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D E C I S I O N
of 21 April 1994

Case Number: T 0145/92 - 3.4.2

Application Number: 83109777.9

Publication Number: 0105485

IPC: G01N 24/08, G01N 24/06

Language of the proceedings: EN

Title of invention:
Apparatus for examining an object by nuclear magnetic resonance

Patentee:
Kabushiki Kaisha Toshiba

Opponent:
Siemens AG

Headword:
-

Relevant legal norms:
EPC Art. 56, 100(a),

Keyword:
"Inventive step - no"
"Inventive step - neighbouring field"

Decisions cited:
-

Catchword:
-



Case Number: T 0145/92 - 3.4.2

D E C I S I O N
of the Technical Board of Appeal 3.4.2
of 21 April 1994

Appellant: Kabushiki Kaisha Toshiba
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Respondent: Siemens AG
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Representative: -

Decision under appeal: Decision of the Opposition Division of the
European Patent Office dated 18 November 1991,
posted on 10 December 1991 revoking European
patent No. 0 105 485 pursuant to Article 102(1)
EPC.

Composition of the Board:

Chairman: E. Turrini
Members: W.W.G. Hofmann
M. Lewenton

Summary of Facts and Submissions

I. The Appellant (Proprietor of the patent) lodged an appeal against the decision of the Opposition Division on the revocation of the patent No. 0 105 485.

Opposition had been filed against the patent as a whole and based on Article 100(a) EPC in connection with Articles 52 to 57 EPC.

The Opposition Division had held that the grounds for opposition mentioned in Article 100(a) EPC in connection with Article 56 EPC prejudiced the maintenance of the patent, having regard *inter alia* to the following documents:

- (D3) Funkschau, 3/1982, pages 43 to 48, E. Stetter et al., "Bildgebende Kernresonanz",
- (D4) J. Magn. Reson., Vol. 32, 1978, pages 199 to 225, R.F. Karlicek, Jr. et al., "A pulsed, broadband NMR spectrometer".

During the appeal proceedings the Board considered the following further documents cited respectively in the patent in suit, in the search report and by the Board of its own motion:

- (D1) US-A-4 254 778,
- (D2) J. Phys. E: Sci. Instrum., Vol. 15, No. 4, April 1982, pages 448 to 455, P.N. Reddy et al., "A phase coherent pulsed NMR spectrometer",
- (D5) Rev. Sci. Instrum., Vol. 52, No. 3, March 1981, pages 386 to 390, B.M. Wood et al., "High-performance cryogenic pulsed NMR spectrometer",

(D6) RCA Designer's Handbook, Solid-State Power Circuits, RCA Corporation, 1971, page 439.

II. Oral proceedings were held on 21 April 1994.

III. The Appellant requested that the decision under appeal be set aside and the patent maintained with the following documents:

Claims:

No.: 1 and 2 received during the oral proceedings of 21 April 1994,

Description:

- column 1, line 3 to column 2, line 46 and column 3, line 49 to column 9, line 16 of the patent specification,
- new description part as filed with letter of 10 April 1992, replacing column 2, line 47 to column 3, line 48 of the patent specification,

Drawings:

Sheets: 1/6 to 6/6 of the patent specification,

with the description still to be adapted to the claims.

IV. The Respondent was not present at the oral proceedings, but requested in writing that the appeal be dismissed.

V. The wording of Claim 1 on file at the time of the present decision reads as follows:

"An apparatus for examining an object (P) by nuclear magnetic resonance comprising:

- (a) magnet means (1) for applying to the object (P) a steady magnetic field (H_0) along a longitudinal axis (Z) thereof,

- (b) first coil means (3-1; 3-2) which is arranged along said longitudinal axis (Z), for applying to the object (P) a first gradient field (G_z), which in conjunction with the steady field (H_0) produces a predetermined field in a cross-sectional slice of the object (P), the field direction of the first gradient field (G_z) being parallel to that of the steady magnetic field (H_0) and the field strength thereof changing linearly and having opposite signs on both sides of a plane perpendicular to the longitudinal axis (Z);
- (c) probe head coil means (9) for applying RF pulses (H_1) having a generation period to the cross-sectional slice of the object (P) in a direction perpendicular to the longitudinal axis (Z) so as to excite a nucleus therein to which is being applied the predetermined field superimposed by the steady field (H_0) and the first gradient field (G_z), and for detecting nuclear magnetic resonance signals having duration times and phase information derived from the cross-sectional slice of the object (P),
- (d) second coil means (5) for applying a second gradient field ($G_{x,y}$) to the cross-sectional slice of the object (P) so as to define a projection angle of the nuclear magnetic resonance signals, the field direction of the second gradient field ($G_{x,y}$) being parallel to the steady magnetic field (H_0) and the strength of the second gradient field ($G_{x,y}$) changing linearly, orthogonal to the first gradient field (G_z);
- (e) a processing unit (11) which receives the nuclear magnetic resonance signals obtained from the cross-sectional slice of the object (P) through the probe head coil means (9) by changing the strength of the first gradient field (G_z), and executes the processing operation on duration time and phase information of the nuclear magnetic resonance

signals by use of two-dimensional Fourier transformation to produce an image of said cross-sectional slice; and

- (f) oscillating means (7) including at least a signal generator (13) for producing the RF pulses (H_1), and a plurality of amplifiers (14; 15; 16) for amplifying the RF pulses (H_1), respectively,

characterized in that each of said amplifiers has at least two operating modes different in class, one of which is determined by the bias which a bias control circuit (18) controls during the generation period ($t_s \dots t_f$) of the RF pulses (H_1) and another of which is determined by the bias which the bias control circuit (18) controls during reception of the nuclear magnetic resonance signals, the gain for small signals of the amplifiers being lower during the reception of the nuclear magnetic resonance signals than during the generation period of the RF pulses (H_1)."

Claim 2 depends on Claim 1.

VI. The Appellant argued as follows:

D3 relates to an apparatus for imaging an object by nuclear magnetic resonance (NMR).

D4 describes a multi-stage RF amplifier used in an NMR spectrometer. This amplifier comprises a first stage amplifier and a gated power amplifier that is normally polarised beyond cutoff between RF pulses but is gated on during these pulses. This switching is operated by means of a pulse amplifier circuit which works as bias control circuit. D4, therefore, teaches the gating of the rear stage amplifier only. On the contrary, the noise suppression effect obtained by the present

invention, according to which each of a cascade of amplifiers is gated, is higher than that obtained when only one of the amplifiers is gated.

D2 discloses an NMR spectrometer, the RF amplifier of which comprises two stages, both of them being gated and kept in an "off" and "beyond cutoff" states during the absence of the RF pulses. According to the invention, however, the amplifiers are switched between classes with different gains, this allowing a smoother operation.

The combination of prior art document D3 with D4 or D2 does not result in the apparatus as claimed. Moreover, such a combination is not possible because an NMR imaging apparatus differs remarkably from an NMR spectrometer.

VII. The Respondent argued as follows:

In D4 only the last-stage amplifier is gated, this stage being indeed essential as far as noise is concerned. It is, however, obvious to apply this measure to each stage of the RF amplifier, if a very good S/N ratio is desired.

The amplifier of an NMR spectrometer is similar to that of an NMR imaging system.

Reasons for the Decision

1. The appeal is admissible.
2. *Article 123(2) and (3) EPC*
 - 2.1 The features which, according to the present Claim 1, have been introduced into the original Claim 1, are disclosed in the application as filed:
 - the feature that the oscillating means includes a plurality of amplifiers (see (f)) is disclosed in Figure 9 and the corresponding part of the description,
 - the features of the characterising part are disclosed on page 13, line 34 to page 14, line 1 in conjunction with the block diagram of Figure 9 and the operation described in Figure 11.
 - 2.2 Dependent Claim 2 essentially corresponds to the original Claim 2.
 - 2.3 As compared with Claim 1 as granted, the amendments of present Claim 1 did not result in an extension of the scope of protection.
 - 2.4 The Board is, therefore, satisfied that the amended version of the claims, on the basis of which the Appellant requests that the patent be maintained, does not contravene the requirements of Article 123(2) and (3) EPC.

3. Article 54 EPC

3.1 An apparatus for examining an object by NMR comprising the features of the precharacterising portion of Claim 1 is known from D1. The same is true for D3. Both documents do not disclose the features of the characterising part of Claim 1.

3.2 D2 relates to an NMR spectrometer. According to the block diagram of Figure 1, an RF gate (see Figure 4) is fed by the outputs from a crystal oscillator (see Figure 3) and a pulse programmer (see Figure 2). The output of the gate is given to an amplifier system comprising a driver amplifier (see Figure 5) and a cascaded power amplifier (see Figure 6). The driver amplifier is biased to the "off" state during the absence of the RF pulse and switched on when an RF pulse is applied. The power amplifier is gated by a pulse amplifier (see Figure 7) and is driven to beyond cutoff during the absence of RF pulses. D2 does not mention the operation of the amplifiers in different classes with different gains.

3.3 D4 also relates to an NMR spectrometer comprising a power amplifier (see Figure 9) in cascade with a first stage amplifier (see Figure 7). The power amplifier is gated by a pulse amplifier circuit (see Figure 8). The grids of the tubes of the gated power amplifier are normally biased beyond cutoff and are gated on during an RF pulse. D4 does not disclose the feature that each stage of the amplifier system is gated. Moreover, it does not teach the operation of the amplifiers in different classes.

- 3.4 The NMR spectrometer described in D5 has less features in common with Claim 1 than D4.

D6 is a general electronics handbook indicating the properties of different amplifier classes without any reference to NMR techniques.

- 3.5 Therefore, none of the cited documents discloses an apparatus for examining an object by NMR comprising all the features of Claim 1.

Thus the subject-matter of Claim 1 is novel in the sense of Article 54 EPC.

4. *Article 56 EPC*

- 4.1 Starting from the apparatus known from D1 or D3, either of which could be considered as the closest prior art document, the problem to be solved consists in improving the S/N ratio caused by the oscillating means generating the RF exciting pulses H_1 , which conventionally greatly degrades the S/N ratio of the FID signals, so as to perform highly precise diagnosis (see the patent in suit, column 2, lines 56 to 62). It is not surprising that the S/N ratio of the FID signals is influenced by the oscillating means. Moreover, improving the S/N ratios is a constant concern of the person skilled in the art. The Board, therefore, cannot perceive an inventive merit in the statement of the above-mentioned problem *per se*.

- 4.2 The claimed solution to the stated problem consists in that **each** of the amplifiers of the oscillating means has at least **two operating modes** different in class determined by the respective bias of the amplifiers, and

that the gain of the amplifiers is lower during the reception of the FID signals than during the generation period of the RF pulses H_1 .

- 4.3 A multistage amplifier system for NMR applications, in which each stage has two operating modes determined by the respective bias of the amplifiers, is already known from D2, as shown above in paragraph 3.2.

Indeed, the transistor of the driver amplifier of Figure 5 of D2 is biased to be in the "off" state during the absence of an input RF pulse, and in the "on" state when the RF pulse is applied. This is, in particular, achieved by biasing the base of the transistor to -5 V and 0 V, respectively (see paragraph 4.3 of D2).

The tube grids of the RF power amplifier of Figure 6 are gated by the output of the pulse amplifier of Figure 7, acting as a bias control circuit. The grids are biased to -100 V, which is beyond the cutoff value (-60 V), during the absence of RF pulses, whereas, when an RF pulse arrives at the tube grids from the driver amplifier of Figure 5, simultaneously the gating pulses from the pulse amplifier of Figure 7 drive the grids to 0 V, which enables the tubes to conduct (see paragraph 4.4 of D2).

Thus, each of the stages of the amplifier system of D2 is operated in the said different operating modes. This prevents leakage of RF noise.

- 4.4 According to D2, the amplifiers are switched between the operating modes by means of bias control circuits. In this respect, there is no difference with the patent in suit.

As to the types of operating modes, D2 mentions, besides the "on" state, the "off" state for the driver amplifier and the "beyond cutoff" state for the power amplifier, in which context it may be assumed that the "beyond cutoff" state of an amplifier is not essentially distinguished from the "off" state. In Claim 1, instead, the modes are defined by the statement that they are "different in class", "the gain for small signals of the amplifiers being lower during the reception of the NMR signals than during the generation period of the RF pulses (H_1)". The latter is naturally also true for the "off" and "beyond cutoff" state mentioned in D2. Whether or not, in D2, the "on" state on the one hand and the "off" and "beyond cutoff" state on the other hand could also be seen as "different in class" in the sense of Claim 1, may be left open since even additionally specifying the lower gain class as being the "C" class (see column 7, line 59 to column 9, line 11 of the patent description) could not introduce an inventive difference into Claim 1.

In the field of RF amplifiers, these classes of operation have well-defined meanings, as appears, for example, from D6. According to this document, the gain in class "C" is less than that of class "A" or "B", but is entirely usable. This means that the "C" class can be considered as a low-gain region contiguous to the "off" or "beyond cutoff" state.

In both cases (whether "off" ("beyond cutoff") state or "C" class), the leakage of RF noise is reduced.

Indeed, the contested patent itself teaches the possibility of turning off the final power amplifier as an alternative to the operation in "C" class (see column 6, lines 41 to 43; column 8, line 56 to column 9, line 6), and the same would also apply to the

preamplifier and the drive amplifier (see column 9, lines 7 to 11). This means that both alternatives should be considered as equivalent, as far as the solution of the problem is concerned.

During the oral proceedings, the Appellant - without giving reasons - hinted at the possibility that the operation of an amplifier switched to "C" class could be smoother than if it is switched to the "off" state. However this may be, the person skilled in the art would, in the Board's view, choose the smaller gating voltage step leading down to the "C" class instead of the somewhat larger voltage step leading to the "off" state if he felt that the remaining non-zero amplification factor might be accepted. In any case, once the skilled person has been taught to gate the amplifiers to low gain during reception of the FID signals, the quantitative choice of the gating voltage step (to "off" state or to "C" class), in order to optimise the performance under the given conditions, only has to make use of predictable properties of amplifiers and thus is only a matter of expert experience.

- 4.5 The solution according to the characterising part of Claim 1, is thus substantially known from D2. This document, however, refers to an NMR spectrometer. The question, therefore, needs to be examined, whether it would be obvious for the skilled person to look for a solution to the stated problem, relating to the noise from the oscillating means of an NMR **imaging apparatus**, in the field of NMR **spectrometers**.

The Appellant argues in his letter of 10 April 1992 (see page 4) that an MRI apparatus, due to its high driving power, differs remarkably from a spectrometer, so that the concept of a spectrometer cannot be transferred to

an MRI apparatus. This statement is, however, contested by the Respondent (see letter of 14 August 1992, last paragraph of page 2 and page 3).

The difference between NMR imaging and NMR spectroscopy is due to a different technical application of the same theory. The basic technique upon which all NMR depends is the excitation of the precession of the nuclear magnetic moments by relatively strong RF pulses and the subsequent detection of the relatively weak emission signals from these precessing magnetic moments. NMR imaging and NMR spectroscopy therefore belong to closely related, neighbouring fields. The problems caused by the large discrepancy between the powers of the excitation and detection signals are the same in both fields.

In NMR imaging, the RF power required depends very much on the imaging method used; the requirements for selective irradiation are normally low, typically a few watts for 5 ms $\pi/2$ pulses, whereas for non-selective techniques much higher powers are required, typically 4 to 5 kW for 10 μ s $\pi/2$ pulses. In comparison, the NMR spectrometer disclosed in D4 has an RF pulse power output of 1.6 kW. Thus, there is no fundamental difference in the RF power required.

In view of the foregoing, the skilled person in the field of NMR imaging can thus be expected to take into account the solution to the same problem found in the neighbouring field of NMR spectroscopy.

- 4.6 For the above reasons, the subject-matter of Claim 1 does not involve an inventive step in the sense of Article 56 EPC and Claim 1 is, therefore, not allowable under Article 52(1) EPC.

Claim 2 depends on Claim 1 and, consequently, is also not allowable. Moreover, Claim 2 essentially refers to the use of a MOSFET in the final stage of the amplifying chain, this measure being already known in the prior art (see D5).

5. Thus, the grounds for opposition mentioned in Article 100(a) EPC in conjunction with Article 56 EPC prejudice the maintenance of the patent.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar:

The Chairman:

P. Martorana

E. Turrini