(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 May 2006 (11.05.2006)

PCT

(10) International Publication Number
WO 2006/048816 A1

(51) International Patent Classification:
G01R 33/3415 (2006.01)

(21) International Application Number:
PCT/IB2005/053549

(22) International Filing Date: 31 October 2005 (31.10.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
04105509.6 4 November 2004 (04.11.2004) EP

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

(72) Inventors; and

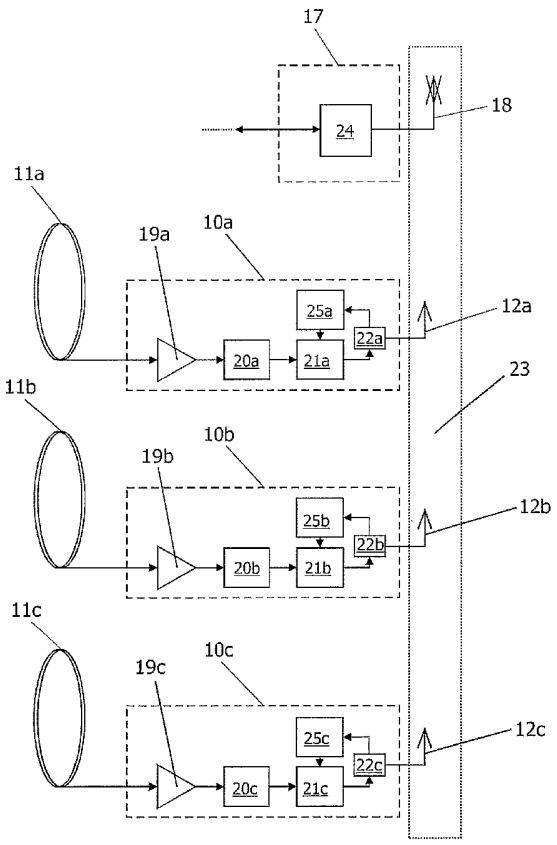
(75) Inventors/Applicants *(for US only)*: **VAN HELVOORT, Marinus, J., A., M.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **VAN LIERE, Filips** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **DE VRIES, Lambertus** [NL/BE]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **DEN BOEF, Johannes, H.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **MELTERS, Marcellinus, H., M., W.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **HAM, Cornelis, L., G.** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **SAES, Marc** [NL/NL]; c/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agents: **COHEN, Julius, S.** et al.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI,

[Continued on next page]

(54) Title: RF RECEIVE COIL ASSEMBLY WITH INDIVIDUAL DIGITIZERS AND MEANS FOR SYNCHRONIZATION THEREOF



(57) Abstract: The invention relates to a device (1) for magnetic resonance imaging of a body (7) placed in a stationary and substantially homogeneous main magnetic field comprising a main magnet (2) for generation of a stationary and substantially homogeneous main magnetic field within the examination zone. In order to provide an MR device (1) which is arranged to allow for massive parallel imaging without extensive cabling between the individual receiving coils and the back end electronics, the invention proposes to make provision for a plurality of receiving units (10a, 10b, 10c) placed in or near the examination zone, which receiving units (10a, 10b, 10c) each comprise a receiving antenna (12a, 12b, 12c) for receiving MR signals from the body, a digitizing means (21a, 21b, 21c) for sampling the received MR signals and for transforming the signal samples into digital signals, and a transmitter (22a, 22b, 22c) for transmitting the digital signals to a central processing unit (13). Further, the device (1) comprises synchronization means (17) for synchronizing the operation of the individual digitizing means (21a, 21b, 21c) of the receiving units (10a, 10b, 10c).

WO 2006/048816 A1

NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

RF RECEIVE COIL ASSEMBLY WITH INDIVIDUAL DIGITIZERS AND MEANS FOR SYNCHRONIZATION THEREOF

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

Furthermore, the invention relates to a method for MR imaging and to a computer program for an MR imaging device.

In MR imaging, pulse sequences consisting of RF and magnetic field gradient pulses are applied to an object (the body of a patient) to generate phase encoded magnetic resonance signals, which are scanned by means of receiving antennas in order to obtain information from the object and to reconstruct images thereof. Since its initial development, the number of clinical 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 information about a number of important functions of the human body. The pulse sequence which is applied during an MR scan determines completely the characteristics of the reconstructed images, such as location and orientation in the object, dimensions, resolution, signal-to-noise ratio, contrast, sensitivity for movements, etcetera. 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 known parallel MRI techniques, multiple receiving antennas with different spatial sensitivity profiles are employed, for example to enhance local sensitivity or to reduce the scan time for a diagnostic image. The latter can be achieved, for example, in accordance with the known SENSE technique by acquiring a smaller set of phase encoded magnetic resonance signals than would actually be necessary to completely cover the predetermined field of view in accordance with Nyquist's theorem.

The above-described SENSE technique as well as other known parallel MR imaging techniques have proven to be very efficient for practical applications. Therefore, modern MR systems increasingly demand massive parallel imaging. This necessarily requires the use of a high number of MR receiving antennas (coils) located in the examination zone of the MR device, each antenna being associated with a separate receiving channel. For connecting the individual receiving antennas to the back end electronics of the MR device, which is usually located outside the actual examination room, many cables are required. This

cabling is expensive and also bulky, which is a major concern when considering the limited space within the examination volume of common MR devices. Particularly in the case of receiving coils integrated in a moving patient support, the necessary cabling is a technical challenge and therefore cost-intensive. The more antennas are used in MR imaging, the more complex the cable handling around the body of the examined patient becomes. Usually, so-called combiner boxes located near the examination zone are used, in which the cables from the individual receiving coils are bundled. From the combiner boxes multifunctional cables lead to the back end electronics of the MR device. Naturally, these multifunctional cables and also the corresponding combiner boxes comprise a plurality of metallic parts and wires. It is a known problem that these metallic parts and wires tend to disturb the radio frequency field in the examination zone and can cause a high local specific absorption rate (SAR) in the tissue of the examined body in the vicinity of the respective metallic parts and wires. This is a major issue with regard to safety of operation of the MR device. For example, a patient may experience local burns of the skin in areas close to wires connecting the receiving antennas to the central processing unit of the MR device.

It is known for example from US 5,245,288 that cabling between MR receiving antennas and the remote signal processing electronics of an MR device can be dispensed with by using wireless transmission of the received and demodulated MR signals from a receiving unit located in the vicinity of the examination zone to the central processing unit of the MR device. The known system uses a mixing stage in which the received MR signal is mixed with a mixing signal of constant frequency. This mixing signal is derived from a reference signal which is also transferred wirelessly to the receiving unit of the known system.

This known technique is unfortunately not applicable for parallel imaging. When using a plurality of wireless receiving units of the known kind, random phase differences and phase fluctuations between the individual mixing stages would cause undesirable image artifacts. Furthermore, the technique of the known system does principally not allow for wireless transmission of MR signals from a plurality of receiving units in parallel due to unresolvable interference of the individual transmission signals.

Therefore it is readily appreciated that there is a need for an improved device for MR imaging which allows for massive parallel imaging using a plurality of receiving antennas. It is consequently the primary object of the present invention to provide an MR device which is arranged to transfer the MR signals received by the individual receiving

antennas to the central processing unit of the MR device in parallel without excessive cabling.

In accordance with the present invention, an MR device for magnetic resonance imaging of a body placed in an examination zone is provided. The device comprises a main magnet for generation of a stationary and substantially homogeneous main magnetic field within the examination zone. Provision is made for a plurality of receiving units placed in or near the examination zone, which receiving units each comprise a receiving antenna for receiving MR signals from the body. The individual receiving units have digitizing means for sampling the received MR signals and for transforming the signal samples into digital signals, which are then transmitted to a central processing unit. The device of the invention further comprises synchronization means for synchronizing the sampling of the MR signals.

The gist of the invention is to transfer a considerable part of the digital electronics from the back end of known MR devices into the examination zone such that the number of cables required between the magnet and the central processing unit can be significantly reduced. The invention enables a drastic increase of the number of receiving channels over conventional MR systems. For the above reasons, a corresponding high number of cables between the individual receiving coils and the back end electronics cannot be handled with the conventional techniques anymore.

The device of the invention is characterized in that each individual receiving unit comprises a digitizing means for transforming the MR signals into digital signal samples, thus enabling the parallel (multiplexed) transfer by digital data transmission without interference between the individual signals. For this purpose, each receiving unit of the MR device also has to be provided with an appropriate transmitter. It is particularly advantageous that only a single common digital data connection for the data transmission between the receiving units and the central processing is required in accordance with the invention.

The invention also addresses the important issue of synchronization of the individual receiving channels of the MR device. The receiving units of the device in accordance with the invention are operating independently. The sampling clocks of the digitizing means of the individual receiving units would have different and random phase relations without the synchronization means. This would cause severe phase distortions of the transmitted signals. For enabling parallel imaging, the MR device of the invention comprises synchronization means synchronizing the operation of the individual digitizing means of the receiving units. The synchronization means ensure that the sampling times of the different

digital signal samples are well defined for each receiving channel, such that phase errors having adverse effects on image quality are effectively avoided.

It has to be noted that the synchronization in accordance with the invention only serves for precise temporal determination of the operation of the digitizing means. It is absolutely not necessary within the meaning of the invention that the signal sampling is performed with identical timing by the individual electronics of the different receiving units.

It has further to be noted that the synchronization of the receiver units does not need to be established over the entire scan duration. In accordance with the invention it is sufficient having the timing of the digitizing means well defined only during the actual signal acquisition. An MR scan typically lasts up to a few minutes and comprises a few hundred to several thousands of acquisition periods, each of the acquisition periods taking only a few milliseconds or even less than a millisecond. Thus there is a requirement for synchronization only during a small time fraction of the complete MR imaging scan.

With the device of the invention it is advantageous if the transmitters of the receiving units are adapted for wireless radio transmission of the digital signals to the central processing unit. Since a completely wireless communication between the individual receiving units and the back end electronics of the MR apparatus is established in this way, the above-mentioned drawbacks of extensive cabling can be effectively avoided. For this embodiment of the invention the individual receiving units of the MR device must comprise appropriate transducers for converting the digital signals into (modulated) radio frequency signals. Standardized electronic components for wireless digital communication with sufficient bandwidth are known as such and are commercially available at low cost. Such components, well known for example in the field of wireless local area computer networks (WLAN), operate for example at a carrier frequency in the 2.4 GHz band and advantageously provide a high data rate that suffices for the application of the invention, even if a comparatively large number of receiving units is employed in parallel.

As an alternative, the transmitters of the receiving units can be adapted for transmission of the digital signals to the central processing unit over an optical fibre. Optical data transmission also has the advantage that standardized electronic components are commercially available and that the achievable data rates are high. Since optical fibres are required, the above-mentioned problems in connection with complex cabling cannot be completely avoided. But optical fibres still have the advantage that they include no metallic parts or wires such that the radio frequency field in the examination zone cannot be disturbed and problems relating to increase SAR are also avoided.

The synchronization means of the MR device in accordance with the invention may comprise a reference signal generator for generation of a reference signal that is supplied to the receiving units. This reference signal can for example be used to establish a fixed phase relation of the sampling clocks of the digitizing means of the individual receiving units.

In accordance with one embodiment of the invention, the reference signal can simply be a pilot tone that is generated in the examination zone having a frequency close to the frequency of the MR signals. The MR signals usually have a bandwidth between 500 Hz and 1.5 MHz. The signals picked up by the receiving antennas of the receiving units are these MR signals spaced around the Larmor frequency (e.g. 64 MHz at 1.5 T). The pilot tone can be generated just outside the signal bandwidth of the MR signals such that it will still be received by the receiving antennas of the individual receiving units together with the actual MR signals without interfering with the MR signals. The pilot tone then propagates throughout the complete receive chain of the MR device and can be used to synchronize the distributed electronics of the receiving units. In the most simple case, the pilot tone is used not until image reconstruction to relate all signal samples received in parallel to a common time frame. With this embodiment, synchronization of the operation of the digitizing means is performed as a pure post-processing of the digital signals. It is of course also possible to provide the reference signal to the digitizing electronics of the receiving units over an appropriate wired connection. If demodulation of the received MR signals is performed by the receiving units prior to digitization, the reference signal may for example be injected into the corresponding base band signal to provide a common time frame for the digital signals.

It has to be noted in this context, that the synchronization means of the MR device according to the invention may not necessarily serve to physically control the operation of the individual digitizing means. When a reference signal is employed in the afore described manner, the actual digitization of the signals acquired with the different receiving units is performed independently and therefore in a virtually asynchronous manner. Synchronization in the context of the invention means merely definition of a common time frame for signal sampling. For this purpose, the actual physical operation of the different digitizing means is not necessarily affected by the synchronization means within the meaning of the invention.

According to a further embodiment of the invention, the receiving units may be arranged such that the sampling frequencies of the digitizing means are derived from the reference signal. Conventional MR devices make use of a single central clock from which

multiple frequencies are derived as required, thereby achieving synchronous operation throughout the whole system. In conventional MR devices the distribution of the central clock is limited to the central processing unit, which is usually a single rack located outside the actual examination room. In accordance with the invention, the central clock signal can be supplied as a reference signal via appropriate cabling to wirelessly to the individual receiving units for establishing synchronous operation of their respective digitization means. Calibration of a delay of the central clock signal might be necessary since the time for propagation of the clock signal to the receiving units has to be taken into account. In a practical implementation of the invention using wireless transmission of the digital signals from the receiving units to the central processing units, the sampling clock of the digitizing means may be transmitted wirelessly as well. It may for example be derived from the carrier frequency of the radio frequency communication link or from other lower frequency signals. For this purpose, the receiving units may be equipped with local oscillators locked to the transmitted reference signal, for example by means of appropriate phase locked loop (PLL) circuits. The frequency of the wirelessly transmitted clock signal should preferably match an integer multiple of the actual sampling frequency of the digitizing means. Influences on the resulting MR image can be avoided in this way.

In accordance with a preferred embodiment of the invention, the receiving units may each comprise a stretch generator which is controlled by a stretch controller of the synchronization means. The stretch controller prescribes the timing for the operation of the digitizing means of the individual receiving units. The stretch generator consists of an input command first-in first-out (FIFO) buffer, a timer and 'next' and 'actual' registers. The output and input events of the stretch generator are controlled with high temporal precision (e.g. 1 nano second precision and 100 nano seconds resolution) by the commands stored in the FIFO buffer. Stretch generators can generally be used to generate waveforms. In MR devices stretch generators are employed for example for the control of front-end devices during MR measurements. In accordance with the invention, the stretch generator is used to precisely control the timing of the sampling of the received MR signals. The central processing unit of the MR device of the invention may comprise a stretch controller connected to the stretch generators of the individual receiving units via the respective communication link (wireless radio transmission or optical fibre). Bit errors occurring during signal transmission can advantageously be dealt with using the above-described principle of operation of the stretch generator/controller. A remote stretch operation may be implemented by establishing a stretch on the "far end" (i.e. on the end of the receiving units of the MR device) of the

communication link. Two synchronized digital counters can be used on the "near end" (i.e. on the end of the back end electronics of the MR device) and on the "far end" of the communication link respectively to guarantee correct timing. For the synchronization of the respective counters a reference signal can be used in the way described above.

With the MR device of the invention it is also advantageous to employ a signal correlation means being arranged to correlate MR signals and/or noise signals received by different receiving units and to determine the sampling times of the digital signals generated by the digitizing means of the individual receiving units on the basis of this correlation. The receiving antennas of neighboring receiving units have an at least partially overlapping field of view and are at least residually inductively coupled. Because of this, the MR signals and also the noise registered by these receiving units are correlated. This correlation can be used to define a common time frame of the MR signals received and digitized by the individual receiving units. A synchronization of the operation of the receiving units can be achieved for example by recalculating the sampling times of the digital signals on the basis of the correlation before the actual image reconstruction.

The invention not only relates to a device but also to a method for magnetic resonance imaging of at least a portion of a body placed in an examination zone of an MR device, the method comprising the following steps: Exciting nuclear magnetization within the body by means of an MR imaging sequence comprising RF pulses and switched magnetic field gradients; acquiring MR signals from the body by means of a plurality of receiving units placed in or near the examination zone, which receiving units each comprise a receiving antenna; sampling the received MR signals and transforming the signal samples into digital signals, wherein synchronization means are used for synchronizing the operation of individual digitizing means of the receiving units; transmitting the digital signals to a central processing unit; and reconstructing an MR image from the digital signal samples.

A computer program adapted for carrying out the imaging procedure of the invention can advantageously be implemented on computer hardware 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.

The following 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 embodiment of a magnetic resonance scanner according to the invention,

Fig. 2 shows schematically an arrangement of a plurality of receiving units and corresponding synchronization means in accordance with the invention.

In Fig.1 a magnetic resonance 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 are energized via a power supply 9. The apparatus 1 further comprises a radiation emitter 6, an antenna or coil, for emitting radio frequency (RF) pulses to a body 7 placed in the examination zone of the device 1, the radiation emitter 6 being coupled to a modulator 8 for generating and modulating the RF pulses. Also provided are receiving units 10a, 10b, 10c placed in or near the examination zone of device 1. Each of the receiving units 10a, 10b, 10c comprises a receiving antenna 11a, 11b, 11c respectively for receiving MR signals from the body 7. These receiving antennas are forming a coil array for the purpose of parallel imaging. The receiving antennas 11a, 11b, 11c can for example be separate surface coils with different spatial sensitivity profiles as they are required for SENSE imaging. The received MR signals are sampled by the individual receiving units 10a, 10b, 10c and transformed into digital signals. The receiving units 10a, 10b, 10c are equipped with signal transmission antennas 12a, 12b, 12c for wireless radio transmission of the digital signals in a multiplexed fashion to a corresponding data processing unit 13, for example a computer equipped with an radio antenna 14, for transformation of the received digital magnetic resonance signals into an image, for example in accordance with the known SENSE technique. This image can be made visible on a visual display unit 15. The modulator 8, the emitter 6 and the power supply 9 for the gradient coils 3, 4 and 5 are controlled by a control system 16 to generate the actual imaging sequence for parallel imaging. The control system 16 is further connected to a synchronization means 17 for synchronization of the digitizing operation of the receiving units 10a, 10b, 10c. In the depicted embodiment of the MR device the synchronization means 17 generates a reference signal, a so-called pilot tone, that is wirelessly supplied via a pilot tone antenna 18 to the receiving units 10a, 10b, 10c. It is

of course also possible to transmit the pilot tone via emitter 6 in an alternative embodiment. This pilot tone is registered by the receiving units 10a, 10b, 10c via the receiving antennas 11a, 11b, 11c together with the MR signals during image acquisition. The pilot tone propagates through the whole receiving chain of the device 1 and can be used by the processing unit 13 to define a common time frame for the digital signal samples generated by the individual receiving units 10a, 10b, 10c. In this way, the operation of the independent digitizing means of the receiving units 10a, 10b, 10c is synchronized as a pure post-processing step carried out by the central processing unit 13 during image reconstruction.

With reference to Fig.2, an arrangement of a plurality of receiving units 10a, 10b, 10c and corresponding synchronization means 17 in accordance with the invention is shown. The receiving units 10a, 10b, 10c are equipped with receiving coils 11a, 11b, 11c for receiving MR signals from the body of an examined patient. The receiving coils 11a, 11b, 11c are connected to sensitive analog radio frequency preamplifiers 19a, 19b, 19c. The receiving units 10a, 10b, 10c further include variable attenuators 20a, 20b, 20c for adjusting the gain in accordance with the amplitude of the received MR signals. The attenuators 20a, 20b, 20c are connected to analog-to-digital converters 21a, 21b, 21c forming the digitizing means of the receiving units 10a, 10b, 10c. The digital signals generated by the analog-to-digital converters are supplied to transmitters 22a, 22b, 22c for (multiplexed) digital radio transmission over a wireless radio communication link 23 of the MR device. For this purpose, each of the receiving units is equipped with a radio signal transmission antenna 12a, 12b, 12c. The synchronization means 17 of the embodiment depicted in Fig.2 comprises a wireless digital radio communication module 24 connected to antenna 18 for establishing the radio communication between the receiving units 10a, 10b, 10c and a central processing unit of the MR device not depicted in Fig.2. For the purpose of synchronization of the operation of the digitizing means 21a, 21b, 21c of the individual receiving units 10a, 10b, 10c in accordance with the invention, the sampling clocks of the analog-to-digital converters 21a, 21b, 21c are derived from local oscillators 25a, 25b, 25c being connected to the transmitters 22a, 22b, 22c. The local oscillators 25a, 25b, 25c are locked to the carrier frequency of the digital communication link 23, for example by means of an appropriate PLL circuit not depicted in Fig.2.

CLAIMS:

1. MR device for magnetic resonance imaging of a body (7) placed in an examination zone, the device (1) comprising:

a main magnet (2) for generation of a stationary and substantially homogeneous main magnetic field within the examination zone;

a plurality of receiving units (10a, 10b, 10c) placed in or near the examination zone, which receiving units (10a, 10b, 10c) each comprise a receiving antenna (12a, 12b, 12c) for receiving MR signals from the body, a digitizing means (21a, 21b, 21c) for sampling the received MR signals and for transforming the signal samples into digital signals, and a transmitter (22a, 22b, 22c) for transmitting the digital signals to a central processing unit (13); and

synchronization means (17) for synchronizing the sampling of the MR signals.

2. MR device of claim 1, wherein the transmitters (22a, 22b, 22c) of the receiving units (10a, 10b, 10c) are adapted for wireless radio transmission of the digital signals to the central processing unit (13).

3. MR device of claim 1, wherein the transmitters of the receiving units are adapted for transmission of the digital signals to the central processing unit over an optical fibre.

4. MR device of claim 1, wherein the synchronization means (17) comprises a reference signal generator for generation of a reference signal, which reference signal is supplied to the receiving units (10a, 10b, 10c).

5. MR device of claim 4, wherein the reference signal is a radio frequency signal to be received by the receiving units (10a, 10b, 10c) in addition to the MR signals.

6. MR device of claim 4, wherein the receiving units (10a, 10b, 10c) are arranged such that the sampling frequencies of the digitizing means (21a, 21b, 21c) are derived from the reference signal.

7. MR device of claim 1, wherein the receiving units (10a, 10b, 10c) each comprise a stretch generator, the stretch generator being controlled by a stretch controller of the synchronization means (17), which stretch controller prescribes the timing for the operation of the digitizing means (21a, 21b, 21c) of the individual receiving units (10a, 10b, 10c).

8. MR device of claim 1, wherein the synchronization means (17) comprises a signal correlation means, which signal correlation means is arranged to correlate MR signals and/or noise signals received by different receiving units (10a, 10b, 10c) and to determine the sampling times of the digital signals generated by the digitizing means (21a, 21b, 21c) of the individual receiving units (10a, 10b, 10c) on the basis of this correlation.

9. Method for MR imaging of at least a portion of a body (7) placed in an examination zone of an MR device (1), the method comprising the following steps:

exciting nuclear magnetization within the body (7) by means of an MR imaging sequence comprising RF pulses and switched magnetic field gradients;

acquiring MR signals from the body (7) by means of a plurality of receiving units (10a, 10b, 10c) placed in or near the examination zone, which receiving units (10a, 10b, 10c) each comprise a receiving antenna and a digitizing means (21a, 21b, 21c);

sampling the received MR signals and transforming the signal samples into digital signals, wherein synchronization means (17) are used for synchronizing the sampling of the MR signals;

transmitting the digital signals to a central processing unit (13); and

reconstructing an MR image from the digital signal samples.

10. Method of claim 9, wherein the digital signals are transmitted from the receiving units (10a, 10b, 10c) to the central processing unit (13) over a wireless digital data connection (23).

11. Computer program for an MR device, with instructions for:

generating an MR imaging sequence comprising RF pulses and switched magnetic field gradients by means of the MR device;

synchronizing the sampling of MR signals by individual digitizing means of a plurality of receiving units of the MR device;

processing sampled and digitized MR signals transmitted from the individual receiving units;

reconstructing an MR image from the digital signal samples.

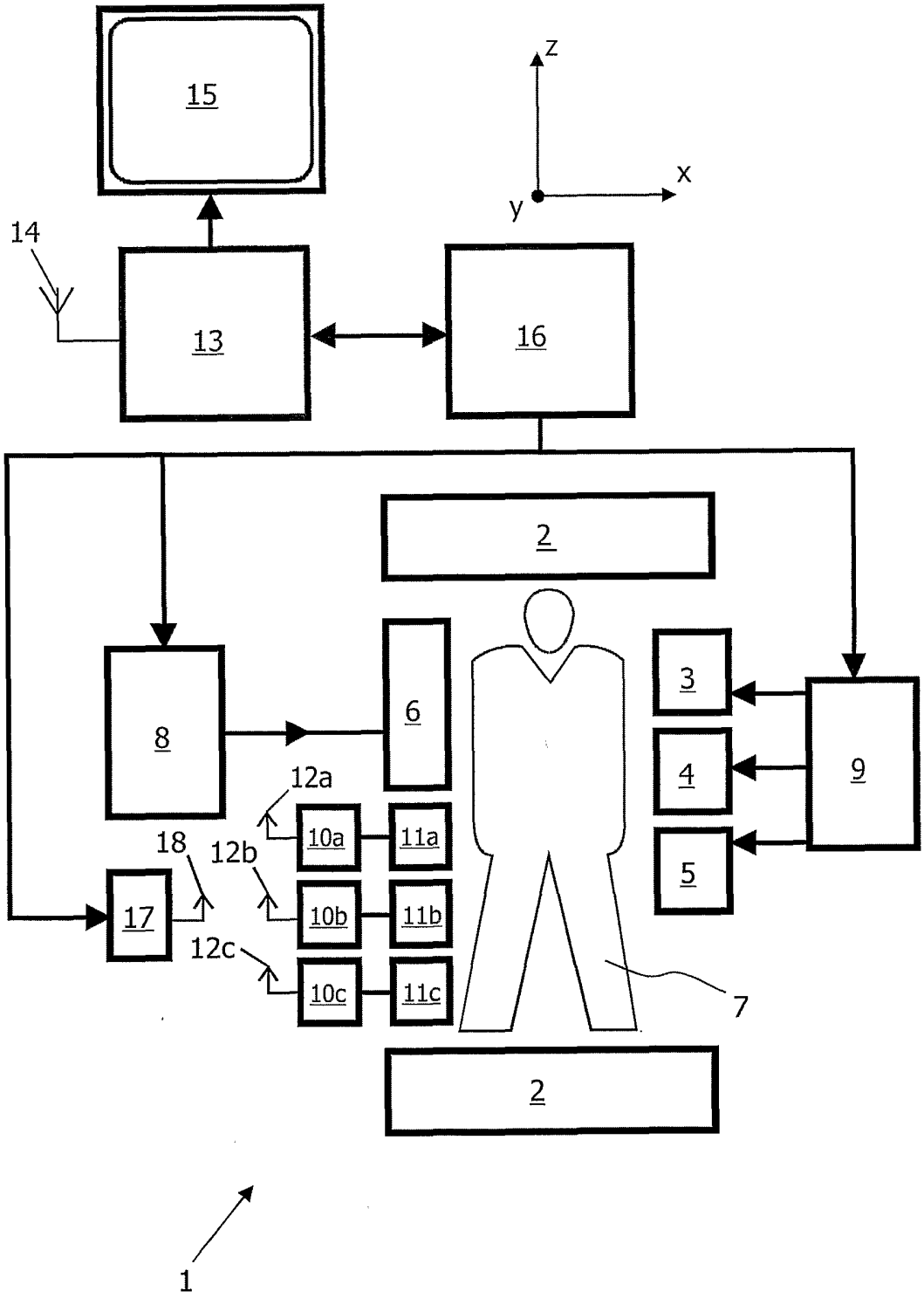

15
z
x
y
14
13
16
2
8
6
3
4
5
9
12a
10a
11a
18
12b
17
10b
11b
12c
10c
11c
7
2
1

FIG.1

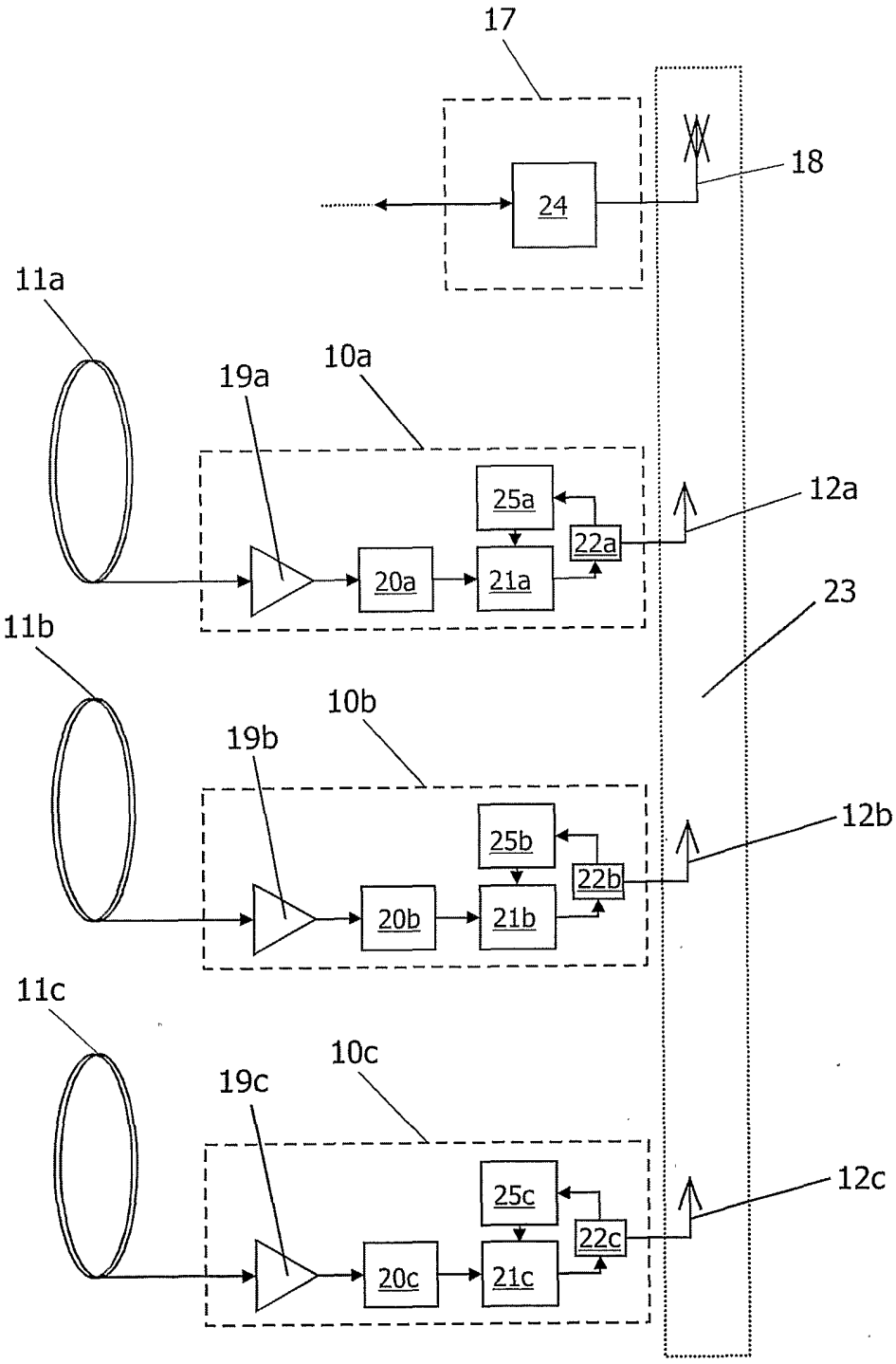

17
18
24
11a
19a
10a
25a
22a
12a
20a
21a
23
11b
10b
19b
25b
22b
12b
20b
21b
11c
10c
19c
25c
22c
12c
20c
21c

FIG.2

INTERNATIONAL SEARCH REPORT

IB2005/053549

A. CLASSIFICATION OF SUBJECT MATTER
G01R33/3415

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, COMPENDEX, INSPEC, BIOSIS, EMBASE, MEDLINE, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 384 536 A (MURAKAMI ET AL) 24 January 1995 (1995-01-24) column 2, line 13 - line 44 column 4, line 29 - column 8, line 50 figures 2,7A,7B,8,9	1-5,7
Y		10

X	US 5 578 925 A (MOLYNEAUX ET AL) 26 November 1996 (1996-11-26) column 6, lines 22-38 figure 8	1,4,9,11
Y		10

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 2006	20/01/2006

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Streif, J

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	SCOTT G, YU K: "Wireless transponders for RF coils: Systems issues" PROCEEDINGS OF THE INTERNATIONAL SOCIETY FOR MAGNETIC RESONANCE IN MEDICINE, 13TH SCIENTIFIC MEETING AND EXHIBITION, MIAMI BEACH, FLORIDA, USA, 7-13 MAY 2005, 7 May 2005 (2005-05-07), page 330, XP002361745 the whole document	1-5,9-11
A	WO 2004/089211 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; TUITHOF, HANS, H; DEN BOEF, JOHAN) 21 October 2004 (2004-10-21) the whole document	1-11
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 25, 12 April 2001 (2001-04-12) & JP 2001 224572 A (GE YOKOGAWA MEDICAL SYSTEMS LTD), 21 August 2001 (2001-08-21) abstract	1-11
A	US 5 245 288 A (LEUSSLER ET AL) 14 September 1993 (1993-09-14) cited in the application the whole document	1-11
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 05, 30 May 1997 (1997-05-30) & JP 09 024036 A (HITACHI MEDICAL CORP), 28 January 1997 (1997-01-28) abstract	1-11
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 571 (C-1267), 2 November 1994 (1994-11-02) & JP 06 209922 A (YOKOGAWA MEDICAL SYST LTD), 2 August 1994 (1994-08-02) abstract	1-11

INTERNATIONAL SEARCH REPORT

IB2005/053549

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5384536 A	24-01-1995	JP 3168675 B2	21-05-2001
		JP 5261083 A	12-10-1993
US 5578925 A	26-11-1996	DE 69624641 D1	12-12-2002
		DE 69624641 T2	18-09-2003
		EP 0759560 A1	26-02-1997
		JP 9117434 A	06-05-1997
WO 2004089211 A	21-10-2004	NONE	
JP 2001224572 A	21-08-2001	NONE	
US 5245288 A	14-09-1993	DE 4126537 A1	11-02-1993
		EP 0527530 A1	17-02-1993
		JP 3187152 B2	11-07-2001
		JP 5261085 A	12-10-1993
JP 09024036 A	28-01-1997	NONE	
JP 06209922 A	02-08-1994	NONE	