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D E C I S I O N
of 22 August 2001

Case Number: T 1121/97 - 3.2.2

Application Number: 91916359.2

Publication Number: 0543928

IPC: A61B 5/055

Language of the proceedings: EN

Title of invention:
Analyzing heart wall motion using spatial modulation of magnetization

Applicant:
THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA

Opponent:
-

Headword:
-

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

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

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Case Number: T 1121/97 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal 3.2.2
of 22 August 2001

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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 10 July 1997 refusing European patent application No. 91 916 359.2 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: W. D. Weiß
Members: S. S. Chowdhury
J. C. M. De Preter

Summary of Facts and Submissions

I. This appeal is against the decision of the examining division dated 10 July 1997 to refuse European patent application No. 91 916 359.2.

The ground of refusal was that the subject-matter of all claims of a main request and first to third auxiliary requests lacked an inventive step having regard to the following documents:

D1: Magnetic Resonance in Medicine, Vol. 15, No. 2, 1 August 1990, Duluth, MN, USA, pages 334-339, Mosher et al. "A Dante Tagging Sequence for the Evaluation of Translational Sample Motion"

D2: Radiology, Vol. 171, No. 3, 1 June 1989, New York, USA, pages 841-845, Axel, et al. "MR Imaging of Motion with Spatial Modulation of Magnetisation"

D3: Radiology, Vol. 172, August 1989, pages 349-350, Axel, et al. "Heart Wall Motion: Improved Method of Spatial Modulation of Magnetisation for MR Imaging"

D4: Magnetic Resonance in Medicine, Vol. 12, pages 81-87, 1989, Shinnar et al. "The Use of Finite Impulse Response Filters in Pulse Design"

D5: Magnetic Resonance in Medicine, Vol. 12, pages 93-98, 1989, Shinnar et al. "The Application of Spinors to Pulse Synthesis and Analysis"

D6: IEEE Transactions on Biomedical Engineering, Vol. 27, No. 6, June 1980, pages 319-329, Meier et al. "Kinematics of the Beating Heart".

The examining division argued that, starting from the closest prior art document D3, which discussed a qualitative evaluation of heart wall displacement, it would be obvious to perform a quantitative evaluation instead, so that the method of claim 1 of the main request did not involve an inventive step. The disclosure of document D3 fell under the wording of claim 1 of the first auxiliary request in that this claim did not exclude the use of binomial pulses to give a sharper stripe pattern, so that the additional features of claim 1 of the first auxiliary request did not involve an inventive step. Claim 1 of the second and third auxiliary requests defined finite impulse response filter techniques, the use of Fourier cosine series converted into complex exponential Fourier series, and use of spinor components. These were known features used for their known purpose and was an obvious application of the teaching of documents D4 and D5.

II. On 9 September 1997 the appellant (applicant) lodged an appeal against the decision and paid the prescribed fee. On 7 November 1997 a statement of grounds of appeal was filed.

III. Oral proceedings were held on 22 August 2001, at the end of which the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the main request or of one of the five auxiliary requests as filed by letter of 23 July 2001, with a minor modification on page 2 of the third

auxiliary request as submitted at the oral proceedings. He further requested that a print-out of appendix B should be part of a granted patent.

IV. Independent claims 1 and 9 of the main request read as follows:

1. "A method of using a magnetic resonance imaging device to noninvasively determine the extent of displacements of a body portion of a patient within an image slice during a pre-imaging time interval, including the steps of applying to the body portion an external magnetic field so as to produce a resultant magnetisation (320), applying to the body portion a pre-imaging pulse sequence (322) including a radio frequency pulse sequence and a magnetic field gradient pulse sequence, said pre-imaging pulse sequence creating over said body portion in said image slice a grid of intersecting stripes having altered magnetisation which intersect at a plurality of intersecting points, and, after said pre-imaging time interval, applying an imaging pulse sequence to the body portion (324) to make visible said grid of intersecting stripes, characterised by the additional steps of:

inputting parameters specifying the desired characteristics of the radio frequency pulse sequence used to generate said grid of intersecting stripes (304), said input parameters including at least one of: the desired stripe thickness of the stripes created by application of said pre-imaging pulse sequence, weights for relating sharpness and flatness of respective stripes, and a size of a transition zone between a striped and a non-striped region;

synthesising a radio frequency pulse sequence

which fits said input parameters, whereby when said pre-imaging pulse sequence is applied to said body portion, a grid of intersecting stripes with desired characteristics in accordance with the input parameters is created over said body portion in said image slice (306-316);

selecting predetermined ones of said plurality of intersecting points from said grid of intersecting stripes created over said body portion in said image slice (806);

calculating the extent of displacements of said predetermined ones of said plurality of intersecting points which occurs during said pre-imaging time interval (808-810); and

providing an image representing the extent of said displacements (812)."

9. "A magnetic resonance imaging device for noninvasively determining the extent of displacements of a body portion of a patient within an image slice during a pre-imaging time interval, said device comprising means (202-210) for applying to the body portion an external magnetic field so as to produce a resultant magnetisation, imaging means (212-218) for applying a pre-imaging pulse sequence to the body portion, said pre-imaging pulse sequence including a radio frequency pulse sequence and a magnetic field gradient pulse sequence, said pre-imaging pulse sequence creating over said body portion in said image slice a grid of intersecting stripes having altered magnetisation which intersect at a plurality of intersecting points, and, after said pre-imaging time interval, for applying an imaging pulse sequence to the body portion to make visible said grid of intersecting stripes, and a display (222), characterised in that

said imaging means (Fig. 3) receives input parameters specifying the desired characteristics of the grid of intersecting stripes (304), said input parameters including at least one of: desired stripe thickness of the stripes created by application of said pre-imaging pulse sequence, weights for relating sharpness and flatness of respective stripes, and a size of a transition zone between a striped and a non-striped region, and said imaging means further synthesises (306-316) a radio frequency pulse sequence which fits said input parameters, whereby when said pre-imaging pulse sequence is applied to said body portion, a grid of intersecting stripes with desired characteristics in accordance with the input parameters is created over said body portion in said image slice, said apparatus further comprising means (Fig. 8) for selecting predetermined ones of said plurality of intersecting points from said grid of intersecting stripes created over said body portion in said image slice (806) and means (808-810) for calculating the extent of displacements of said predetermined ones of said plurality of intersecting points which occurs during said pre-imaging time interval for display on said display (812).

The independent claims of the auxiliary requests differ from the corresponding claims of the main request as follows:

First auxiliary request: "optimally" has been added after "synthesising a radio frequency pulse sequence which".

Second auxiliary request: "using finite impulse response

filter techniques" has been added after "frequency pulse sequence used to generate said grid of intersecting stripes (304)".

Third auxiliary request: Claim 1 is a combination of claims 1 and 5 (see below) of the main request, and Claim 8 is a combination of claims 9 and 13 of the main request.

Fourth auxiliary request: Claim 1 is a combination of claims 1 and 4 (see below) of the main request, and Claim 8 is a combination of claims 9 and 12 of the main request.

Fifth auxiliary request: Claim 1 is a combination of claims 1, 4, and 5 of the main request, and Claim 7 is a combination of claims 9, 12 and 13 of the main request.

Claim 4 of the main request reads as follows:

"The method of claim 1, wherein said synthesized radio frequency pulse sequence is applied to said body portion so as to cause a selective periodic excitation of said resultant magnetization and said synthesized radio frequency pulse sequence comprises respective radio frequency pulses having amplitudes which are not related in accordance with a binomial amplitude function.".

Claim 12 is a correspondingly worded device claim.

Claim 5 of the main request reads as follows:

"The method of claim 1, wherein said radio frequency pulse sequence is synthesized in accordance with the following steps: calculating a Fourier cosine series in M_z which fits said input parameters, where M_z is a magnetization response of said body portion to said synthesized radio frequency pulse sequence; converting said Fourier cosine series into a complex exponential Fourier series; generating a Fourier series for spinor components of said complex exponential Fourier series of the form: $(1+M_z)/2=P^2$ and $(1-M_z)/2=Q^2$; deconvoluting said Fourier series for spinor components to find P and Q; and calculating as said synthesized radio frequency pulse sequence which yields a spinor with P and Q as its spinor components.".

Claim 13 is a correspondingly worded device claim.

V. The appellant argued as follows:

The closest prior art document, D3, taught the use of binomial pulse sequences that resulted in a sharper stripe, but the amplitudes of such pulses were predefined and other characteristics of the pulses could not be adjusted. Document D3 viewed sharpness as the sole important characteristic of the pulses, whereas the presently claimed invention recognised, besides sharpness, other characteristics such as stripe thickness, flatness of the stripes, and a size of a transition zone between a striped and a non-striped region as also being significant, which itself was inventive activity.

In document D3 the binomial pulses were first specified, after which it was seen which stripe characteristics

came out. In document D1 a DANTE pulse sequence was similarly used. The present inventors were the first to realise that the stripe parameters could be specified beforehand and the RF pulse sequence synthesised accordingly.

The general knowledge of the person skilled in the art would not extend to deriving any quantitative details of heart wall motion. In document D3 only a very vague hint was given of the possibility of a quantitative evaluation method, from which the present invention could not be derived.

The person skilled in the art was an engineer narrowly focussing on the details of NMR and having no knowledge of mathematics or physics other than that pertaining to MR technology. He would not have consulted documents D4 and D5, which were remote from the SPAMM techniques. However, even a combination of these documents with document D3 would not lead to the present invention since inputting parameters to specify a pulse sequence, and then synthesising the pulse sequence would not be disclosed, nor would the steps of calculating the extent of the displacement using the intersecting points, and then providing an image representing the displacement.

In order to attack the claims of the auxiliary requests a combination of at least three documents was necessary, which was not permitted.

Reasons for the Decision

1. The appeal is admissible since it complies with the provisions mentioned in Rule 65(1) EPC.

2. *The main request*

2.1 Amendments

2.1.1 The amendments to the claims are such that they are allowable under Article 123(2) EPC since they are supported by the application as originally filed.

2.1.2 In its decision refusing the application the examining division had objected to some parts of the claims as being unclear. This point is not discussed here since, as seen below, the claims do not meet the requirements of Article 52(1) EPC.

2.2. Novelty

This has not been an issue during the examination procedure and the Board sees no reason to re-visit it.

2.3 Inventive step

2.3.1 The closest prior art

The document D3 comprises the closest prior art and it discloses a method of using a magnetic resonance imaging device to noninvasively determine the extent of displacements of a body portion of a patient within an image slice during a pre-imaging time interval, including the steps of applying to the body portion an external magnetic field so as to produce a resultant magnetisation, applying to the body portion a pre-imaging pulse sequence (see Figure 1) including a radio frequency pulse sequence

and a magnetic field gradient pulse sequence, said pre-imaging pulse sequence creating over said body portion in said image slice a grid of intersecting stripes having altered magnetisation which intersect at a plurality of intersecting points, and, after said pre-imaging time interval, applying an imaging pulse sequence to the body portion to make visible said grid of intersecting stripes (Figure 3). These features are set out in the pre-characterising part of claim 1, accordingly.

2.3.2 This document describes the use of a binomial radio frequency pulse sequence to obtain tagging stripes with sharper profiles than obtained in document D2, where simple RF pulses were used. However, it also states, on page 350, left column, that "For convenience we focussed on the binomial pulse sequence, although other related selective excitation techniques could be similarly applied".

The person skilled in the art knows that pulse characteristics other than sharpness, for example stripe spacing, width etc, also determine the overall appearance of the image and are important in the resolution of the stripes. This is general knowledge and not inventive insight as the appellant argues. It is also clearly desirable to be able to specify these characteristics in advance so that a desired pattern of stripes may be generated in a given body part. For example a relatively wide stripe spacing may suffice for a large muscle whereas a fine stripe pattern is necessary when imaging a thin muscle such as the myocardium. Given this and the cited passage on page 350, the skilled person would investigate the prior art to see whether there is any information regarding the use of different pulse sequences for use in NMR.

2.3.3 In his investigation of the prior art the person skilled in the art would not confine his search to the narrow field of SPAMM technology, as the appellant argues, but would extend the search to all medical literature in the field of NMR imaging. This is a technology requiring expertise in different technical fields and the notional person skilled in the art would actually be a team of technicians pooling their resources. Thus the skilled person would become aware of documents D4 and D5, since these documents disclose how an RF pulse sequence having an optimal frequency response may be synthesised after certain desired parameters are specified.

The first publication (document D2) in the branch of NMR imaging known as SPAMM appeared in 1989. This was an ongoing development and appeared to be a very promising diagnostic tool, and the skilled person would have eagerly read any literature reporting further advances in this field, including documents D4 and D5, which appeared in the same year as document D2. These documents are published in a well known medical journal in the field of magnetic resonance and all these documents belong to the general knowledge of this ongoing technical development, and the above person skilled would certainly have been aware of their contents.

2.3.4 The document D4 relates to the field of NMR technology and discloses how, if a desirable frequency response is inputted, a pulse sequence may be synthesised accordingly. As an example (page 83 "Application to NMR"), if an N-pulse sequence lasting for a total time T is required, a pulse sequence with optimal frequency characteristics may be synthesised accordingly, by designing an appropriate Fourier cosine series.

Document D4, therefore, discloses the features: inputting parameters specifying the desired characteristics of the radio frequency pulse sequence, and synthesising a radio frequency pulse sequence which fits said input parameters. The corresponding features in the characterising part of claim 1 do not involve an inventive step, accordingly.

2.3.5 The method of claim 1 includes the further features: selecting predetermined intersecting points from the grid of intersecting stripes, and calculating the displacements of the intersecting points during the pre-imaging time interval. The appellant's representative argues that nowhere is this suggested in the prior art.

2.3.6 However, document D3 clearly suggests performing a quantitative evaluation of myocardial function, by employing tensor analysis (see "Discussion" on page 350). The person skilled in the art would, therefore, look in the prior art for details of this analysis, and find document D6, which explains how displacements of small segments of myocardium may be described by a rotation tensor and a stretch tensor. The regional deformation in the heart wall is then ascertained through the calculation of the eigenvalues and eigenvectors of deformation. This is the same technique as used in the application.

In document D6 three implanted radiopaque markers define the apices (points) of a triangle which is used to define vectors upon which the mathematical operations are performed. The only points that are available for such operations in the present case are those defined at the intersections of the grid lines, so clearly these intersecting points would be selected and form the basis for the calculation of displacement.

These features in point 2.3.5 above also do not involve an inventive step, accordingly.

2.3.7 The final step in claim 1 of providing an image representing the extent of the displacements is trivial since it is commonplace to provide images representing measured or calculated physical values, and cannot endow the claim an with inventive step.

2.3.8 For the above reasons the method of claims 1 of the main and first auxiliary requests do not involve an inventive step. Corresponding arguments apply to the corresponding device claims 9. These claims define a series of means for carrying out the respective steps of the corresponding method claim, and no inventive step is seen in any particular means for carrying out any individual step. In this respect the appellant has not argued for the inventive merit of any particular means or the combination thereof.

3. *The remaining auxiliary requests*

3.1. Second auxiliary request

The use of finite pulse response filters in pulse design is well known in the art, as exemplified by document D4 (see the abstract on page 81), so that this feature cannot endow the claims with an inventive step.

3.2. Third auxiliary request

The main claims of this request include the limitation of claim 5 of the main request, which gives details of how the RF pulse is synthesised, which is by the use of Fourier cosine series being converted into a complex exponential Fourier series and the use of spinor components. This

technique is described, however, in document D5, which discloses how the frequency response of a series of pulses can be written as a Fourier series, whose coefficients are nonlinear functions of the pulse amplitudes (see particularly the sections "Refocusing pulse" on page 95 and "The cost of refocusing" on page 96). A method is also described whereby, if one specified the desired M_z magnetization as a Fourier series, which is analogous to the design of finite impulse response filters, one could generate a pulse sequence which will actually yield that magnetization. A radio frequency pulse sequence is synthesized by calculating a Fourier cosine series in M_z, converting the Fourier cosine series into a complex exponential Fourier series; generating a Fourier series for spinor components of the complex exponential Fourier series of the form: $(1+M_z)/2=P^2$ and $(1-M_z)/2=Q^2$, deconvoluting the Fourier series for spinor components to find P and Q; and calculating a frequency pulse sequence which yields a spinor with P and Q as its spinor components.

All these steps are used in the method of claim 1 for the same purpose, and lack an inventive step, accordingly.

3.4 Fourth auxiliary request

The claims of this request exclude the use of a binomial pulse sequence. However, alternatives to a binomial pulse sequence were already envisaged by document D3, see page 350, left column, first sentence of the first complete paragraph.

Document D1 also discloses the use of a non-binomial pulse sequence, viz. a DANTE sequence for producing a tagging grid, whereby the properties of the sequence determine the characteristics of the image slice, so the tag thickness,

spacing, image contrast, etc. may be varied by altering the pulse parameters. The performance of a DANTE sequence is compared with that of a binomial sequence in Figure 3 of this document, and the DANTE sequence is said to produce well-resolved tags. The DANTE sequence produces a tag thickness of only 0.07 mm as compared with 0.53 mm for a binomial sequence (page 337, results). Further advantages of the DANTE sequence as well as of a Gaussian-shaped sequence over a binomial sequence are given in the conclusion commencing at the end of page 337.

The use of a non-binomial pulse sequence, as defined in this request, is not inventive, accordingly.

3.5 Fifth auxiliary request

The claims of this request include both the additional features of the third and fourth auxiliary requests, that is, details of how the RF pulse is synthesised and the use of a non-binomial pulse sequence. These features are not technically related and their combination is simply an aggregation of the teachings of the prior art teachings, as set out above, and does not involve an inventive step.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

V. Commare W. D. Weiß