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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 May 2016 (19.05.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/077438 A3

(51) International Patent Classification:
A61B 5/055 (2006.01)

(21) International Application Number:
PCT/US2015/060117

(22) International Filing Date:
11 November 2015 (11.11.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/078,378 11 November 2014 (11.11.2014) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(88) Date of publication of the international search report:
18 August 2016

(54) Title: PULSE SEQUENCES FOR LOW FIELD MAGNETIC RESONANCE

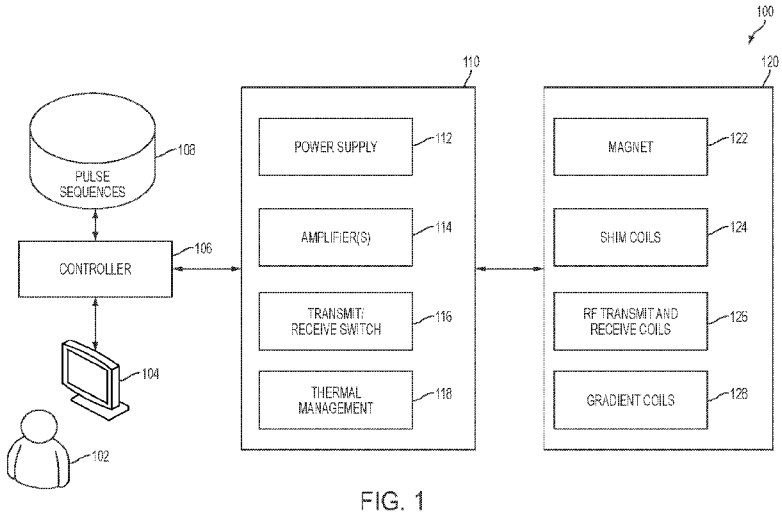

FIG. 1

(57) Abstract: A low-field magnetic resonance imaging (MRI) system. The system includes a plurality of magnetics components comprising at least one first magnetics component configured to produce a low-field main magnetic field B0 and at least one second magnetics component configured to acquire magnetic resonance data when operated, and at least one controller configured to operate one or more of the plurality of magnetics components in accordance with at least one low-field zero echo time (LF-ZTE) pulse sequence.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060117

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 5/055 (2015.01)
CPC - A61B 5/055 (2015.12)
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)
IPC(8) - A61B 5/055; G01N 24/08; G01R 33/54 (2015.01)
CPC - A61B 5/055; G01N 24/08; G01R 33/54 (2015.12)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
US: 324312; 324262; 600410 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, Google Scholar, Google
Search terms used: low-field, magnetic, resonance, imaging,"second magnetic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/0010497 A1 (EHMAN et al) 12 January 2012 (12.01.2012) entire document	1-3, 17, 18
Y	Li et al. Correction of Excitation Profile in Zero Echo Time (ZTE) Imaging Using Quadratic Phase-Modulated RF Pulse Excitation and Iterative Reconstruction. 2014.04 [retrieved on 2016-02-10]. Retrieved from the Internet:<URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4136480/ >. entire document.	1-3, 17, 18
A	US 20040021464 A1 (FAHRIG et al) 05 February 2004 (05.02.2004) entire document	1-3, 17, 18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 February 2016	25 FEB 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060117

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-16
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-3, 17, 18

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060117

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-18, drawn to a low-field magnetic resonance imaging system.
Group II, claims 19-36, drawn to a low-field magnetic resonance imaging system comprising RF excitation pulses.
Group III, claims 37-63, drawn to a low-field magnetic resonance imaging system comprising applying a series of RF pulses having at least one parameter.

The inventions listed as Groups I, II and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: at least one low-field zero echo time (LF-ZTE) pulse sequence as claimed therein is not present in the invention of Groups II and III. The special technical feature of the Group II invention: a flip angle that reduces effect of Bo inhomogeneities on net transverse magnetization as claimed therein is not present in the invention of Groups I or III. The special technical feature of the Group III invention: apply a series of RF pulses having at least one parameter that varies during a respective series of pulse repetition periods of the pulse sequence as claimed therein is not present in the invention of Groups I or II.

Groups I, II and III lack unity of invention because even though the inventions of these groups require the technical feature of a low-field magnetic resonance imaging (MRI) system, comprising: a plurality of magnetics components comprising at least one first magnetics component configured to produce a low-field main magnetic field Bo and at least one second magnetics component configured to acquire magnetic resonance data when operated, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2004/0021464 A1 (FAHRIG et al) 05 February 2004 (05.02.2004) teaches a low-field magnetic resonance imaging (MRI) system (Paras. 7-8), comprising: a plurality of magnetics components comprising at least one first magnetics component configured to produce a low-field main magnetic field Bo and at least one second magnetics component configured to acquire magnetic resonance data when operated (lower portion of the image demonstrating B0 inhomogeneity while in the baseline condition, the B0 main field had only a two parts per million (ppm) inhomogeneity, Para. 15 and Figs. 4A-4B).

Since none of the special technical features of the Group I, II or III inventions are found in more than one of the inventions, unity of invention is lacking.