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[Continued on next page]

(54) Title: MULTI-ECHO MRI USING REPEATED SAMPLING OF K-LINES WITH DIFFERENT SEQUENTIAL ORDER PER REPETITION

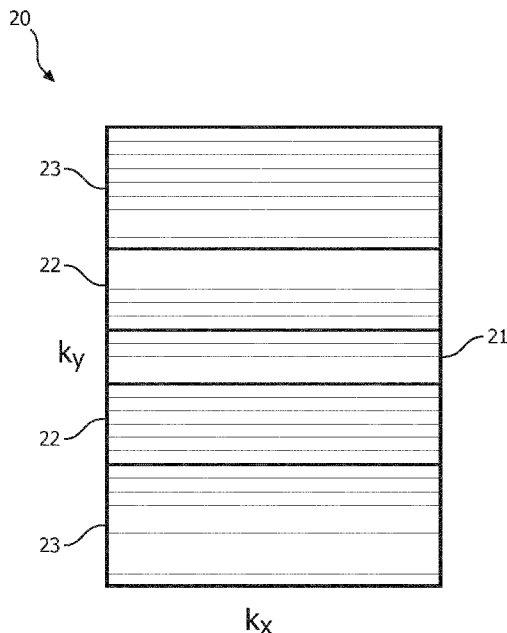


FIG. 2

(57) Abstract: The invention relates to a method of MR imaging of at least an object (10) placed in an examination volume of a MR device (1). It is an object of the invention to enable fast MR imaging using a multi-echo imaging technique which is robust with respect to motion. The method of the invention comprises the steps of: - generating echo signals by subjecting the object (10) to an imaging sequence, - acquiring the echo signals, each echo signal being attributed to a k-space line, wherein a number of k-space lines, which are adjacently arranged in a part of k-space, are repeatedly sampled, with said number of k-space lines being sampled in a different sequential order per repetition, and - reconstructing a MR image from the acquired echo signals. Moreover, the invention relates to a MR device for carrying out this method as well as to a computer program to be run on a MR device.

**Declarations under Rule 4.17:**

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

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

**Published:**

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

**(88) Date of publication of the international search report:**

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INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2015/061441

A. CLASSIFICATION OF SUBJECT MATTER  
INV. G01R33/48 G01R33/50 G01R33/56 G01R33/561 G01R33/565  
ADD.  
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 practicable, search terms used)  
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/061779 A1 (FEIWEIER THORSTEN [DE]) 13 March 2008 (2008-03-13) cited in the application paragraph [0058] - paragraph [0113] -----	1-7,9, 13-15
X,P	BECK ET AL: "A novel partial averaging approach for reducing motion ghosting in Dixon TSE", PROCEEDINGS OF THE INTERNATIONAL SOCIETY FOR MAGNETIC RESONANCE IN MEDICINE, 23ND ANNUAL MEETING AND EXHIBITION, TORONTO, CANADA, 30 MAY - 5 JUNE 2015, vol. 23, 15 May 2015 (2015-05-15), page 3649, XP040669325, the whole document ----- -/--	1-7,9-15

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  3 September 2015	Date of mailing of the international search report  07/12/2015
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Raguin, Guy
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2015/061441

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>GUOBIN LI ET AL: "Reducing fluctuation of train trajectories in 3D TSE imaging with compressed sampling", PROCEEDINGS OF THE INTERNATIONAL SOCIETY FOR MAGNETIC RESONANCE IN MEDICINE, 21ST ANNUAL MEETING AND EXHIBITION, SALT LAKE CITY, UTAH, USA, 20-26 APRIL 2013, vol. 21, 6 April 2013 (2013-04-06), page 3711, XP055150517, the whole document</p> <p style="text-align: center;">-----</p>	2,3,5,9
A	<p>DUAN-DUAN LIU ET AL: "Under-sampling trajectory design for compressed sensing MRI", THE EFFECT OF APPLIED COMPRESSIVE LOADING ON TISSUE-ENGINEERED CARTILAGE CONSTRUCTS CULTURED WITH TGF-BETA3, IEEE, 28 August 2012 (2012-08-28), pages 73-76, XP032462863, ISSN: 1557-170X, DOI: 10.1109/EMBC.2012.6345874 the whole document</p> <p style="text-align: center;">-----</p>	3,7,9
A	<p>TINGFANG ZHANG ET AL: "Variable Density K-space Trajectories for Reducing Aliasing Artifacts in MRI Reconstruction", MULTIMEDIA SIGNAL PROCESSING, 2005 IEEE 7TH WORKSHOP ON, IEEE, PI, 1 October 2005 (2005-10-01), pages 1-4, XP031018263, ISBN: 978-0-7803-9288-5 the whole document</p> <p style="text-align: center;">-----</p>	3

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/EP2015/061441

## 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.:  
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 additional sheet

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 an 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.:

1-7, 9-13(completely); 14, 15(partially)

### 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.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-7, 9-13(completely); 14, 15(partially)

MRI method, device and computer program, whereby a multi-echo imaging sequence is used to repeatedly sample a number of k-space lines, wherein said number of k-space lines are sampled in a differential sequential order and at different spin conditions per repetition.

1.1. claims: 1-7, 9, 13(completely); 14, 15(partially)

MRI method, device and computer program, whereby a multi-echo imaging sequence is used to repeatedly sample a number of k-space lines, wherein said number of k-space lines are sampled in a differential sequential order and at different spin conditions per repetition, wherein partial averaging, variable density sampling and/or a random sequential order is used.

1.2. claims: 10-12(completely); 14, 15(partially)

MRI method, device and computer program, whereby a multi-echo Dixon sequence is used to repeatedly sample a number of k-space lines, wherein said number of k-space lines are sampled in a differential sequential order and at different spin conditions per repetition, and signal contributions from water and fat are separated.

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2. claims: 8(completely); 14, 15(partially)

MRI method, device and computer program, whereby a multi-echo imaging sequence is used to repeatedly sample a number of k-space lines, wherein said number of k-space lines are sampled in a differential sequential order and at different spin conditions per repetition, and motion information is derived from the echo signals acquired from the repeatedly sampled k-space lines.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/061441

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 2008061779	A1	13-03-2008	CN 101144853 A	19-03-2008
			DE 102006042998 A1	27-03-2008
			JP 5361160 B2	04-12-2013
			JP 2008068089 A	27-03-2008
			US 2008061779 A1	13-03-2008
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