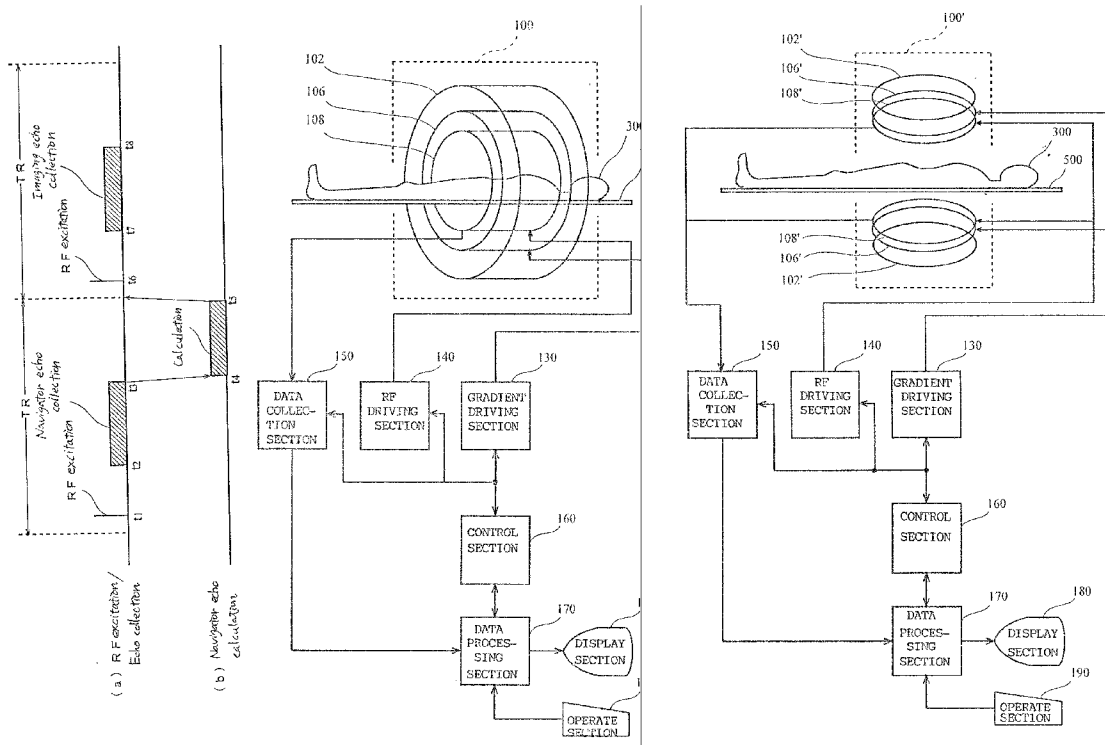
FIG. 1
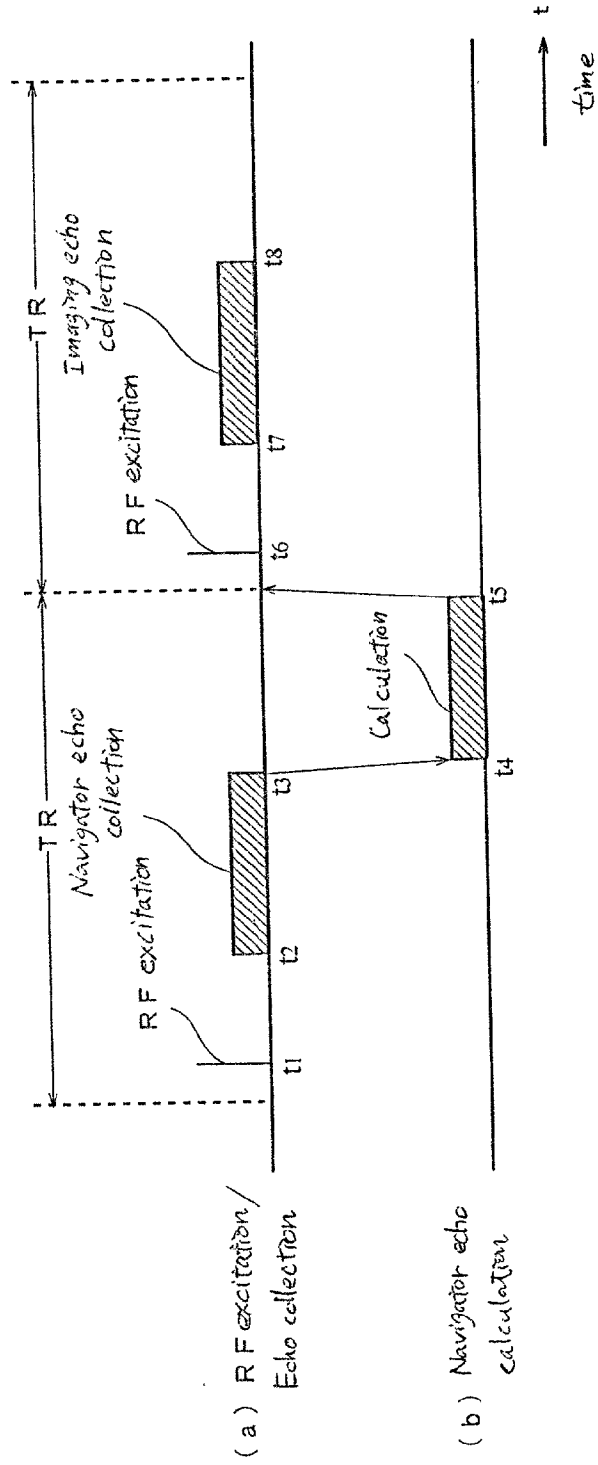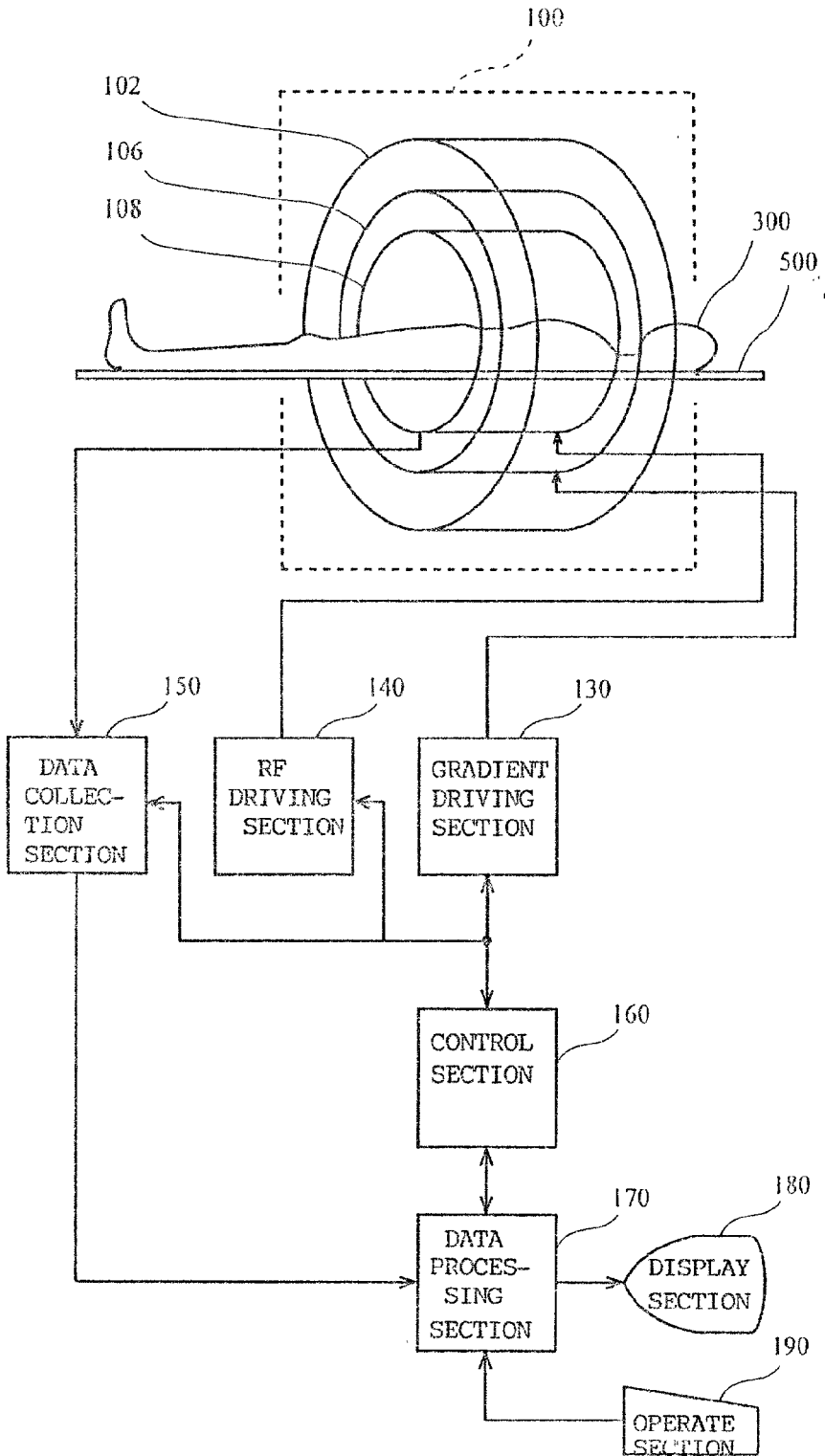
(a) RF excitation / Echo collection

RF excitation — t1

Navigator echo collection — t2, t3

RF excitation — t6

Imaging echo collection — t7, t8

TR

TR

(b) Navigator echo calculation

Calculation — t4, t5

time

t

FIG. 2

FIG. 3

time
→ t

Grc

α°

FIG. 4A   RF

FIG. 4B   Gs

FIG. 4C   Gr

FIG. 4D   Gp

FIG. 4E   MR

TE

FIG. 5A RF

FIG. 5B Gs

FIG. 5C Gr

FIG. 5D Gp

FIG. 5E MR

FIG. 6

(a) R F excitation/
Echo collection

R F excitation

Navigator echo
collection

TR

R F excitation

Imaging echo
collection

TR

t1   t2   t3   t4   t5   t6   t7   t8

(b) Navigator echo
calculation

Calculation

MAGNETIC RESONANCE SIGNAL ACQUIRING METHOD AND APPARATUS, RECORDING MEDIUM AND MAGNETIC RESONANCE IMAGING APPARATUS

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a magnetic resonance signal acquiring method and apparatus, a recording medium and a magnetic resonance imaging apparatus, and more particularly to a magnetic resonance signal acquiring method and apparatus for effecting RF (radio frequency) excitation on spins within an object and acquiring a navigator echo and an imaging echo, a recording medium recorded with a program for causing a computer to perform such a magnetic resonance signal acquiring function, and a magnetic resonance imaging apparatus comprising such magnetic resonance signal acquiring means.

[0002] In a magnetic resonance imaging (MRI) apparatus, an object to be imaged is carried into an internal space of a magnet system, i.e., a space in which a static magnetic field is generated; a gradient magnetic field and a high frequency magnetic field are applied to generate magnetic resonance signals from spins within the object; and a tomographic image is constructed based on the received signals. The magnetic resonance signal for use in constructing the tomographic image is sometimes referred to as an imaging echo.

[0003] Since the spin frequency is proportional to the magnetic field strength, the spin frequency varies as the static magnetic field strength varies. If the temporal variation in the spin frequency is considerably large, the current value of the spin frequency is determined before effecting RF excitation for generating an imaging echo, and the RF excitation for generating the imaging echo is effected by the high frequency magnetic field having a frequency equal to the current value of the spin frequency.

[0004] In order Lo evaluate the current value of the spin frequency, the spins are RF-excited separately to measure an FID (free induction decay) signal. The FID is sometimes referred to as navigator echo. The spin frequency is determined from the navigator echo by a calculation.

[0005] FIG. 1 is a time chart of navigator echo collection, a calculation on the navigator echo and imaging echo collection. The timing of gradient magnetic field application is omitted in the drawing.

[0006] As shown, the navigator echo collection and the imaging echo collection are separately performed during two consecutive periods. The length of each period is TR (repetition time).

[0007] In the earlier period, RF excitation for generating a navigator echo is effected at a time t1. Next, from a time t2 to a time t3, navigator echo collection is performed.

[0008] Next, from a time t3 to a time t5, a calculation is performed based on the collected echo data. The spin frequency is determined by the calculation. The result of the calculation is reflected on the frequency of the RF excitation in the later period.

[0009] In the later period, RF excitation for generating an imaging echo is effected at a time t6. The frequency of the RF excitation is made equal to the spin frequency deter-

mined by the calculation in the earlier period. Next, from a time t7 to a time t8, imaging echo collection is performed.

[0010] By repeating the above operation, imaging echoes for a plurality of views are sequentially collected. Each of the imaging echoes is given different phase encoding for each view by the gradient magnetic field, which is omitted in the drawing.

[0011] In the above operation, the calculation on the navigator echo should be completed within an interval after the navigator echo collection up to the beginning of the next period. However, this interval is short because it is the remainder of the period TR after subtraction of the time required for the RF excitation and navigator echo collection, and the time available for performing the calculation is insufficient. Accordingly, the calculation must be sped up to complete the calculation within the interval, or, if this is not possible, the period TR must be extended.

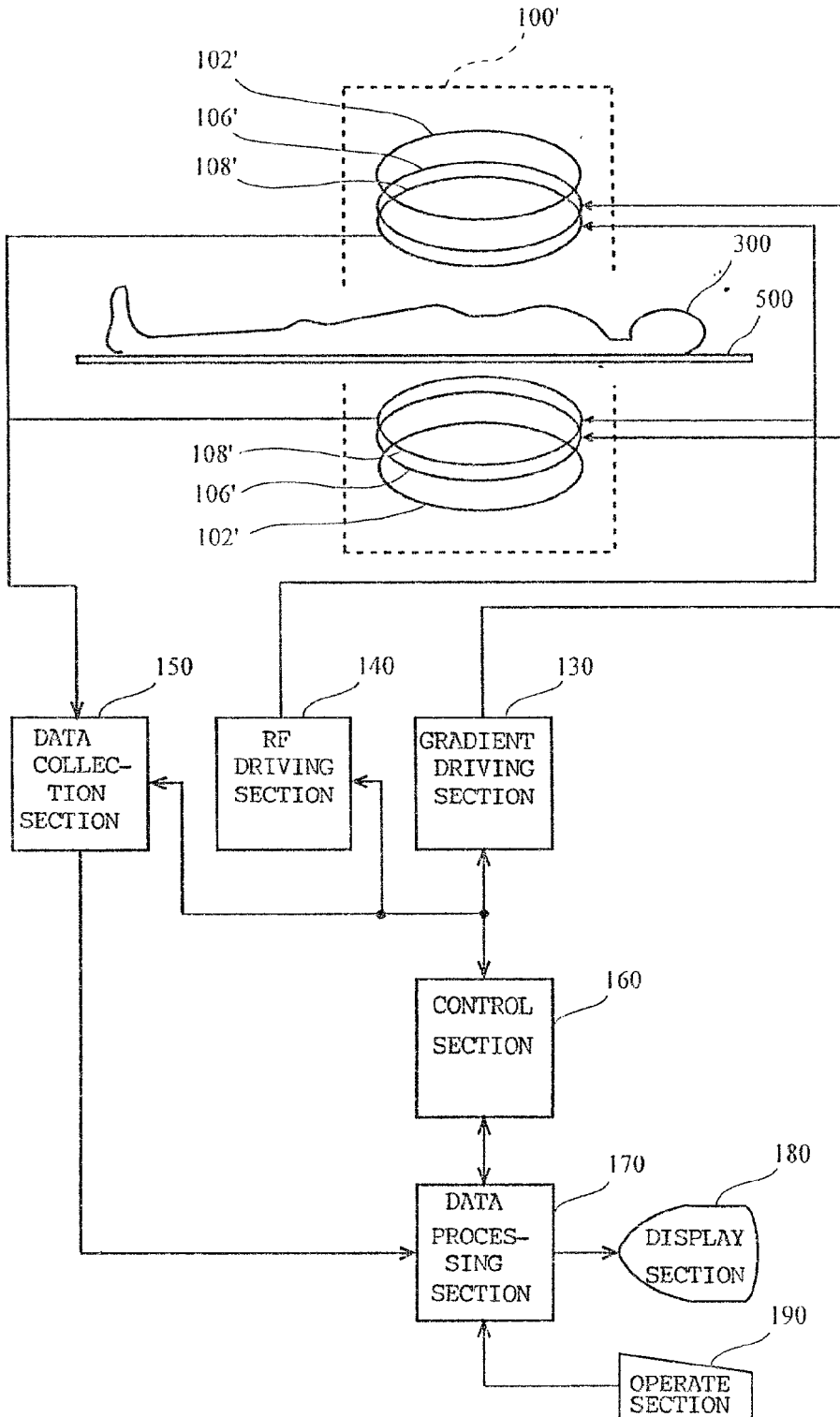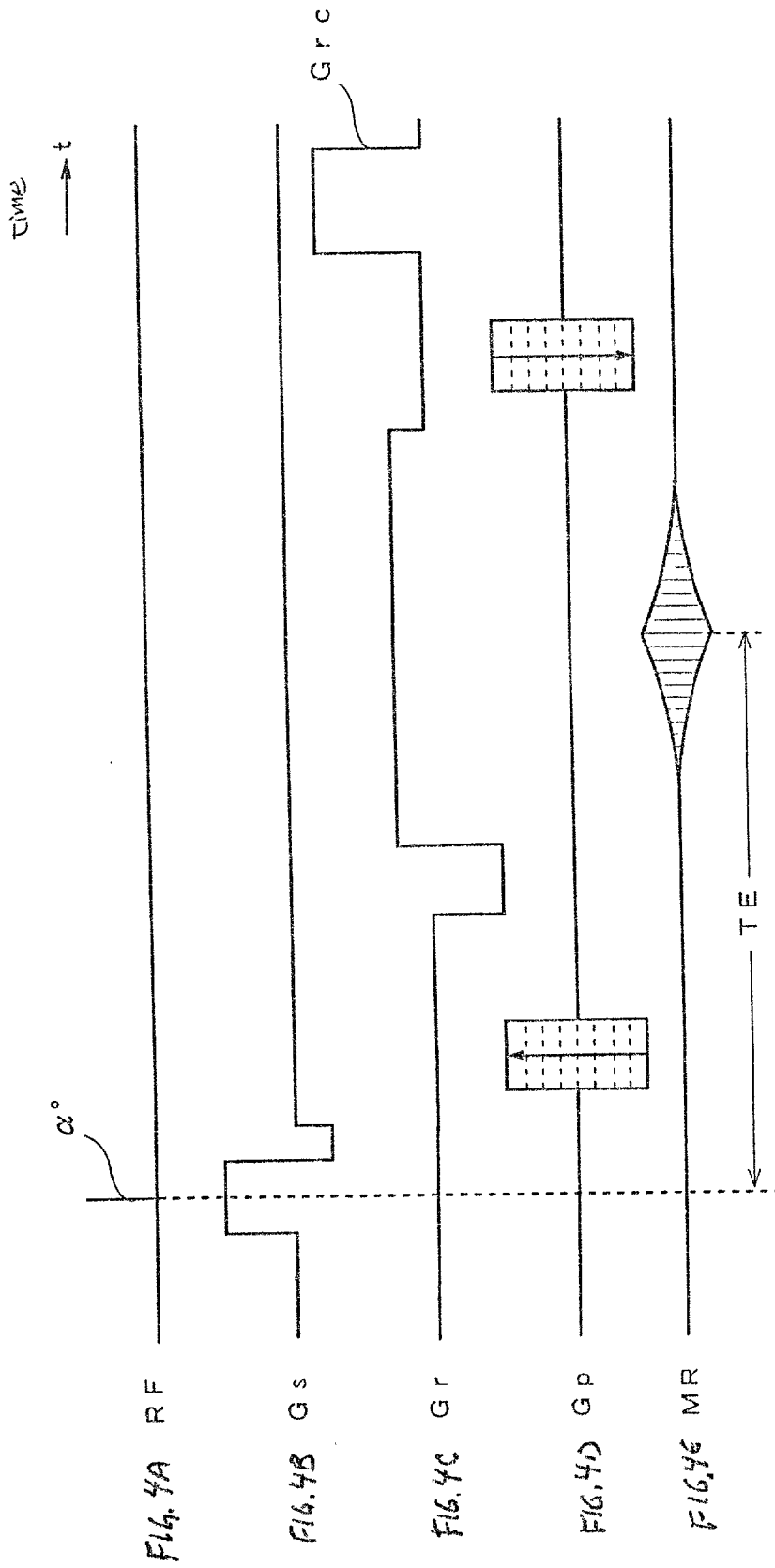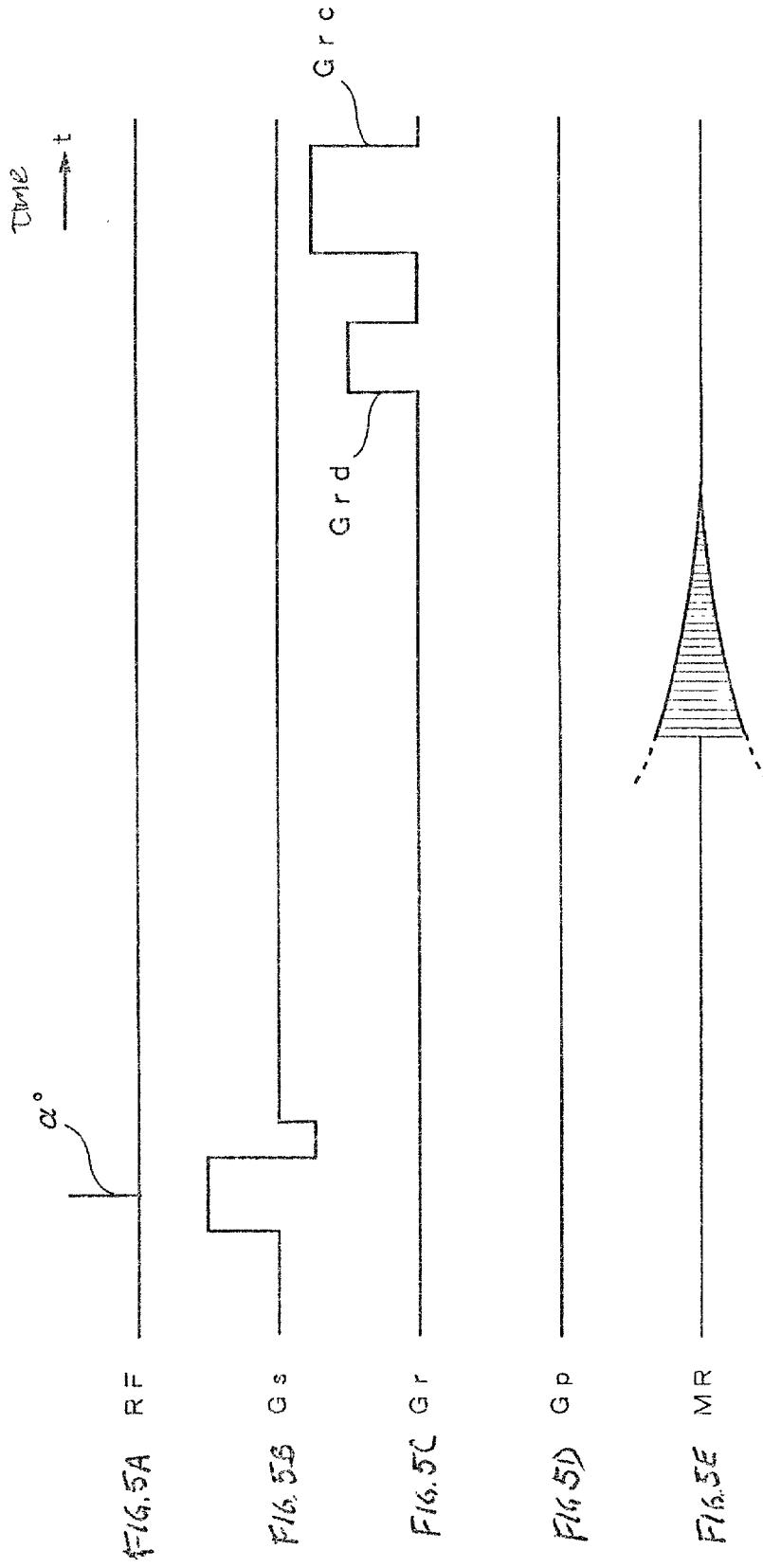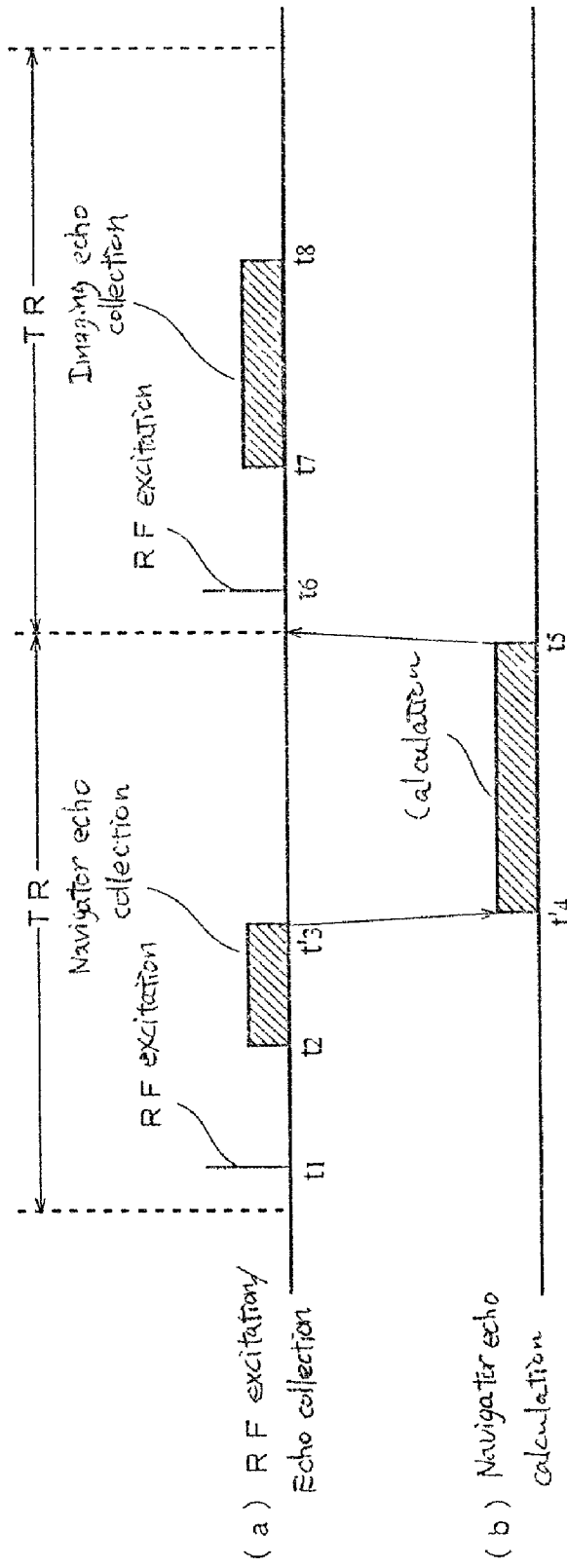## SUMMARY OF THE INVENTION

[0012] Therefore, it is an object of the present invention to provide a magnetic resonance signal acquiring method and apparatus in which the time available for a calculation on a navigator echo is large, and a recording medium recorded with a program for causing a computer to perform such a magnetic resonance signal acquiring function, and a magnetic resonance imaging apparatus comprising such magnetic resonance signal acquiring means.

[0013] (1) The present invention, in accordance with one aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, which method is characterized in comprising: making the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo.

[0014] (2) The present invention, in accordance with another aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, characterized in that the apparatus comprises: echo acquiring means for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo; calculating means for performing a calculation on said acquired navigator echo; frequency adjusting means for adjusting the frequency of RF excitation based on the result of said calculation; and control means for making the sampling frequency for said echo acquiring means to acquire the navigator echo higher than the sampling frequency for said echo acquiring means to acquire the imaging echo.

[0015] (3) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a recording medium that recorded in a computer-readable manner with a program for causing a computer to execute the functions of effecting RF excitation on spins within an

object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, which recording medium is characterized in that the program causes the computer to: make the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo.

[0016] (4) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance imaging apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, and constructing an image based on said acquired magnetic resonance signals, characterized in that means for acquiring said magnetic resonance signals comprises: echo acquiring means for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo; calculating means for performing a calculation on said acquired navigator echo; frequency adjusting means for adjusting the frequency of RF excitation based on the result of said calculation; and control means for making the sampling frequency for said echo acquiring means to acquire the navigator echo higher than the sampling frequency for said echo acquiring means to acquire the imaging echo.

[0017] According to the invention in these aspects, since the sampling frequency for acquiring the navigator echo is made higher than the sampling frequency for acquiring the imaging echo, the time required for the navigator echo data acquisition can be reduced relative to the time required for the imaging echo data acquisition. Thus, the time available for the calculation on the navigator echo can be increased.

[0018] (5) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, which method is characterized in comprising: making the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

[0019] (6) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, characterized in that the apparatus comprises: echo acquiring means for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo; calculating means for performing a calculation on said acquired navigator echo; frequency adjusting means for adjusting the frequency of RF excitation based on the result of said calculation; and control means for making the number of sampling points for said echo acquiring means to acquire the navigator echo fewer

than the number of sampling points for said echo acquiring means to acquire the imaging echo.

[0020] (7) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a recording medium recorded in a computer-readable manner with a program for causing a computer to execute the functions of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, which recording medium is characterized in that the causes the computer to: make the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

[0021] (8) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance imaging apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, and constructing an image based on said acquired magnetic resonance signals, characterized in that means for acquiring said magnetic resonance signals comprises: echo acquiring means for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo; calculating means for performing a calculation on said acquired navigator echo; frequency adjusting means for adjusting the frequency of RF excitation based on the result of said calculation; and control means for making the number of sampling points for said echo acquiring means to acquire the navigator echo fewer than the number of sampling points for said echo acquiring means to acquire the imaging echo.

[0022] According to the invention in these aspects, since the number of sampling points for acquiring the navigator echo is made fewer than the number of sampling points for acquiring the imaging echo, the time required for the navigator echo data acquisition can be reduced relative to the time required for the imaging echo data acquisition. Thus, the time available for the calculation on the navigator echo can be increased.

[0023] (9) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, which method is characterized in comprising: making the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo; and making the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

[0024] (10) The present invention, in accordance with still another aspect for solving the aforementioned problem, is a magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static

magnetic field, a gradient magnetic field and a high fre-
quency magnetic field, characterized in that the apparatus
comprises: echo acquiring means for effecting RF excitation
on spins within the object and acquiring a navigator echo,
and for effecting RF excitation on the spins within the object
and acquiring an imaging echo; calculating means for per-
forming a calculation on said acquired navigator echo;
frequency adjusting means for adjusting the frequency of RF
excitation based on the result of said calculation; and control
means for making the sampling frequency for said echo
acquiring means to acquire the navigator echo higher than
the sampling frequency for said echo acquiring means to
acquire the imaging echo, and for making the number of
sampling points for said echo acquiring means to acquire the
navigator echo fewer than the number of sampling points for
said echo acquiring means to acquire the imaging echo.

[0025] (11) The present invention, in accordance with still
another aspect for solving the aforementioned problem, is a
recording medium recorded in a computer-readable manner
with a program for causing a computer to execute the
functions of effecting RF excitation on spins within an
object and acquiring a navigator echo; performing a calcu-
lation on said acquired navigator echo and adjusting the
frequency of RF excitation based on the result of the
calculation; and effecting RF excitation on the spins within
the object and acquiring an imaging echo, which recording
medium is characterized in that the program causes the
computer to: make the sampling frequency for acquiring
said navigator echo higher than the sampling frequency for
acquiring said imaging echo; and make the number of
sampling points for acquiring said navigator echo fewer than
the number of sampling points for acquiring said imaging
echo.

[0026] (12) The present invention, in accordance with still
another aspect for solving the aforementioned problem, is a
magnetic resonance imaging apparatus for acquiring mag-
netic resonance signals from an object using a static mag-
netic field, a gradient magnetic field and a high frequency
magnetic field, and constructing an image based on said
acquired magnetic resonance signals, characterized in that
means for acquiring said magnetic resonance signals com-
prises: echo acquiring means for effecting RF excitation on
spins within the object and acquiring a navigator echo, and
for effecting RF excitation on the spins within the object and
acquiring an imaging echo; calculating means for perform-
ing a calculation on said acquired navigator echo; frequency
adjusting means for adjusting the frequency of RF excitation
based on the result of said calculation; and control means for
making the sampling frequency for said echo acquiring
means to acquire the navigator echo higher than the sam-
pling frequency for said echo acquiring means to acquire the
imaging echo, and for making the number of sampling
points for said echo acquiring means to acquire the navigator
echo fewer than the number of sampling points for said echo
acquiring means to acquire the imaging echo.

[0027] According to the invention in these aspects, since
the sampling frequency for acquiring the navigator echo is
made higher than the sampling frequency for acquiring the
imaging echo, and the number of sampling points for
acquiring the navigator echo is made fewer than the number
of sampling points for acquiring the imaging echo, the time
required for the navigator echo data acquisition can be
reduced relative to the time required for the imaging echo

data acquisition. Thus, the time available for the calculation
on the navigator echo can be increased.

[0028] Therefore, the present invention can provide a
magnetic resonance signal acquiring method and apparatus
in which the time available for a calculation on a navigator
echo is long, and a recording medium on which a program
is recorded for causing a computer to perform such a
magnetic resonance signal acquiring function, and a mag-
netic resonance imaging apparatus comprising such mag-
netic resonance signal acquiring means.

[0029] Further objects and advantages of the present
invention will be apparent from the following description of
the preferred embodiments of the invention as illustrated in
the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. 1 is a time chart of the operation of a
conventional apparatus.

[0031] FIG. 2 is a block diagram of an apparatus in
accordance with an embodiment of the present invention.

[0032] FIG. 3 is a block diagram of an apparatus in
accordance with an embodiment of the present invention.

[0033] FIG. 4 is a diagram illustrating an exemplary pulse
sequence executed by the apparatus shown in FIG. 2 or 3.

[0034] FIG. 5 is a diagram illustrating an exemplary pulse
sequence executed by the apparatus shown in FIG. 2 or 3.

[0035] FIG. 6 is a time chart of the operation of the
apparatus shown in FIG. 2 or 3.

DETAILED DESCRIPTION OF THE INVENTION

[0036] Several embodiments of the present invention will
now be described in detail with reference to the accompa-
nying drawings. FIG. 2 is a block diagram of a magnetic
resonance imaging apparatus, which is an embodiment of
the present invention. The configuration of the apparatus
represents an embodiment of the apparatus in accordance
with the present invention. The operation of the apparatus
represents an embodiment of the method in accordance with
the present invention.

[0037] As shown in FIG. 2, the present apparatus has a
magnet system 100. The magnet system 100 has a main
magnetic field coil section 102, a gradient coil section 106
and an RF (radio frequency) coil section 108. These coil
sections have a generally cylindrical shape and are concen-
trically disposed. An object to be imaged 300 is rested on a
cradle 500 and carried into and out of the generally cylin-
drical internal space (bore) of the magnet system 100 by
carrier means, which is not shown.

[0038] The main magnetic field coil section 102 generates
a static magnetic field in the internal space of the magnet
system 100. The direction of the static magnetic field is
generally in parallel with the direction of the body axis of the
object 300. That is, a "horizontal" magnetic field is gener-
ated. The main magnetic field coil section 102 is made using
a superconductive coil, for example. It will be easily rec-
ognized that the main magnetic field coil section 102 is not
limited to the superconductive coil, but may be made using
a normal conductive coil or the like.

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[0039] The gradient coil section **106** generates gradient magnetic fields for imparting gradients to the static magnetic field strength. The gradient magnetic fields to be generated are the following three: a slice gradient magnetic field, a phase encoding gradient magnetic field and a readout gradient magnetic field. The gradient coil section **106** has three gradient coils, which are not shown, corresponding to these three gradient magnetic fields. A gradient magnetic field will sometimes be referred to simply as a gradient hereinbelow. The three gradient magnetic fields impart respective gradients to the static magnetic field strength in three mutually orthogonal directions.

[0040] The RF coil section **108** generates a high frequency magnetic field for exciting spins within the object **300** in the static magnetic field space. The generation of the high frequency magnetic field will be sometimes referred to as transmission of an RF excitation signal hereinbelow. The RF coil section **108** also receives electromagnetic wave, i.e., magnetic resonance signals, generated by the excited spins.

[0041] The RF coil section **108** has transmission and receive coils, which are not shown. For the transmission and receive coils, the same coil or separate dedicated coils may be used.

[0042] The gradient coil section **106** is connected with a gradient driving section **130**. The gradient driving section **130** supplies driving signals to the gradient coil section **106** to generate the gradient magnetic fields. The gradient driving section **130** has three driving circuits, which are not shown, corresponding to the three gradient coils in the gradient coil section **106**.

[0043] The RF coil section **108** is connected with an RF driving section **140**. The RF driving section **140** supplies driving signals to the RF coil section **108** to transmit the RF excitation signal, thereby exciting the spins within the object **300**.

[0044] The RF coil section **108** is connected with a data collecting section **150**. The data collecting section **150** gathers receive signals received by the RF coil section **108** by sampling them, and collects the signals as digital data.

[0045] The received signals include two types, i.e., a navigator echo and an imaging echo, and the respective data for the echoes are collected. The data concerning the navigator echo will be sometimes referred to simply as a navigator echo, and the data concerning the imaging echo will be sometimes referred to simply as an imaging echo hereinbelow.

[0046] The gradient driving section **130**, RF driving section **140** and data collecting section **150** are connected with a control section **160**. The control section **160** controls the gradient driving section **130**, RF driving section **140** and data collecting section **150** to carry out imaging.

[0047] The control section **160** also adjusts the frequency of the output signal from the RF driving section **140**, i.e., the RF excitation frequency. Moreover, the control section **160** controls one or both of the sampling frequency and the number of sampling points for the navigator echo collection in the data collecting section **150**. The control section **160** also controls one or both of the sampling frequency and the number of sampling points for the imaging echo collection in the data collecting section **150**.

[0048] The control section **160** is, for example, constituted using a computer. The control section **160** has a memory, which is not shown. The memory stores programs for the control section **160** and several kinds of data. The function of the control section **160** is achieved by the computer executing a program stored in the memory.

[0049] The output of the data collecting section **150** is connected to a data processing section **170**. The data collected by the data collecting section **150** is input to the data processing section **170**. The data processing section **170** is, for example, constituted using a computer. The data processing section **170** has a memory, which is not shown. The memory stores programs for the data processing section **170** and several kinds of data. The function of the present apparatus is achieved by the data processing section **170** executing a program stored in the memory.

[0050] A portion consisting of the magnet system **100**, gradient driving section **130**, RF driving section **140**, data collecting section **150**, control section **160** and data processing section **170** is an embodiment of the magnetic resonance signal acquiring apparatus of the present invention. The configuration of the apparatus represents an embodiment of the apparatus in accordance with the present invention. The operation of the apparatus represents an embodiment of the method in accordance with the present invention.

[0051] The data processing section **170** stores the navigator echo and imaging echo input from the data collecting section **150** into the memory. A data space for storing the imaging echo is formed in the memory. The data space constitutes a two-dimensional Fourier space. The two-dimensional Fourier space will be sometimes referred to as a k-space hereinbelow.

[0052] The data processing section **170** performs a two-dimensional inverse Fourier transformation on the data in the k-space to produce (reconstruct) an image of the object **300**. The data processing section **170** also performs a calculation based on the navigator echo input from the data collecting section **150**. The frequency and phase of spins are obtained from the calculation.

[0053] The data processing section **170** is connected to the control section **160**. The data processing section **170** is above the control section **160** and controls it. The frequency and phase of spins obtained from the calculation based on the navigator echo are input to the control section **160** as information for adjusting the frequency of the RF excitation signal.

[0054] The data processing section **170** is connected with a display section **180** and an operating section **190**. The display section **180** comprises a graphic display, etc. The operating section **190** comprises a keyboard, etc., provided with a pointing device.

[0055] The display section **180** displays the reconstructed image and several kinds of information output from the data processing section **170**. The operating section **190** is operated by a user, and the section **190** inputs several commands, information and so forth to the data processing section **170**. The user interactively operates the present apparatus via the display section **180** and operating section **190**.

[0056] **FIG. 3** is a block diagram of a magnetic resonance imaging apparatus of another type, which is another embodi-

ment of the present invention. The configuration of the apparatus represents an embodiment of the apparatus in accordance with the present invention. The operation of the apparatus represents an embodiment of the method in accordance with the present invention.

[0057] The apparatus shown in **FIG. 3** has a magnet system **100** of a type different from that in the apparatus shown in **FIG. 2**. Since the apparatus has a configuration similar to that of the apparatus shown in **FIG. 1**, except for the magnet system **100'**, similar portions are designated by similar reference numerals and the explanation thereof will be omitted.

[0058] The magnet system **100'** has a main magnetic field magnet section **102'**, a gradient coil section **106'** and an RF coil section **108'**. The main magnetic field magnet section **102'** and the coil sections each consists of a pair of members facing each other across a space. These sections have a generally disk-like shape and are disposed to have a common center axis.

[0059] The object **300** is rested on the cradle **500** and carried into and out of the internal space (bore) of the magnet system **100'** by carrier means, which is not shown.

[0060] The main magnetic field magnet section **102'** generates a static magnetic field in the internal space of the magnet system **100'**. The direction of the static magnetic field is generally orthogonal to the direction of the body axis of the object **300**. That is, a "vertical" magnetic field is generated. The main magnetic field magnet section **102'** is made using a permanent magnet, for example. It will be easily recognized that the main magnetic field magnet section **102'** is not limited to a permanent magnet, but may be made using a super or normal conductive electromagnet or the like.

[0061] The gradient coil section **106'** generates gradient magnetic fields for imparting gradients to the static magnetic field strength. The gradient magnetic fields to be generated are the following three: a slice gradient magnetic field, a readout gradient magnetic field and a phase encoding gradient magnetic field. The gradient coil section **106** has three gradient coils, which are not shown, corresponding to these three gradient magnetic fields.

[0062] The RF coil section **108'** transmits an RF excitation signal for exciting spins within the object **300** in the static magnetic field space. The RF coil section **108'** also receives magnetic resonance signals generated by the excited spins.

[0063] The RF coil section **108** has transmission and receive coils, which are not shown. For the transmission and receive coils, the same coil or separate dedicated coils may be used.

[0064] A portion consisting of the magnet system **100'**, gradient driving section **130**, RF driving section **140**, data collecting section **150**, control section **160** and data processing section **170** is an embodiment of the magnetic resonance signal acquiring apparatus of the present invention. The configuration of the apparatus represents an embodiment of the apparatus in accordance with the present invention. The operation of the apparatus represents an embodiment of the method in accordance with the present invention.

[0065] **FIG. 4** illustrates an exemplary pulse sequence for the imaging echo acquisition executed by the apparatus

shown in **FIG. 2** or **3**. The pulse sequence is one for acquiring a gradient echo as the imaging echo.

[0066] Specifically, (1) is a sequence of an α° pulse for RF excitation, and (2), (3), (4) and (5) are sequences of a slice gradient Gs, a readout gradient Gr, a phase encoding gradient Gp and a gradient echo MR, respectively. It should be noted that the α° pulse is represented by its central signal. The pulse sequence proceeds from the left to the right along a time axis t.

[0067] As shown, the α° pulse effects α° excitation of the spins, wherein α is not greater than 90. At the same time, the slice gradient Gs is applied to achieve selective excitation for a certain slice.

[0068] After the α° excitation, the spins are phase-encoded by the phase encoding gradient Gp. Next, the spins are first dephased and are subsequently rephased by the readout gradient Gr to generate a gradient echo MR. The gradient echo MR is an RF signal having a waveform symmetric with respect to an echo center. The central echo occurs after TE (echo time) from the α° excitation. The gradient echo MR is the imaging echo.

[0069] The gradient echo MR is collected as view data by the data collecting section **150**. After the data collection, the phase encoding gradient Gp is applied in a direction opposite to the aforementioned one to effect "rewind" for bringing the phase encoding back to zero. Moreover, the readout gradient Grc is applied to dephase the spins. The readout gradient Grc is a so-called "crusher".

[0070] Such a pulse sequence is repeated 64-256 times. The phase encoding gradient Gp is varied for each repetition to provide different phase encoding each time. Thus, view data for 64-256 views are obtained in the k-space.

[0071] The view data obtained by the pulse sequence of **FIG. 4** is collected into the memory in the data processing section **170**. The data processing section **170** performs a two-dimensional inverse Fourier transformation on the view data to reconstruct a tomographic image of the object **300**.

[0072] **FIG. 5** illustrates an exemplary pulse sequence for the navigator echo acquisition executed by the apparatus shown in **FIG. 2** or **3**. (1) is a sequence of an α° pulse for RF excitation, and (2), (3), (4) and (5) are sequences of a slice gradient Gs, a readout gradient Gr, a phase encoding gradient Gp and a navigator echo MR, respectively. It should be noted that the α° pulse is represented by its central signal. The pulse sequence proceeds from the left to the right along a time axis t.

[0073] As shown, the α° pulse effects α° excitation of the spins, wherein α is not greater than 90. At the same time, the slice gradient Gs is applied to achieve selective excitation for a certain slice.

[0074] The navigator echo MR, i.e., an FID signal, generated by the α° excitation is collected by the data collecting section **150**. After the navigator echo collection, a readout gradient Grd is applied. The readout gradient Grd has an integral value equal to that of the readout gradient Gr for generating the gradient echo shown in **FIG. 4**. Subsequent to the gradient, a crusher Grc is applied. No readout gradient is applied before the navigator echo collection. Moreover, no phase encoding gradient is applied throughout the period.

[0075] Such navigator echo collection is performed before the imaging echo collection, and the frequency and phase of the navigator echo is determined by a calculation based on the navigator echo to obtain data for adjustment on the frequency of RF excitation, or $\alpha°$ excitation, for generating the imaging echo.

[0076] FIG. 6 schematically shows an exemplary time chart of the navigator echo acquisition, calculation on the navigator echo and imaging echo acquisition. As shown, during one of two consecutive periods TR, $\alpha°$ excitation is effected at a time t1, and a navigator echo is collected from a time t2 to a time t3'. The $\alpha°$ excitation and navigator echo collection is achieved by the pulse sequence shown in FIG. 5.

[0077] The magnet system 100 (100'), gradient driving section 130, RF driving section 140 and data collecting section 150 involved in the $\alpha°$ excitation and navigator echo collection constitute an embodiment of the echo acquiring means of the present invention.

[0078] After the navigator echo collection, a calculation based on the collected navigator echo is performed from a time t4' to a time t5 to evaluate the frequency and phase of the navigator echo. The data processing section 170 involved in the calculation is an embodiment of the calculating means of the present invention.

[0079] The result of the calculation is supplied from the data processing section 170 to the control section 160. The control section 160 adjusts the RF excitation frequency for the next period based on the supplied calculation result. The control section 160 involved in the frequency adjustment is an embodiment of the frequency adjusting means of the present invention.

[0080] The frequency adjustment enables $\alpha°$ excitation in agreement with the current value of the spin frequency to be effected in the next period. It should be noted that the frequency for the $\alpha°$ excitation in the first period is adjusted to a suitable value beforehand by the tuning performed before commencing imaging.

[0081] During the other of the periods, $\alpha°$ excitation is effected at a time t6, and an imaging echo is collected from a time t7 to a time t8. The $\alpha°$ excitation and imaging echo collection is achieved by the pulse sequence shown in FIG. 3.

[0082] The magnet system 100 (100'), gradient driving section 130, RF driving section 140 and data collecting section 150 involved in the $\alpha°$ excitation and imaging echo collection constitute an embodiment of the echo acquiring means of the present invention.

[0083] With such two periods as a unit, the navigator and imaging echo acquisition is repeated for, for example, 64-512 times. Instead of performing the navigator echo acquisition before each imaging echo acquisition, the navigator echo acquisition may be performed at a less frequent rate of occurrence than the imaging echo acquisition, such as by performing navigator echo acquisition in one period followed by imaging echo acquisition over a plurality of consecutive periods. Alternatively, instead of separating the navigator echo acquisition and imaging echo acquisition between two periods, they may be performed within the same period.

[0084] At this time, the navigator echo collection and imaging echo collection are performed with one or both of the sampling frequency and the number of sampling points differentiated under the control of the control section 160.

[0085] Specifically, the sampling frequency for the navigator echo is made higher than that for the imaging echo. Alternatively, the number of sampling points for the navigator echo is made fewer than that for the imaging echo. Otherwise, the sampling frequency for the navigator echo is made higher than that for the imaging echo and the number of sampling points for the navigator echo is made fewer than that for the imaging echo. The control section 160 involved in the control of the sampling frequency and/or the number of sampling points is an embodiment of the control means of the present invention.

[0086] By making the sampling frequency higher, the navigator echo can be collected to comprise as much data as the data in the imaging echo within a shorter time period. By making the number of sampling points fewer, the navigator echo can be collected within a time shorter than the time for collecting the imaging echo. By making the sampling frequency higher and making the number of sampling points fewer, a synergistic time reduction can be achieved.

[0087] In the present apparatus, such control of the sampling frequency and/or the number of sampling points as described above causes an interval from the end of the navigator echo collection to the beginning of the next period to be extended as compared with the conventional technique shown in FIG. 1. Therefore, the time available for performing a calculation on the navigator echo is increased. Thus, the calculation can be completed within the interval without particularly speeding up the calculation. Moreover, the period TR does not need to be extended, or can be even reduced in some cases.

[0088] A program for causing a computer to perform the magnetic resonance signal acquiring function as described above is recorded on a recording medium in a computer-readable manner. For the recording medium, any one of, for example, a magnetic recording medium, an optical recording medium, a magneto-optical recording medium and other appropriate types of recording medium can be employed. The recording medium may be a semiconductor storage medium. A storage medium is synonymous with a recording medium in the present specification.

[0089] Many widely different embodiments of the invention may be configured without departing from the spirit and the scope of the present invention. It should be understood that the present is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

1. A magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the method comprises:

   making the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo.

2. A magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the method comprises:

    making the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

3. A magnetic resonance signal acquiring method that executes the steps of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the method comprises:

    making the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo; and

    making the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

4. A magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, wherein the apparatus comprises:

    an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

    a calculating device for performing a calculation on said acquired navigator echo;

    a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

    a control device for making the sampling frequency for said echo acquiring device to acquire the navigator echo higher than the sampling frequency for said echo acquiring device to acquire the imaging echo.

5. A magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, wherein the apparatus comprises:

    an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

    a calculating device for performing a calculation on said acquired navigator echo;

    a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

    a control device for making the number of sampling points for said echo acquiring device to acquire the navigator echo fewer than the number of sampling points for said echo acquiring device to acquire the imaging echo.

6. A magnetic resonance signal acquiring apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, wherein the apparatus comprises:

    an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

    a calculating device for performing a calculation on said acquired navigator echo;

    a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

    a control device for making the sampling frequency for said echo acquiring device to acquire the navigator echo higher than the sampling frequency for said echo acquiring device to acquire the imaging echo, and for making the number of sampling points for said echo acquiring device to acquire the navigator echo fewer than the number of sampling points for said echo acquiring device to acquire the imaging echo.

7. A recording medium that is recorded in a computer-readable manner with a program for causing a computer to execute the functions of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the program causes the computer to:

    make the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo.

8. A recording medium that is recorded in a computer-readable manner with a program for causing a computer to execute the functions of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the program causes the computer to:

    make the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

9. A recording medium that is recorded in a computer-readable manner with a program for causing a computer to execute the functions of effecting RF excitation on spins within an object and acquiring a navigator echo; performing a calculation on said acquired navigator echo and adjusting the frequency of RF excitation based on the result of the calculation; and effecting RF excitation on the spins within the object and acquiring an imaging echo, wherein the program causes the computer to:

    make the sampling frequency for acquiring said navigator echo higher than the sampling frequency for acquiring said imaging echo; and

make the number of sampling points for acquiring said navigator echo fewer than the number of sampling points for acquiring said imaging echo.

10. A magnetic resonance imaging apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, and constructing an image based on said acquired magnetic resonance signals, wherein a device for acquiring said magnetic resonance signals comprises:

an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

a calculating device for performing a calculation on said acquired navigator echo;

a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

a control device for making the sampling frequency for said echo acquiring device to acquire the navigator echo higher than the sampling frequency for said echo acquiring device to acquire the imaging echo.

11. A magnetic resonance imaging apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, and constructing an image based on said acquired magnetic resonance signals, wherein a device for acquiring said magnetic resonance signals comprises:

an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

a calculating device for performing a calculation on said acquired navigator echo;

a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

a control device for making the number of sampling points for said echo acquiring device to acquire the navigator echo fewer than the number of sampling points for said echo acquiring device to acquire the imaging echo.

12. A magnetic resonance imaging apparatus for acquiring magnetic resonance signals from an object using a static magnetic field, a gradient magnetic field and a high frequency magnetic field, and constructing an image based on said acquired magnetic resonance signals, wherein a device for acquiring said magnetic resonance signals comprises:

an echo acquiring device for effecting RF excitation on spins within the object and acquiring a navigator echo, and for effecting RF excitation on the spins within the object and acquiring an imaging echo;

a calculating device for performing a calculation on said acquired navigator echo;

a frequency adjusting device for adjusting the frequency of RF excitation based on the result of said calculation; and

a control device for making the sampling frequency for said echo acquiring device to acquire the navigator echo higher than the sampling frequency for said echo acquiring device to acquire the imaging echo, and for making the number of sampling points for said echo acquiring device to acquire the navigator echo fewer than the number of sampling points for said echo acquiring device to acquire the imaging echo.

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