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(71) Applicant *(for all designated States except DE, US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(71) Applicant *(for DE only)*: **PHILIPS INTELLECTUAL PROPERTY & STANDARDS GMBH** [DE/DE]; Lübeckertordamm 5, 20099 Hamburg (DE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **EGGERS, Holger** [DE/DE]; c/o High Tech Campus Building 44, NL-5656 AE Eindhoven (NL). **NEHRKE, Kay** [DE/DE]; c/o High Tech Campus Building 44, NL-5656 AE Eindhoven (NL). **BOERNERT, Peter** [DE/DE]; c/o High Tech Campus Building 44, NL-5656 AE Eindhoven (NL).

(74) Agents: **SCHOUTEN, Marcus, M.** et al.; High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).

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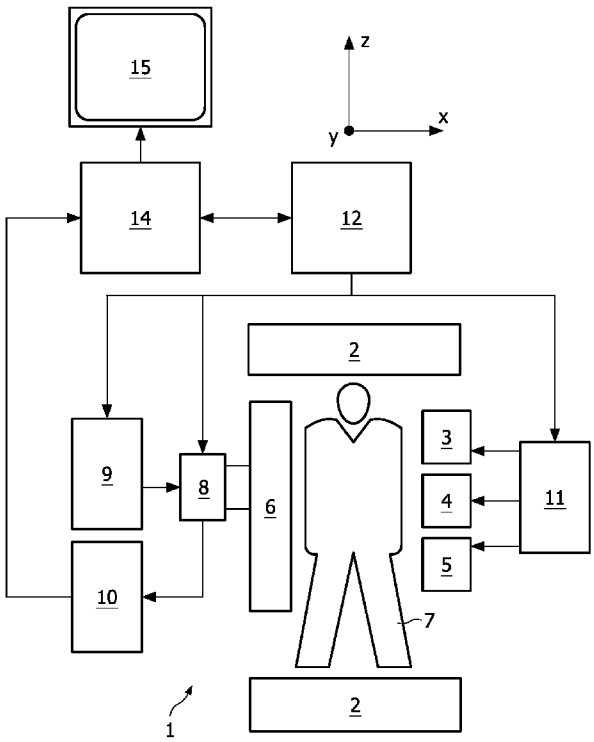


FIG. 1

(57) Abstract: The invention relates to a device for MRI of a body (7) placed in an examination volume. The device (1) comprises means (2) for establishing a substantially homogeneous main magnetic field in the examination volume, means (3, 4, 5) for generating switched magnetic field gradients superimposed upon the main magnetic field, means (6) for radiating RF pulses towards the body (7), control means (12) for controlling the generation of the magnetic field gradients and the RF pulses, means (10) for receiving and sampling MR signals, and reconstruction means (14) for forming MR images from the signal samples. According to one aspect of the invention, the device (1) is arranged to acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein the rotation angle of the k-space blades is incremented during MR signal acquisition by the Golden Angle (or by the half Golden Angle). According to another aspect of the invention, the device (1) is arranged to acquire an MR reference data set from a central portion of k-space prior to a multi-slice PROPELLER acquisition. According to still another aspect of the invention, the device (1) is arranged to weight the acquired MR data, wherein weighting factors are computed on the basis of acquisition times for contrast manipulation, correlation measures for motion compensation, and on the basis of the geometry of the overlapping areas of the k-space blades.

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Magnetic resonance device and method

FIELD OF THE INVENTION

The invention relates to a device for magnetic resonance imaging (MRI) of a body placed in an examination volume.

Furthermore, the invention relates to a method for MRI and to a computer program for a magnetic resonance (MR) device.

DESCRIPTION OF THE PRIOR ART

In MRI, pulse sequences consisting of RF pulses and switched magnetic field gradients are applied to an object (a patient) placed in a homogeneous magnetic field within an examination volume of an MR device. In this way, MR signals are generated, which are scanned by means of radiofrequency (RF) receiving antennas in order to obtain information about the object and to reconstruct images thereof. Since its initial development, the number of clinically relevant fields of application of MRI has grown enormously. MRI can be applied to almost every part of the body, and it can be used to obtain important functional information about the human body. The pulse sequence, which is applied during an MRI scan, plays a significant role in the determination of the characteristics of the reconstructed image, such as location and orientation in the object, dimensions, resolution, signal-to-noise ratio, contrast, sensitivity for movements, et cetera. An operator of an MRI device has to choose the appropriate sequence and has to adjust and optimize its parameters for the respective application.

In the known so-called PROPELLER concept (Periodically Rotated Overlapping ParalEL Lines with Enhanced Reconstruction, see James G. Pipe: "Motion Correction With PROPELLER MRI: Application to Head Motion and Free-Breathing Cardiac Imaging", Magnetic Resonance in Medicine, vol. 42, 1999, pages 963-969), MR signals are acquired in k-space in N strips, each consisting of L parallel lines, corresponding to the L lowest frequency phase-encoding lines in a Cartesian k-space sampling scheme. Each strip, which is also referred to as k-space blade, is rotated in k-space by an angle $\delta\varphi = 180° / N$, so that the total MR data set spans approximately a circle in k-

space. If a data matrix having a diameter M is desired, then L and N are, for instance, chosen so that $L \cdot N = M \cdot \pi / 2$. One essential characteristic of PROPELLER is that a central circular portion in k-space, having a diameter L, is acquired for each k-space blade. This central portion can be used to reconstruct a low-resolution image for each k-space blade. These low-resolution images, or their k-space representations, are compared to each other to remove in-plane displacements and phase errors, which are due to patient motion. In addition, a suitable technique such as cross-correlation is employed to determine which k-space blades were acquired with significant through-plane displacement. As the MR signals are combined in k-space before the reconstruction of the final MR image, the MR data from k-space blades with the least amount of through-plane motion are preferentially used in regions in which the k-space blades overlap, so that artifacts arising from through-plane motion are reduced. The PROPELLER technique makes use of oversampling in the central portion of k-space in order to obtain an MR image acquisition technique that is robust with respect to motion of the examined patient during MR signal acquisition.

SUMMARY OF THE INVENTION

One problem of the known PROPELLER concept is that a complete rejection of motion-corrupted k-space blades results in undersampling of the peripheral k-space regions and, hence, in a potentially degraded image quality.

Another problem associated with multi-slice PROPELLER imaging is that individual slices from a multi-slice PROPELLER acquisition may be misaligned. The reason for this is that PROPELLER cross-correlates repeatedly measured MR signals in the central k-space as a reference for motion correction. Typically a reference is chosen showing the most similarity to the central k-space data of the other blades. The reference data chosen in accordance with PROPELLER is thus not an absolute but a relative reference, which may cause misalignment of the individual slices. A retrospective alignment of the slices of a multi-slice MR scan is possible in principle, provided that adjacent slices show substantial similarity. This pre-requisite is questionable in general, however.

For an accurate MR image reconstruction, the known PROPELLER imaging method requires a weighting of the acquired k-space samples. This is usually referred to as sampling density compensation. To compute the weighting factors, an iterative approach is commonly taken. The weighting also permits a prioritization of MR signals according to various criteria, such as correlation measures of the cross-correlated k-space blades, in order to achieve the above-mentioned reduction of motion-induced image artifacts. This

prioritization can be applied in k-space areas that are more densely sampled than actually required to support the selected field of view. A drawback of the known technique is that the usually taken iterative approach for computing the weighting factors is slow and sporadically instable, especially if a strong contrast weighting is applied

Therefore, it is readily appreciated that there is a need for an improvement of the known PROPELLER imaging concept. It is consequently an object of the invention to provide an MR device that enables a reduction of image artifacts and an improved efficiency with PROPELLER imaging.

In accordance with the present invention, an MR device for MRI of a body placed in an examination volume is disclosed, which comprises means for establishing a substantially homogeneous main magnetic field in the examination volume, means for generating switched magnetic field gradients superimposed upon the main magnetic field, means for radiating RF pulses towards the body, control means for controlling the generation of the magnetic field gradients and the RF pulses, means for receiving and sampling MR signals, and reconstruction means for forming MR images from the signal samples. The invention proposes that the MR device is arranged to

a) generate a series of MR signals by subjecting at least a portion of the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein the rotation angle of the k-space blades is incremented during MR signal acquisition by an angle larger than $180°/N$, N being the total number of k-space blades acquired, and

c) reconstruct an MR image from the acquired MR signals.

The invention is based on the recognition of the fact that a regular angular undersampling produces only minimal image artifacts. Hence, the least artifacts can be expected if, in accordance with the invention, motion-corrupted k-space blades are distributed as uniformly as possible over the circle spanned by the rotated k-space blades. Since the angle is incremented according to the invention by an angle larger than $180°/N$, an interleaved arrangement of successively acquired k-space blades is achieved. The regular angular undersampling proposed by the invention is more robust for image reconstruction than the omission of several motion-corrupted adjacent k-space blades which is characteristic for the conventional linear order of blades.

Preferably, the MR device of the invention is further arranged to increment the angle of the k-space blades by the Golden Angle of $137{,}51°$ or by the half Golden Angle of $68{,}75°$. According to this embodiment of the invention, the so-called Golden Angle principle is applied to PROPELLER MRI to generate an interleaved spatiotemporal order of k-space blades. The Golden Angle is the angle created by dividing the circumference c of a circle into two sections a and b, such that $c = a + b$ and $c/a = a/b$. The Golden Angle principle applied to PROPELLER MRI according to the invention enables a particularly isotropic distribution of corrupted k-space blades over the circle spanned by the rotated blades and, thus, a minimization of motion-induced artifacts in the finally reconstructed MR image. By incrementing the rotation angle by the Golden Angle an isotropic, increasingly dense angular coverage of the circle is achieved. For the diametric PROPELLER blades, only a semicircle has to be considered, which results in a rotation increment of the half Golden Angle.

In a practical embodiment of the invention, the rotation angle of the k-space blades is selected according to the formula $\varphi(i) = f(i) \cdot 180°/N$ or $\varphi(i) = f(i) \cdot 180° \cdot (1 + 1/N)$, wherein $i = 1,2,\ldots N$ represents an index of the consecutively acquired k-space blades, and $f(i)$ represents a function that maps the index i to an integral number between 0 and $N-1$ such that the rotation angle increment $\varphi(i+1) - \varphi(i)$ is larger than $180°/N$. As a consequence of the infinite sequence period resulting from the Golden Angle increment, the blade arrangement within the circle spanned by the k-space blades is slightly asymmetric. However, in a typical PROPELLER acquisition, the number of k-space blades is fixed, making a symmetric arrangement of blades more preferable. This can be achieved by the above formula. The function $f(i)$ is chosen such that the above-described interleaved arrangement results, wherein the angles $\varphi(i)$ approximate the Golden Angle (or the half Golden Angle) as closely as possible. In case the formula $\varphi(i) = f(i) \cdot 180°/N$ applies, the readout gradient rotates about 180° during one acquisition. If the rotation angle is determined by the formula $\varphi(i) = f(i) \cdot 180° \cdot (1 + 1/N)$, the readout gradient rotates about 360° during each acquisition.

According to a further aspect of the invention, a device for MRI of a body placed in an examination volume is disclosed, wherein the device comprises means for establishing a substantially homogeneous main magnetic field in the examination volume, means for generating switched magnetic field gradients superimposed upon the main

magnetic field, means for radiating RF pulses towards the body, control means for controlling the generation of the magnetic field gradients and the RF pulses, means for receiving and sampling MR signals, and reconstruction means for forming MR images from the signal samples. The invention proposes that device is arranged to

a) generate a series of MR signals by subjecting at least a portion of the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire an MR reference data set from a central portion of k-space,

c) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein at least a part of said central portion of k-space is acquired for each k-space blade,

d) compare the MR data acquired in step c) to the MR reference data set in said central area of k-space for each k-space blade in order to estimate and correct motion-induced displacements and phase errors, and

e) reconstruct an MR image from the acquired and corrected MR signals.

The features of this second aspect of the invention can advantageously be combined with the features of the above-described first aspect of the invention.

The gist of the second aspect of the invention is the acquisition of a separate MR reference data set (approximately) from the circular central portion of k-space which is acquired for each k-space blade. The acquisition only from the central k-space portion implies that the MR reference data set forms a low-resolution image. The acquisition of this reference data set can be performed without a significant increase in total scan time. According to the invention, the data from the common central portion of the k-space blades is compared to the reference data set, in order to estimate and correct motion-induced displacements and phase errors. The idea behind this approach is to establish a common reference for all k-space blades for the purpose of motion estimation and correction. If the MR reference data set is a three-dimensional volume data set, the technique of the invention ensures a proper alignment of all slices of a multi-slice PROPELLER measurement. In this case, the k-space blades are acquired for two or more parallel image slices spaced in a direction perpendicular to the plane of rotation of the k-space blades. The common reference provided in accordance with the invention avoids misalignment of the image slices even if there is no significant similarity between adjacent slices of the multi-slice acquisition.

According to still a further aspect of the invention, a device for MRI of a body placed in an examination volume is disclosed, wherein the device comprises means for establishing a substantially homogeneous main magnetic field in the examination volume, means for generating switched magnetic field gradients superimposed upon the main magnetic field, means for radiating RF pulses towards the body, control means for controlling the generation of the magnetic field gradients and the RF pulses, means for receiving and sampling MR signals, and reconstruction means for forming MR images from the signal samples. The invention proposes that the device is arranged to

a) generate a series of MR signals by subjecting at least a portion of the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space,

c) weight the acquired MR data, wherein weighting factors are computed on the basis of acquisition times for contrast manipulation, correlation measures for motion compensation, and on the basis of the geometry of the overlapping areas of the k-space blades, and

d) reconstruct an MR image from the acquired and weighted MR signals.

The features of this third aspect of the invention can advantageously be combined with the features of the above-described first and/or second aspect of the invention.

The essential feature of the third aspect of the invention is that the weighting factors used for the sampling density compensation are not computed by an iterative approach as in the conventional PROPELLER concept. Instead, the weighting factors are computed directly on the basis of various criteria, such as acquisition times depending on the chosen MR imaging pulse sequence (for example a TSE sequence) for the purpose of prioritization of MR signals acquired at certain echo times, correlation measures for the purpose of prioritization of the acquired k-space blades, and the geometry of the overlapping areas of the k-space blades for the purpose of sampling density compensation. Preferably, the weighting factors are additionally normalized prior to the final image reconstruction step.

The invention not only relates to a device but also to a method for MRI of at least a portion of a body placed in an examination volume of an MR device.

A computer program adapted for carrying out the imaging procedure of the invention can advantageously be implemented on any common computer hardware, which is

presently in clinical use for the control of magnetic resonance scanners. The computer program can be provided on suitable data carriers, such as CD-ROM or diskette. Alternatively, it can also be downloaded by a user from an Internet server.

BRIEF DESCRIPTION OF THE DRAWINGS

The enclosed drawings disclose preferred embodiments of the present invention. It should be understood, however, that the drawings are designed for the purpose of illustration only and not as a definition of the limits of the invention. In the drawings

Fig. 1 shows an MR scanner according to the invention;

Fig. 2 illustrates the k-space sampling scheme of PROPELLER MRI including the Golden Angle rotation of PROPELLER blades;

Fig. 3 illustrates the acquisition of an MR reference data set for PROPELLER MRI according to the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In Fig.1 an MR imaging device 1 in accordance with the present invention is shown as a block diagram. The apparatus 1 comprises a set of main magnetic coils 2 for generating a stationary and homogeneous main magnetic field and three sets of gradient coils 3, 4 and 5 for superimposing additional magnetic fields with controllable strength and having a gradient in a selected direction. Conventionally, the direction of the main magnetic field is labelled the z-direction, the two directions perpendicular thereto the x- and y-directions. The gradient coils 3, 4 and 5 are energized via a power supply 11. The imaging device 1 further comprises an RF transmit antenna 6 for emitting RF pulses to a body 7. The antenna 6 is coupled to a modulator 9 for generating and modulating the RF pulses. Also provided is a receiver for receiving the MR signals, the receiver can be identical to the transmit antenna 6 or be separate. If the transmit antenna 6 and receiver are physically the same antenna as shown in Fig. 1, a send-receive switch 8 is arranged to separate the received signals from the pulses to be emitted. The received MR signals are input to a demodulator 10. The send-receive switch 8, the modulator 9, and the power supply 11 for the gradient coils 3, 4 and 5 are controlled by a control system 12. Control system 12 controls the phases and amplitudes of the RF signals fed to the antenna 6. The control system 12 is usually a microcomputer with a memory and a program control. The demodulator 10 is coupled to reconstruction means 14, for example a computer, for transformation of the received signals into images that can be made visible, for example, on a visual display unit 15. For the

practical implementation of the invention, the MR device 1 comprises a programming for executing an MRI PROPELLER scheme in the above-described manner.

Fig. 2 illustrates the k-space sampling of PROPELLER MRI according to the invention. Eight k-space PROPELLER blades are acquired. The blades are rotated about the center of k-space, so that the total acquired MR data set approximately spans a circle in k-space. The arrows shown in Fig. 2 indicate the directions of the readout magnetic field gradients generated for the respective k-space blades. In Fig. 2a, the rotation angle of the successively acquired k-space blades is incremented by the half Golden angle, which is approximately $68{,}75°$. An isotropic, increasingly dense angular coverage of the circle is achieved in this way, which is also used e.g. by nature for the arrangement of leaves on a plant. The Golden Angle increment generates the interleaved arrangement of successive PROPELLER blades shown in Fig. 2a. As a result, motion-corrupted k-space blades are distributed uniformly over the circle spanned by the PROPELLER acquisition. Image artifacts are reduced as compared to conventional PROPELLER imaging, in which a linear order of consecutive k-space blades is applied. For the diametric PROPELLER blades, only a semicircle of rotation has to be considered. For this reason, the rotation angle increment can be the half Golden Angle instead of the full Golden Angle. The (half) Golden Angle increment results in an infinite sequence period and in a correspondingly asymmetric arrangement of the PROPELLER blades in k-space as can be seen in Fig. 2a. However, in a typical PROPELLER acquisition, the number of k-space blades is fixed. In order to achieve a symmetric arrangement of k-space blades, the Golden Angle blade order shown in Fig. 2a can simply be assigned to a symmetric order as shown in Fig. 2b. Here, the rotation angle of the i-th acquired k-space blade is determined by the formula $\varphi(i) = f(i) \cdot 180° / N$, wherein $f(i)$ represents a function that maps the index i to an integral number between 0 and $N-1$ such that the desired order is obtained. For the depicted embodiment $f(i)$ can be tabulated as follows:

i	1	2	3	4	5	6	7	8
$f(i)$	0	3	6	1	4	7	2	5

As illustrated by the arrows in Fig. 2b, the readout gradient rotates about 180° during one acquisition in this case. The blade order shown in Fig. 2c is determined by the

slightly modified formula $\varphi(i) = f(i) \cdot 180° \cdot (1 + 1/N)$. In this case, the readout gradient rotates about 360° during each acquisition.

In Fig. 3, the acquisition of an MR reference data set for multi-slice PROPELLER MRI according to the invention is illustrated. The left diagram in Fig. 3 shows the acquisition of a plurality of k-space blades during the acquisition of a single image slice. The k-space blades are rotated about the center of k-space, so that the total acquired MR data set approximately spans a circle in k-space. In Fig. 3, the central portion of k-space acquired for each k-space blade is indicated as a black circle in the left diagram. Before the acquisition of the k-space blades, a three-dimensional low-resolution MR reference data set is acquired from the central portion of k-space indicated by the tubular central k-space region in the right diagram of Fig. 3. Multiple parallel image slices as also indicated in the right diagram of Fig. 3 are then acquired by the PROPELLER technique, and the MR data acquired from the central portion of k-space is compared to the MR reference data set for each k-space blade in order to estimate and correct motion-induced displacements and phase errors. Since the inital MR reference measurement covers the central portion of k-space of all image slices and (at least approximately) the central k-space portion of all PROPELLER blades, it can serve as a common reference for all k-space blades of the multi-slice acquisition. This approach ensures that no motion-induced misalignment of the image slices occurs during the multi-slice PROPELLER acquisition. The acquisition of the low-resolution MR reference data set takes approximately the same time as the acquisition of one single PROPELLER blade, which means that the technique of the invention minimizes the risk of motion during the acquisition of the MR reference data and does not significantly increase the total scan time.

As described herein before, the invention further proposes a direct approach to compute the weighting factors for sampling density compensation during the reconstruction of an MR image from the MR signals acquired by means of the PROPELLER technique. The approach of the invention combines geometry and prioritization considerations for the computation of the weighting factors. The conventional iterative approach, which is known to be slow and sporadically instable, is avoided in accordance with the invention. Thus, a very rapid and reliable data weighting procedure is obtained. The weigting factor for a signal sample s in readout line l and in k-space blade b is initialized in accordance with the invention with

$$w_0(b,l,s) = w_D(l,s)w_C(b),$$

wherein w_D denotes the weight derived from acquistion times for contrast weighting, which is usually independent of b. w_C denotes the weight derived from correlation measures for (through-plane) motion correction, which is usually dependent on b only. As a next step, the weights are added according to

$$w_1(b,l,s) = \sum_{p,q,r} w_0(p,q,r)d(p,q,r,b,l,s) \quad ,$$

wherein $d(p,q,r,b,l,s)$ denotes a neighborhood indicator factor determined by the geometry of the overlapping areas of the PROPELLER blades. It is of course possible (and it may be necessary) to replace this summation by an appropriate form of interpolation. As a last step, a normalization of the weighting factors is optionally computed in accordance with the formula

$$w_2(b,l,s) = \frac{w_1(b,l,s)}{\left[EE^H w_1\right]_{(b,l,s)}} \quad ,$$

wherein E denotes the encoding matrix of the PROPELLER acquisition, i.e.

$$[E]_{mn} = e^{ik_m x_n}$$

with the k-space sampling positions k_m and the pixel positions x_n, and E^H the corresponding Hermitian. The normalization is preferably computed by applying gridding reconstruction or non-uniform fast Fourier transform principles.

CLAIMS:

1. Device for MR imaging of a body (7) placed in an examination volume, the device (1) comprising

means (2) for establishing a substantially homogeneous main magnetic field in the examination volume,

means (3, 4, 5) for generating switched magnetic field gradients superimposed upon the main magnetic field,

means (6) for radiating RF pulses towards the body (7),

control means (12) for controlling the generation of the magnetic field gradients and the RF pulses,

means (10) for receiving and sampling MR signals, and

reconstruction means (14) for forming MR images from the signal samples,

the device (1) being arranged to

a) generate a series of MR signals by subjecting at least a portion of the body (7) to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein the rotation angle of the k-space blades is incremented during MR signal acquisition by an angle larger than $180°/N$, N being the total number of k-space blades acquired, and

c) reconstruct an MR image from the acquired MR signals.

2. Device of claim 1, wherein the device (1) is further arranged to increment the angle of the k-space blades by the Golden Angle of $137{,}51°$ or by the half Golden Angle of $68{,}75°$.

3. Device of claim 1 or 2, wherein the device (1) is further arranged to select the rotation angle according to the formula $\varphi(i) = f(i) \cdot 180°/N$ or $\varphi(i) = f(i) \cdot 180° \cdot (1 + 1/N)$, wherein $i = 1,2,\ldots N$ represents an index of the consecutively acquired k-space blades, and

$f(i)$ represents a function that maps the index i to an integral number between 0 and $N-1$ such that the rotation angle increment $\varphi(i+1)-\varphi(i)$ is larger than $180°/N$.

4. Device for MR imaging of a body (7) placed in an examination volume, the device (1) comprising

means (2) for establishing a substantially homogeneous main magnetic field in the examination volume,

means (3, 4, 5) for generating switched magnetic field gradients superimposed upon the main magnetic field,

means (6) for radiating RF pulses towards the body (7),

control means (12) for controlling the generation of the magnetic field gradients and the RF pulses,

means (10) for receiving and sampling MR signals, and

reconstruction means (14) for forming MR images from the signal samples, the device (1) being arranged to

a) generate a series of MR signals by subjecting at least a portion of the body (7) to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire an MR reference data set from a central portion of k-space,

c) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein at least a part of said central portion of k-space is acquired for each k-space blade, d) compare the MR data acquired in step c) to the MR reference data set in said central portion of k-space for each k-space blade in order to estimate and correct motion-induced displacements and phase errors, and

e) reconstruct an MR image from the acquired and corrected MR signals.

5. Device according to claim 4, wherein the MR reference data set acquired in step b) is a three-dimensional volume data set.

6. Device according to claim 5, wherein the k-space blades are acquired in step c) for two or more parallel image slices spaced in a direction perpendicular to the plane of rotation of the k-space blades.

7. Device for MR imaging of a body (7) placed in an examination volume, the device (1) comprising

means (2) for establishing a substantially homogeneous main magnetic field in the examination volume,

means (3, 4, 5) for generating switched magnetic field gradients superimposed upon the main magnetic field,

means (6) for radiating RF pulses towards the body (7),

control means (12) for controlling the generation of the magnetic field gradients and the RF pulses,

means (10) for receiving and sampling MR signals, and

reconstruction means (14) for forming MR images from the signal samples,

the device (1) being arranged to

a) generate a series of MR signals by subjecting at least a portion of the body (7) to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquire a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space,

c) weight the acquired MR data, wherein weighting factors are computed directly on the basis of acquisition times for contrast manipulation, correlation measures for motion compensation, and on the basis of the geometry of the overlapping areas of the k-space blades, and

d) reconstruct an MR image from the acquired and weighted MR signals.

8. Device of claim 7, wherein the weighting factors are normalized in step c) before image reconstruction in step d).

9. Method for MR imaging of at least a portion of a body placed in an examination volume of an MR device, the method comprising the following steps:

a) generating a series of MR signals by subjecting at least a portion of

the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein the rotation angle of the k-space blades is incremented during MR signal acquisition by an angle approximating the golden angle of $137{,}51°$ or the half golden angle of $68{,}75°$, and

c) reconstructing an MR image from the acquired MR signals.

10. Method for MR imaging of at least a portion of a body placed in an examination volume of an MR device, the method comprising the following steps:

a) generating a series of MR signals by subjecting at least a portion of the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a three-dimensional MR reference data set from a central portion of k-space,

c) acquiring a plurality of k-space blades according to the PROPELLER scheme from two or more parallel image slices, the k-space blades being rotated about a center of k-space, wherein at least a part of said central portion of k-space is acquired for each k-space blade,

d) comparing the MR data acquired in step c) to the MR reference data set in said central area of k-space for each k-space blade in order to estimate and correct motion-induced displacements and phase errors, and

e) reconstructing an MR image from the acquired and corrected MR signals.

11. Method for MR imaging of at least a portion of a body placed in an examination volume of an MR device, the method comprising the following steps:

a) generating a series of MR signals by subjecting at least a portion of the body to an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space,

c) weighting the acquired MR data, wherein weighting factors are directly computed on the basis of acquisition times for contrast manipulation, correlation

measures for motion compensation, and on the basis of the geometry of the overlapping areas of the k-space blades, and

d) reconstructing an MR image from the acquired and weighted MR signals.

12. Computer program for an MR device, the program comprising instructions for

a) generating an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space, wherein the rotation angle of the k-space blades is incremented during MR signal acquisition by an angle approximating the golden angle of $137{,}51°$ or the half golden angle of $68{,}75°$, and

c) reconstructing an MR image from the acquired MR signals.

13. Computer program for an MR device, the program comprising instructions for

a) generating an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a three-dimensional MR reference data set from a central portion of k-space,

c) acquiring a plurality of k-space blades according to the PROPELLER scheme from two or more parallel image slices, the k-space blades being rotated about a center of k-space, wherein at least a part of said central portion of k-space is acquired for each k-space blade,

d) comparing the MR data acquired in step c) to the MR reference data set in said central area of k-space for each k-space blade in order to estimate and correct motion-induced displacements and phase errors, and

e) reconstructing an MR image from the acquired and corrected MR signals.

14. Computer program for an MR device, the program comprising instructions for

a) generating an MR imaging sequence of at least one RF pulse and switched magnetic field gradients,

b) acquiring a plurality of k-space blades according to the PROPELLER scheme, the k-space blades being rotated about a center of k-space,

c) weighting the acquired MR data, wherein weighting factors are directly computed on the basis of acquisition times for contrast manipulation, correlation measures for motion compensation, and on the basis of the geometry of the overlapping areas of the k-space blades, and

d) reconstructing an MR image from the acquired and weighted MR signals.

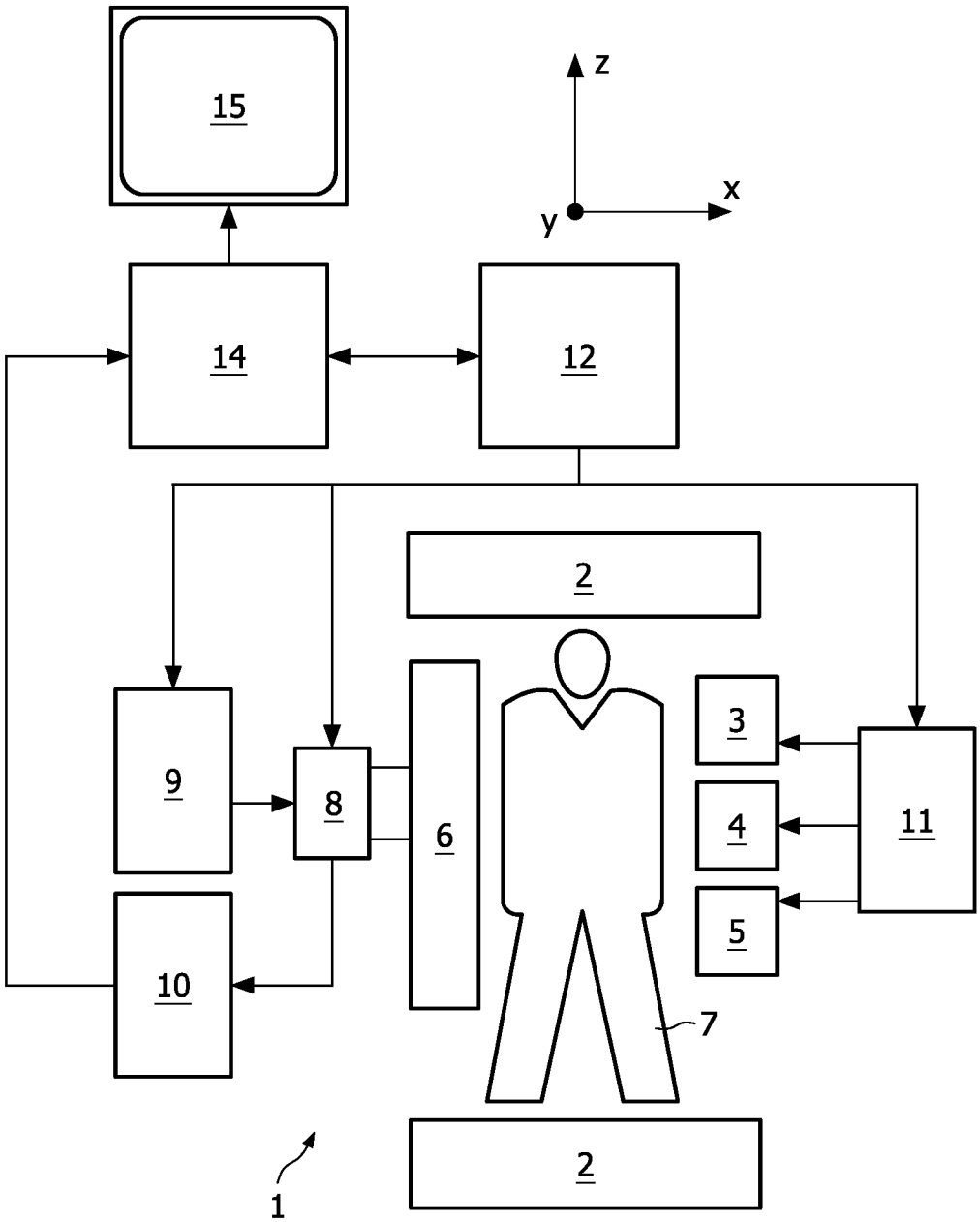


FIG. 1

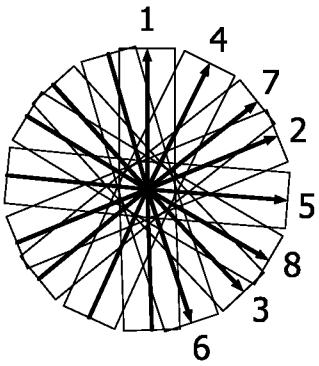


FIG. 2a

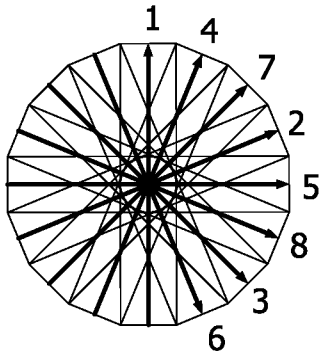


FIG. 2b

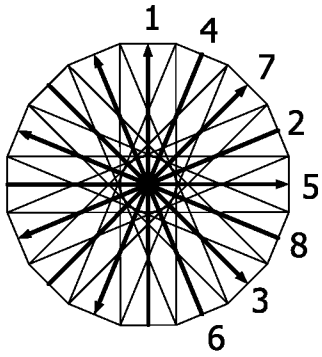


FIG. 2c

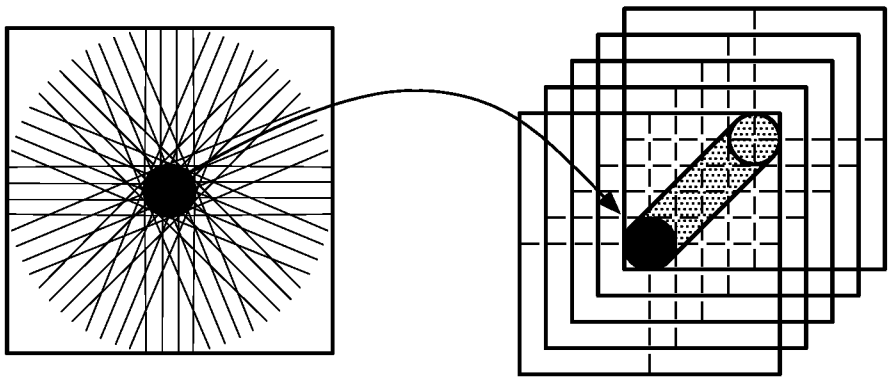


FIG. 3