BESCHWERDEKAMMERN DES EUROPÄISCHEN PATENTAMTS

BOARDS OF APPEAL OF THE EUROPEAN PATENT OFFICE

CHAMBRES DE RECOURS DE L'OFFICE EUROPEEN DES BREVETS

Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [X] To Chairmen

D E C I S I O N
of 8 February 1996

Case Number: T 0530/93 - 3.4.2

Application Number: 87116440.6

Publication Number: 0273153

IPC: G01N 24/08

Language of the proceedings: EN

Title of invention:
Method for fast scan cine NMR imaging

Applicant:
GENERAL ELECTRIC COMPANY

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - (yes) after amendment"

Decisions cited:
-

Catchword:
-

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 0530/93 - 3.4.2

D E C I S I O N
of the Technical Board of Appeal 3.4.2
of 8 February 1996

Appellant: GENERAL ELECTRIC COMPANY
1 River Road
Schenectady
New York 12305 (US)

Representative: Pratt, Richard Wilson
London Patent Operation
G.E. Technical Services Co. Inc.
Essex House
12/13 Essex Street
London WC2R 3AA (GB)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 20 January 1993 refusing European patent application No. 87 116 440.6 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: E. Turrini
Members: W. W. G. Hofmann
B. J. Schachenmann

Summary of Facts and Submissions

I. The Appellant (Applicant) lodged an appeal against the decision of the Examining Division on the refusal of the application No. 87 116 440.6 (publication No. 0 273 153).

The Examining Division had held that the application did not meet the requirements of Articles 56 and 52(1) EPC. It had cited the documents

(D1) EP-A-0 200 049 and
(D2) EP-A-0 228 129.

II. Oral proceedings were held, at the end of which the Appellant requested that the decision under appeal be set aside and a patent granted on the basis of Claims 1 to 7 submitted at the oral proceedings, with the description and, if necessary, the drawings to be adapted.

III. The wording of the independent Claims 1 and 7 according to the single request on file at the time of the present decision reads as follows:

"1. A method for producing images with an NMR imaging system of a human heart at selected cardiac phases of its functional cardiac cycle, comprising the steps of:

(a) repeatedly executing an NMR fast scan pulse sequence at regular time intervals throughout a functional cycle to acquire a subset of NMR data, said execution being asynchronous with respect to

said functional cycle to produce NMR data at each of a plurality of times within the functional cycle, and said NMR pulse sequence including a position encoding gradient pulse;

(b) detecting the start of each cardiac cycle and deriving therefrom phase angles of the cardiac cycle which vary linearly as a function of time between starts of successive cycles;

(c) correlating the NMR data acquired during the execution of each NMR fast scan pulse sequence with the phase angle of the functional cycle at the time the NMR data is acquired;

(d) repeating steps (a), (b) and (c) for a plurality of functional cycles with a different position encoding gradient pulse employed during each functional cycle to produce other subsets of NMR data;

(e) reconstructing an image at a selected phase angle of the functional cycle by interpolating between the corresponding correlated NMR data within each subset of acquired NMR data to produce a set of NMR data interpolated to said selected phase angle which is employed to produce the image; and

repeating step (e) at a plurality of successive phases [read: phase] angles of the functional cycle to produce a plurality of images which depict the heart at successive phase angles of its functional cycle."

"7. An apparatus when suitably programmed for carrying out the method of any one of the preceding claims comprising:

(a) means for repeatedly executing an NMR fast scan pulse sequence continuously at regular intervals throughout a functional cardiac cycle to acquire a subset of NMR data, said execution being asynchronous with respect to said functional cycle to produce NMR data at each of a plurality of times within the functional cycle, and said NMR pulse sequence including a position encoding gradient pulse;

(b) means for detecting the start of each cardiac cycle and deriving therefrom phase angles of the cardiac cycle which vary linearly as a function of time between starts of successive cycles;

(c) means for correlating the NMR data acquired during the execution of each NMR fast scan pulse sequence with the phase angle of the functional cycle at the time the NMR data is acquired;

(d) means for repeating steps (a), (b) and (c) for a plurality of functional cycles with a different position encoding gradient pulse employed during each functional cycle to produce other subsets of NMR data; and

(e) means for reconstructing an image at a selected phase angle of the functional cycle by interpolating between the corresponding correlated NMR data within each subset of acquired NMR data to produce a set of NMR data interpolated to said selected phase angle which is employed to produce the image, and for repeating step (e) at a

plurality of successive phase angles of the functional cycle to produce a plurality of images which depict the heart at successive phase angles of its functional cycle."

Claims 2 to 6 are dependent on Claim 1.

IV. The Appellant argued in substance as follows:

Present Claims 1 and 7 clearly define the points of time which, in the different functional cycles, correspond to the same phase angle since it is expressed that within each functional cycle the phase angle varies linearly as a function of time, which means that in each functional cycle the time interval corresponding to a given progression of the phase angle is proportional to the duration of the functional cycle, ie to the time between one start signal and the next. This way of correlating a selected phase angle within each functional cycle with the corresponding pulse sequences is entirely different from the method according to D1, where not a phase angle common to all functional cycles, but a certain amplitude value of the respiratory curves of all the functional cycles is selected as NMR data correlating reference. Moreover, Claims 1 and 7 relate to imaging the human heart while D1 deals with imaging the lung, and Claims 1 and 7 use interpolation for determining the corresponding pulse sequence data while interpolation is not mentioned in D1. There is no hint either in D1 or somewhere else in the prior art which could suggest this approach to NMR imaging.

Reasons for the Decision

1. The appeal is admissible.

2. *Clarity*

In Claim 1, "fast scan pulse sequence" is a term which is well known and has a definite meaning in the art (see also the comments from page 6, line 31 to page 7, line 7; on page 17, lines 12 to 15; and on page 16, lines 6, 7, and 13 to 15, of the original description).

The term "at regular time intervals" now clearly defines the regular repetition of the pulse sequences in the absolute time scale. How the phase angles within each cardiac cycle (which naturally range from 0° to 360°) are defined as a function of absolute time, is clearly indicated by the definition "... which vary linearly as a function of time between starts of successive cycles". In this way, it is clear how the correlation between the NMR data and the phase angles in the various functional cycles can be performed.

The same comments apply to Claim 7.

In Claim 4, it is now clear that the position encoding gradient is changed after each NMR pulse, and that the number N does not relate to the real, but to the expected number of pulse sequences in a functional cycle.

In Claims 5 and 6, the obscure reference to the polarity of data is corrected.

Thus, the claims are clear in the sense of Article 84 EPC.

3. *Amendments*

The present version of Claim 1 is primarily based on a combination of the original Claims 1, 4 and 6. That the NMR pulse sequences are fast scan pulse sequences, is disclosed at various places of the original description, eg on page 5, lines 18, 19; page 6, line 31 to page 7, line 4; and page 12, lines 10 to 15.

The regular time intervals of the NMR pulse sequences are disclosed on the original page 14, lines 5 to 10. Detection of the start of each cardiac cycle is mentioned on page 5, lines 21, 22 and page 11, line 25, and deriving linearly varying phase angles between these starts follows from Figures 3 and 5 in combination with page 14, lines 3 to 7 and 10 to 12.

The amendments to Claim 7 correspond to those of Claim 1. In Claim 4, the amendments "after each NMR pulse" and "expected to be run" correspond to the text on page 18, line 28 to page 19, line 1.

Therefore, the claims fulfil the requirements of Article 123(2) EPC.

4. *Diagnostic method*

According to the established case law of the Boards of Appeal of the EPO (see eg T 385/86, OJ EPO 1988, 308, and T 400/87 (unpublished)), methods which only comprise the data gathering phase of a diagnosis and only provide interim results which would require a further step in order to attribute the data to a particular clinical picture, are not diagnostic methods in the meaning of Article 52(4) EPC. The method according to present Claim 1 corresponds to this definition and is thus not excluded from patentability under Article 52(4) EPC.

5. *Novelty*

5.1 In correspondence with the subject-matter of Claim 1, D1 (see in particular the abstract; column 4, lines 4 to 8; column 8, lines 23 to 26; and Figure 5) describes a method for producing images with an NMR imaging system of a human organ (the lungs) moving in a cyclic pattern, at selected phases of its functional cycle. The known method also comprises the following steps: Repeatedly an NMR pulse sequence is executed at regular time intervals throughout a functional cycle of the organ to acquire a subset of NMR data, the NMR pulse sequence including a position encoding gradient pulse (see abstract; column 6, lines 36 to 43; and Figure 5). The start of each functional cycle is detected (column 10, lines 17 to 26; column 6, lines 2 to 4 and 12 to 16). The NMR data acquired during the execution of each NMR pulse sequence are correlated with the phase angle of the functional cycle of the organ at the time the NMR data are acquired (abstract, lines 11 to 13; column 3, lines 1, 2, 53 to 56; column 8, lines 18 to 23; since all the NMR data are correlated with functional amplitudes, and the amplitudes (and slopes) of the functional movement of the organ within the cycle are representative of the phase angles of this cyclic motion, correlation with the phase angles is achieved). These steps are repeated for a plurality of functional cycles with a different position encoding gradient pulse employed during each functional cycle to produce other subsets of NMR data (Figure 5; abstract, lines 3 to 6; column 6, lines 14 to 16). An image is reconstructed at a selected phase angle of the functional cycle of the organ by choosing the corresponding correlated NMR data within each subset of acquired NMR data to produce a set of NMR data chosen for said selected phase angle which is employed to produce the image (abstract, lines 16 to 20; column 3, lines 6 to 24; as already mentioned above,

fixing a reference value for the amplitude (and possibly the slope) of the motion in the functional cycles is one way of defining a certain phase angle). The latter step is repeated at a plurality of successive phase angles of the functional cycle of the organ to produce a plurality of images which depict the moving organ at successive phase angles of its functional cycle (column 4, lines 4 to 8; column 8, lines 23 to 26).

The method according to Claim 1 is distinguished therefrom by the following features:

The moving organ is the human heart.

The NMR pulse sequences are fast scan pulse sequences.

For correlating the NMR data with the phase angles, instead of defining the phases by means of certain values of the amplitude of the movement of the organ, the phase angles are defined to be distributed linearly in time between the starts of successive cycles, which starts (instead of all the amplitude values of the cycle) are specifically detected. This makes a difference if the cycles - as in the present case - deviate from true periodicity.

The reconstruction of the image at a selected phase angle of each functional cycle is not done by choosing the data of the one NMR pulse sequence whose corresponding phase (amplitude value) is closest to the selected one, but by interpolating between the NMR data of each subset so that the interpolated data directly correspond to the selected phase angle.

5.2 D2 is not prepublished. However, it is a European patent application filed before the priority date of the present application and also designates the Contracting States DE, FR, GB and NL. It thus constitutes prior art in the sense of Article 54(3) EPC.

It relates to a method for producing images with an NMR imaging system of an object moving under the influence of the breathing cycle.

The cardiac cycle is not mentioned in the context of the described method. (The short mention of (among others) cardiac movement in column 3, lines 3, 4, only refers to general comments made in another prior art article and is not necessarily connected to the method described in D2.) As to further differences, it will do to state that no fast scan pulse sequence is used, that no interpolation is used between NMR data, and that no plurality of images at successive phases of the functional cycle are mentioned.

5.3 (D3) "Physics in Medicine & Biology " volume 31, No. 7, July 1986, pages 779 to 787, describes a method of producing images with an NMR imaging system of a human heart at a plurality (cf page 782, last paragraph) of selected cardiac phases of its functional cardiac cycle.

In this method, the NMR pulse sequences are executed at fixed distances in time from a gating pulse derived from the ECG, and the correlation of the NMR data with the phase in the functional cycle is done by equating equal distances in time from the gating pulse with equal phases in each functional cycle. Thus, in the known method, the NMR pulse sequences are not executed asynchronously with respect to the functional cycle, and the phase within the cardiac cycle is not linearly adjusted to varying lengths of this cardiac cycle.

5.4 Neither one of the other documents cited in the European search report comes closer to the claimed subject-matter than those mentioned above.

5.5 The subject-matter of Claim 1 is therefore novel in the sense of Article 54 EPC.

5.6 Apparatus Claim 7 contains essentially the same features as Claim 1.

Although choosing the human heart as the object of the images cannot directly form a feature of the claimed apparatus, the condition that the apparatus must be suitable for producing images of the heart indirectly defines the design of the apparatus, in particular as regards the adaptation to relatively short functional cycles and the way of deriving the start signal of the cycles.

It may be mentioned that - in the context of a clearly technical apparatus - the means for executing certain steps of the process performed by the apparatus (ie mainly computer programs), also form distinctive apparatus features.

For the same reasons as given above for Claim 1, the subject-matter of Claim 7 is therefore novel in the sense of Article 54 EPC.

6. *Inventive step*

6.1 The only prior art document describing NMR imaging of the human heart is D3. NMR imaging requires a set of (eg 128) data to be taken of the object, for all of which the object should have the same position and shape. Such a number of data can only be collected from different cycles of the heart's movement. Since according to D3

the NMR data are collected at fixed time intervals after each gating pulse while the periodicity of the human heart is imperfect, the reconstructed image, in particular for the later stages in the cycle between the gating pulses, is degraded. The present invention aims at improving the image in this respect (cf page 3, line 30 to page 4, line 4; page 4, lines 20 to 25; and page 6, lines 1 to 3, of the original description).

6.2 The main idea on which the subject-matter of present Claim 1 is based for achieving this goal, is to collect the required data from points of time not fixed at equal intervals after each start (gating) signal of the cardiac cycles, but corresponding, within each cardiac cycle, to the lapse of equal proportions of the whole duration of the respective cycle after each start signal. This is expressed in Claim 1 by defining phase angles which, within each cardiac cycle, vary linearly as a function of time. If this principle of selecting corresponding points of time is used, the times within the cycles at which the data used for producing the image are to be collected, can no longer be determined beforehand because the duration of the individual cycles is only known afterwards. Consequently, according to Claim 1, first the measurements within the cardiac cycles are made at a plurality of regular time intervals (without synchronising them with the cycles) and the starts of the cardiac cycles detected, and then the steps of correlating the measured NMR data with the corresponding phase angles and of determining those data used for reconstructing the image at a selected phase angle are performed.

6.3 The only prior art document containing a comparable idea is D1. D1 relates to the respiratory cycle. NMR pulse sequences are repeatedly executed at regular time intervals during each respiratory cycle, and the

corresponding NMR data as well as the data describing the course of the respiratory cycle (measured by a variable resistance belt put around the patient's abdomen) are stored. The selection of those NMR data from the different functional cycles which - as much as possible - correspond to the same status of the lung, is made afterwards.

However, this selection of the corresponding NMR data is made according to principles different from those of the present subject-matter since those points of time are selected for which the amplitude of the respiratory movement has a predetermined value. Transferring this idea to a method of imaging the heart as known from D3 (even if this were possible), thus would not lead to the method according to Claim 1. Moreover, it is apparent that the method according to D1 could not be transferred to imaging the heart since the ECG signal does not follow the varying shape of the heart as a resistance belt signal does for the lung.

Thus, although the present method has some steps in common with the method according to D1, a person skilled in the art could not learn from D1 how to improve NMR images of the heart.

6.4 The remaining documents cited in the European search report are still more remote from the ideas of the present subject-matter and could not provide any suggestions.

6.5 The Board also does not see general knowledge leading a skilled person to the solution specified in Claim 1. Looking at it ex post facto, the idea of creating a common phase scale for all cardiac cycles by linearly expanding or compressing the time scales within the different cardiac cycles in accordance with the lengths

of these cycles, might appear simple. However, it must be borne in mind that certainly no great fund of experience existed in dealing with irregularly cyclic processes, and that - much more than with regularly cyclic processes - each of the irregular ones requires individual consideration. So, the present solution depends on the realization of the fact that, although the periods of the cardiac cycles are different in length, the relative course of the movement within the cycles is mostly much the same. This would not necessarily apply to the same extent to other irregular cycles as for example the respiratory cycle or stomach movements.

Thus, the Board does not consider the above-mentioned idea underlying Claim 1 as evident.

6.6 The use of fast scan pulse sequences is also not described in the cited prior art documents. This may be due to the less urgent need for high repetition rates in the prior art methods. The significance of this feature in the present case is linked to the main idea of collecting correlated data for an image at time intervals proportional to the duration of the cycles. This idea makes it necessary to fill each cardiac cycle as densely as possible with a plurality of NMR pulse sequences, which in turn - due to the particularly short period of the cardiac cycle to which the present method is directed - necessitates high repetition rates.

6.7 The further feature of Claim 1 that the NMR data employed for producing the image corresponding to a certain phase angle are determined by interpolation between the measured NMR data close to that phase angle, is also not mentioned in any of the cited documents. In particular, according to D1, instead of interpolating, the closest neighbouring NMR data are chosen.

Although the use of interpolation is not, per se, a step involving inventive skill, this feature adds to the differences from the prior art.

6.8 For the above reasons, the Board concludes that the subject-matter of Claim 1 involves an inventive step in the sense of Article 56 EPC.

6.9 The same is true for Claim 7 which, as already mentioned above, contains essentially the same features as Claim 1.

7. Consequently, Claims 1 and 7 are allowable in accordance with Article 52(1) EPC.

Claims 2 to 6 relate to suitable embodiments of the method according to Claim 1. Due to their dependence on Claim 1, they are allowable as well.

8. The description of the present application needs adaptation to the new set of claims and proper acknowledgment of the relevant prior art. In order to have these amendments performed, the Board makes use of its power under Article 111(1) EPC and remits the case to the Examining Division.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Examining Division with the order to grant a patent on the basis of Claims 1 to 7, submitted at the oral proceedings, with the description and, if necessary, the drawings to be adapted.

The Registrar: The Chairman:

P. Martorana E. Turrini