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# Datasheet for the decision of 12 December 2006

**Case Number:** T 1517/05 - 3.4.01

**Application Number:** 98116655.6

**Publication Number:** 0909958

**IPC:** G01R 33/561

**Language of the proceedings:** EN

**Title of invention:**
Use of navigator echoes for the correction of motion artifacts in MRI

**Applicant:**
HITACHI MEDICAL CORPORATION

**Opponent:**
-

**Headword:**
-

**Relevant legal provisions:**
EPC Art. 52(1), 56

**Keyword:**
"Inventive step - (no)"

**Decisions cited:**
-

**Catchword:**
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

**Case Number:** T 1517/05 - 3.4.01

# D E C I S I O N
**of the Technical Board of Appeal 3.4.01**
**of 12 December 2006**

**Appellant:** HITACHI MEDICAL CORPORATION
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Chiyoda-ku
Tokyo 101-0047 (JP)

**Representative:** Strehl Schübel-Hopf & Partner
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**Decision under appeal:** **Decision of the Examining Division of the European Patent Office posted 22 July 2005 refusing European application No. 98116655.6 pursuant to Article 97(1) EPC.**

**Composition of the Board:**

**Chairman:** B. Schachenmann
**Members:** R. Bekkering
H. Wolfrum

## Summary of Facts and Submissions

I. European patent application 98 116 655.6 (publication no. EP-A-0 909 958) was refused pursuant to Article 97(1) EPC by a decision of the examining division dispatched on 22 July 2005, on the ground of lack of inventive step (Articles 52(1) and 56 EPC), as well as lack of clarity and support by the description (Article 84 EPC).

II. The applicant (appellant) lodged an appeal against the decision on 1 September 2005. The appeal fee was paid on 29 September 2005. The statement setting out the grounds of appeal was received on 1 December 2005.

III. Reference was made *inter alia* to the following prior art documents:

D1: PATENT ABSTRACTS OF JAPAN vol. 1995, no. 03, 28 April 1995 & JP-A-06 343 621, 20 December 1994 and English translation

D5: US-A-5 539 312

IV. Oral proceedings, requested as an auxiliary measure by the appellant, were held on 12 December 2006.

V. The appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the following documents:

Main request:

Claims: no. 1 to 10 filed in the oral proceedings on 12 December 2006;
Description: pages 1 to 4, 4a, 5 to 25 filed with the grounds of appeal on 1 December 2005;
Drawings: Sheets 1/4 to 4/4 as published.

Auxiliary request:

Claims: no. 1 to 8 filed in the oral proceedings on 12 December 2006;
Description and drawings as for the main request.

VI. Claim 1 according to the main request reads as follows:

"*1. A magnetic resonance imaging method comprising the steps of:*
*irradiating an RF pulse (201, 2011, 2012) of magnetic resonance frequencies toward a predetermined slicing surface of an object to be inspected;*
*then detecting an echo signal group (207) sequentially produced in association with the irradiation of the RF pulse (201, 2011, 2012);*
*reconstructing an image of the predetermined slicing surface by making use of a plurality of echo signal groups (207) which have been acquired by repeating said irradiation step and said echo signal group detecting step a plurality of times and which constitute echo signals of all phase encodings necessary for reconstructing the image;*
*further reconstructing a subsequent image of the predetermined slicing surface by making use of a part of the plurality of echo signal groups which have been*

*used for the previous image reconstruction and an echo signal group which has been newly acquired by performing subsequently said irradiation step and said echo signal group detecting step at least once; and repeating said further step of reconstructing the subsequent image while renewing a part of the plurality of echo signal groups used for the image reconstruction,* ***characterised*** *in that the magnetic resonance imaging method further comprises the steps of:*
*introducing in each of said echo signal group detecting steps at least one navigator echo (3021, 3022) for each of the echo signal groups;*
*selecting one of the respective navigator echoes introduced for the plurality of echo signal groups which are used for reconstructing an image as a reference navigator echo exclusively for the reconstruction of the image and the remaining navigator echoes as monitor navigator echoes;*
*determining phase differences between the reference navigator echo and the monitor navigator echoes; and correcting, in k-space, the phases of echo signal groups to which the respective monitor navigator echoes belong based on the determined phase differences;*
*wherein in the step of reconstructing a subsequent p-th image, a new reference navigator echo is selected,*
*wherein the new reference navigator echo has the same irradiation pulse shot number n among the navigator echoes for the p-th image as the previous reference navigator echo among the navigator echoes for the (p-1)-th image.*"

Claim 1 according to the auxiliary request differs from that according to the main request in that, in the step of further reconstructing a subsequent image, it reads

"*by performing subsequently said irradiation step and said echo signal group detecting step more than once*" and in that it contains the following additional feature at the end of the claim "*wherein the reference navigator echo belongs to an echo signal group generated from a low spatial frequency region in k-space*".

Furthermore, both requests include an independent claim directed to a corresponding magnetic resonance imaging device.

## Reasons for the Decision

1. The appeal complies with the requirements of Articles 106 to 108 and Rule 64 EPC and is, therefore, admissible.

2. Main request

2.1 Novelty, inventive step

2.1.1 Document D1, cited in the application as filed on page 20 of the description, provides the closest prior art.

Document D1 discloses a magnetic resonance imaging (MRI) method, in particular echo planar imaging, for repeatedly taking images so as to provide a moving image of, for instance, brain function. To this end the k-space is divided in the phase-encoding direction into a number (eg three) of regions. Each image is built from the data obtained from each of the three regions.

However, in order to provide a new image at a rate higher than the data acquisition for an entire new image would require, only new data is acquired for two of the three regions and the previously acquired data for the third region is used for building the image (see figure 1 and corresponding description).

Phase changes in the detected signals from the respective regions may occur due to factors such as distortion and instability of the equipment. In order to compensate for such phase changes, in one embodiment, the regions are overlapped by about 1 to 5 phase encodings. The phase deviation between the same phase encoding from respective regions is used to compensate the phase deviation in the detected signals from the respective regions (see translation of D1, page 12, lines 13 to 23).

Hence, having regard to claim 1 under consideration, document D1 discloses a magnetic resonance imaging method comprising the steps of:
irradiating an RF pulse of magnetic resonance frequencies toward a predetermined slicing surface of an object to be inspected;
then detecting an echo signal group sequentially produced in association with the irradiation of the RF pulse (follows from the fact that echo planar imaging is used);
reconstructing an image (51) of the predetermined slicing surface by making use of a plurality of echo signal groups (eg three, see figure 1(a), (b), regions 41, 42, 43) which have been acquired by repeating said irradiation step and said echo signal group detecting step a plurality of times and which constitute echo

signals of all phase encodings necessary for reconstructing the image;
further reconstructing a subsequent image (52) of the predetermined slicing surface by making use of a part (43) of the plurality of echo signal groups which have been used for the previous image reconstruction and an echo signal group (42, 41) which has been newly acquired by performing subsequently said irradiation step and said echo signal group detecting step at least once; and
repeating said further step of reconstructing the subsequent image (cf 53, 54) while renewing a part of the plurality of echo signal groups used for the image reconstruction.

Document D1, thus, discloses a magnetic resonance imaging method corresponding to the preamble of claim 1.

2.1.2 The difference between the method according to claim 1 and document D1 consists in the features of the characterising part of claim 1.

Accordingly, the subject-matter of claim 1 is novel with respect to document D1 (Articles 52(1) and 54(1), (2) EPC). Novelty is also given having regard to the remaining available, more remote prior art.

2.1.3 The difference of the subject-matter of claim 1 over document D1 provides in substance for the detection of a navigator echo for each echo signal group, the selection of the navigator echo pertaining to the same echo signal group number of each image as a reference navigator echo for building the image, and the correction of the phases of the individual echo signal

groups of one image based on the phase difference between the reference navigator echo and the navigator echoes of the remaining echo signal groups.

The effect hereof is that phase changes in the detected signals from the respective echo signal groups, caused by the equipment but also by eg motion of the object to be imaged, can be corrected.

In document D1, the phase deviation between successive phase encoding regions is determined by comparing the phase of one or more of the phase encodings in the overlap part of one phase encoding region with the same phase encodings in the overlap part of the previous region. This phase deviation is then used to correct all signals acquired from either phase encoding region. Document D1 does not provide any further indications as to how exactly the phase of the successive phase encoding regions is corrected. It is, however, apparent that by linking directly or indirectly the phase of all successive phase encoding regions, as would be the case, phase variations caused by changes in the imaging object over time may be suppressed, thereby concealing relevant image features.

For this reason, the appellant's argument that document D1 already provided a complete solution for phase correction, thereby removing any incentive for the skilled person to look for improvements, is not convincing.

In view of the above, the objective problem to be solved by the present application having regard to document D1 may be seen as improving the correction of

phase shifts between phase encoding regions causing image artefacts.

2.1.4 A method for correcting phase shifts between phase encoding regions in k-space (phase encoded views) causing image artefacts in MRI is known for instance from document D5. The phase shifts are indicated to be caused by object motion between the respective phase encodings (see column 3, lines 46 to 55). It would, nonetheless, be clear to the skilled person working in the technical field of magnetic resonance imaging at issue that the phase shift reduction of document D5 would be equally effective where phase shifts between phase encodings are caused for example by distortion and instability of the equipment mentioned in document D1.

Accordingly, faced with the above objective problem, the skilled person would consider the teaching of document D5.

In particular, document D5 discloses an MRI method in which an imaging scan acquires a plurality of phase encoded views of image data and corresponding orbital navigator signals. Each orbital navigator signal is processed to arrive at phase corrections for its corresponding view of image data (see column 8, lines 29 to 45). These corrections offset artefact-producing errors caused by in-plane translational motion of spins in any direction, as well as errors caused by in-plane rotational motion of spins between views caused by object motion (see column 3, lines 46 to 55). By measuring shifts in the orbital navigator NMR signals with respect to a reference orbital navigator signal,

corrective values for translational movement and rotation can be calculated for each corresponding view of image data. In particular, the first acquired orbital navigator signal is used as the reference orbital navigator signal (see column 8, lines 57 to 60) for the image.

The next step is to correct each of the image data views with the corrective values from its corresponding orbital navigator signal (see column 9, line 16 to column 10, line 7 and figure 4). The measured translational movements are used to calculate phase corrections for the corresponding NMR image data. The correction for object rotation is made by back-rotating the affected NMR image data samples an offsetting amount. The Fourier rotation theorem states that a rotation of the object will produce an equal rotation of its Fourier transform. Thus, rotation correction can be made on the acquired k-space NMR image data. Finally, the corrected image data views are used to reconstruct an image by a standard 2DFT reconstruction.

Applying this correction of phase shifts between phase encoding regions (views) taught by document D5 to the method of document D1 would lead to the acquisition of a (monitor) navigator echo signal in each phase encoding region and selecting for each image the first acquired navigator echo signal as the reference navigator echo signal for the image. Moreover, in accordance with the teaching of document D5, this would be followed by a determination of the phase differences between the reference navigator echo and the monitor navigator echoes, and the correction of the echo

signals of the phase encoding region to which the respective monitor navigator echoes belong based on the determined phase differences. Furthermore, document D5 suggests, at least for object rotation, correcting the phases of the image data in k-space.

Accordingly, the skilled person would arrive at the subject-matter of claim 1 without the exercise of inventive skills.

2.1.5 The appellant argued that starting from document D1, a skilled person would not consider document D5, as it sought to avoid any motion.

It is, however, noted that also in a sequence of images for generating a moving image, as in document D1, phase corrections between phase encoding regions are desirable in order to remove image artefacts within the individual images of the sequence. Document D5 provides a suitable solution hereto.

The appellant furthermore argued that a distinction had to be made between object motion desired to be imaged (such as brain function or catheter movement) and object motion (such as body motion or breathing) undesired to be imaged, the application allowing imaging only the desired motion.

The application does, however, not allow this. It should be clear that the application images object motion by a sequence of altering images, while substantially removing image artefacts due to object motion within individual images, irrespective of the origin of the object motion.

Finally it was argued by the appellant that document D5 taught away from correcting the image data in k-space. In particular, the practical problems indicated in document D5 (column 9, line 31 to column 10, line 3) arising from a rotation correction in k-space would be a serious disincentive for the skilled person. It is, however, noted that document D5 provides individual solutions to all practical problems mentioned in this respect and, as a matter of fact, performs the rotation correction in k-space, so that this argument is not convincing.

2.1.6 For the reasons above, the subject-matter of claim 1 according to the main request lacks an inventive step (Articles 52(1) and 56 EPC).

The main request is, therefore, not allowable.

3. Auxiliary request

3.1 In claim 1 according to the auxiliary request the subsequent image of the predetermined slicing surface is reconstructed by making use of a part of the plurality of echo signal groups which have been used for the previous image reconstruction and an echo signal group which has been newly acquired by performing subsequently said irradiation step and said echo signal group detecting step more than once. As is apparent from the corresponding embodiment (see figures 2A, 2B and description page 20, line 19 to page 23, line 5 of the application as filed), meant hereby is that the image is reconstructed by making use of more than one newly acquired echo signal group. As indicated

in the application as filed, document D1 provides such an image reconstruction by making use of two newly acquired echo signal groups pertaining to two phase encoding regions of k-space and one echo signal group which has been used for the previous image (see figures 1a, 1b and corresponding description).

Moreover, according to document D1 (see translation page 12, line 23 to page 14, line 19), since the region of k-space which contributes most to variations of the images over time is the low spatial frequency region, this region is newly acquired for each image (see also application, page 20, line 19 to page 22, line 5).

3.2 Concerning the choice, which of the navigator echoes would be selected in this case as the reference navigator echo, in fact only a very limited number of possibilities are available. As discussed above, document D5 suggests the use of the first one acquired. Since the first region in document D1 does not correspond to low spatial frequencies, it is not newly acquired for each image. Selecting the navigator echo in this first region as reference navigator echo would, thus, have the drawback of using an older reference navigator echo for correcting echo signals from two newly acquired regions out of three. As would be readily apparent to the skilled person, selecting in this case the second navigator belonging to the low spatial frequency region which is newly acquired with every image, would guarantee that the reference navigator echo is more fitting with the newly acquired echo signals. Accordingly, the selection of the reference navigator echo in accordance with the last

feature of claim 1 of the auxiliary request would be obvious to the skilled person.

It is noted in this regard that although, as argued by the appellant, other correction schemes, eg based on an average as reference navigator echo, would be conceivable, document D5 teaches the use of one particular acquired navigator echo as reference for each image, rendering this scheme obvious to the skilled person.

3.3 For the reasons above, the subject-matter of claim 1 according to the auxiliary request lacks an inventive step (Articles 52(1) and 56 EPC).

The auxiliary request is, therefore, not allowable either.

## Order

## For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

R. Schumacher B. Schachenmann