

## PATENT COOPERATION TREATY

From the  
INTERNATIONAL SEARCHING AUTHORITY

# PCT

WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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| To:<br>LAFHEY, Bridget M.<br><br>Schlumberger 10001 Richmond Avenue Room 4720 Houston,<br>Texas 77042 USA |
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| Date of mailing<br>(day/month/year) <b>14 November 2018 (14.11.2018)</b> |
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| Applicant's or agent's file reference<br>IS161704WPC  | <b>FOR FURTHER ACTION</b><br>See paragraph 2 below                               |  |
| International application No.<br><b>PCT/US2018/045312</b>   | International filing date (day/month/year)<br><b>06 August 2018 (06.08.2018)</b> | Priority date(day/month/year)<br>11 August 2017 (11.08.2017) |
| International Patent Classification (IPC) or both national classification and IPC<br><b>E21B 49/00(2006.01)i, G01V 3/32(2006.01)i, G01R 33/44(2006.01)i</b> |  |  |
| Applicant<br><b>SCHLUMBERGER TECHNOLOGY CORPORATION et al.</b>  |  |  |

1. This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the international application
- Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.  
For further options, see Form PCT/ISA/220.

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| Name and mailing address of the ISA/KR<br>International Application Division<br>Korean Intellectual Property Office<br>189 Cheongsa-ro, Seo-gu, Daejeon,<br>35208, Republic of Korea<br>Facsimile No. +82-42-481-8578 | Date of completion of this opinion<br><br>13 November 2018 (13.11.2018) | Authorized officer<br><br>LEE, Jong Kyung<br><br>Telephone No. +82-42-481-3360 |
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WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US2018/045312

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :
  - the international application in the language in which it was filed
  - a translation of the international application into \_\_\_\_\_ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
2.  This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43bis.1(a))
3.  With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
  - a.  forming part of the international application as filed:
    - in the form of an Annex C/ST.25 text file.
    - on paper or in the form of an image file.
  - b.  furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
  - c.  furnished subsequent to the international filing date for the purposes of international search only:
    - in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
    - on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
4.  In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

**WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

**PCT/US2018/045312**

**Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

|                               |        |                        |     |
|-------------------------------|--------|------------------------|-----|
| Novelty (N)                   | Claims | <u>1-32</u>            | YES |
|                               | Claims | <u>NONE</u>            | NO  |
| Inventive step (IS)           | Claims | <u>6-17,29</u>         | YES |
|                               | Claims | <u>1-5,18-28,30-32</u> | NO  |
| Industrial applicability (IA) | Claims | <u>1-32</u>            | YES |
|                               | Claims | <u>NONE</u>            | NO  |

2. Citations and explanations :

Reference is made to the following documents:

D1: US 5539309 A (VAN WYK et al.) 23 July 1996

D2: US 2015-0268323 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 24 September 2015

D3: EP 0478632 B1 (BRITISH TECHNOLOGY GROUP LIMITED) 26 February 1997

D4: US 4728892 A (VINEGAR et al.) 01 March 1988

D5: WO 2016-061335 A1 (SCHLUMBERGER CANADA LIMITED et al.) 21 April 2016

1. Novelty and Inventive Step

1.1 Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a nuclear magnetic resonance (NMR) apparatus comprising: a magnet (3); a coil (2) acting either as a transmitting coil or receiving coil via a transmit/receive switch (4) including a pulse generator (5) and an amplifier (7), wherein the pulse generator (5) generates a pulse sequence including a 90° rf pulse signal in the x direction, a 90° rf pulse signal in the y direction, and 180° rf pulse signal, and arranged to detect signals resulting from an interaction of an NMR field with a sample in a sample region (1), including an FID signal following the 90° rf pulse in the y direction, and an FID signal following the 180° rf pulse signal; and a processor (8) for processing the FID signals to obtain a measure of solid and liquid contents of the sample (see column 1, lines 7-50, column 3, line 26 - column 4, line 67, claim 1, and figures 1, 2). Claim 1 differs from D1 in that a train of echoes between pulses of a CPMG pulse sequence portion is detected and processed. However, this feature would be easily conceived from D2 considering that a plurality of echoes between pulses of CPMG pulse sequence are detected for characterizing a sample (see paragraphs [0034]-[0040] and figure 1A).

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**WRITTEN OPINION OF THE  
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International application No.

**PCT/US2018/045312**

**Box No. VIII Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claims 1, 9, 16, 27, and 31 are not clear because "said NMR field" (claim 1), 'said two dimensional line-narrowing sequence portion' (claim 9), 'said line-narrowing pulse sequence portion' (claim 16), 'said processor' (claim 27), and 'the solid portion' (claim 31) have not been previously defined. Therefore, claims 1, 9, 16, 27, and 31 do not meet the requirements of PCT Article 6.

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As D1 and D2 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of documents to arrive at the claimed invention. Accordingly, claim 1 would have been obvious over D1 in view of D2. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

1.2 Dependent Claims 2-20

1.2.1 Concerning Claim 2

The additional feature of claim 2 is identical to the 90° rf pulse signal in the x direction and the 90° rf pulse signal in the y direction in D1 (see figure 2). Accordingly, claim 2 would have been obvious over D1 in view of D2. Therefore, claim 2 lacks an inventive step under PCT Article 33(3).

1.2.2 Concerning Claim 3

The additional feature of claim 3 is identical to the 90° rf pulse signal in the y direction and the 180° rf pulse signal in D1 (see figure 2). Accordingly, claim 3 would have been obvious over D1 in view of D2. Therefore, claim 3 lacks an inventive step under PCT Article 33(3).

1.2.3 Concerning Claim 4

The additional feature of claim 4, concerning a two-dimensional line-narrowing sequence portion, is not disclosed either in D1 or in D2. However, this feature would be easily conceived from multipulse sequences to provide line narrowing for obtaining NMR imaging information from solid objects in D3 (see paragraph [0002], claim 1, and figure 1). As D1-D3 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of documents to arrive at the claimed invention. Accordingly, claim 4 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 4 lacks an inventive step under PCT Article 33(3).

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1.2.4 Concerning Claim 5

The additional feature of claim 5 is characterized in that the CPMG pulse sequence portion follows the two-dimensional line-narrowing sequence portion. This feature would be easily conceived from the  $90^\circ$  rf pulse signal in the y direction and the  $180^\circ$  rf pulse signal in D1 (see figure 2) and the multipulse sequences in D3 (see figure 1). Accordingly, claim 5 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 5 lacks an inventive step under PCT Article 33(3).

1.2.5 Concerning Claims 6-9

The additional feature of claim 6 is characterized in that a solid state pulse sequence portion includes a first ninety degree excitation pulse followed by a sub-sequence including a second ninety degree excitation pulse following the first ninety degree excitation pulse after a time period of  $2\tau + \tau_p$ , the second ninety degree excitation pulse followed after a time period  $\tau$  by an 180 degree pulse of length  $\tau_p$ , followed after a time period  $2\tau$  by three 180 degree pulses each spaced by a time period  $2\tau$ , and followed by another ninety degree excitation pulse. This feature is not disclosed in any of the prior art documents, nor is it obvious to a person skilled in the art by the documents. Accordingly, claim 6 is novel and involves an inventive step under PCT Article 33(2) and (3).

Claims 7-9 are directly or indirectly dependent on claim 6 and therefore meet the requirements of PCT Article 33(2) and (3).

1.2.6 Concerning Claims 10-13

The additional feature of claim 10 is characterized in that a solid state pulse sequence portion includes a first ninety degree excitation pulse followed by a sub-sequence comprising a second ninety degree excitation pulse that follows the first ninety degree excitation pulse after a period of time  $\tau$ , followed after a period of time  $\tau$  by a third ninety degree excitation pulse followed after a period of time  $2\tau$  by a fourth ninety degree excitation pulse, followed after a period of time  $\tau$  by a fifth ninety degree excitation pulse. This feature is not disclosed in any of the prior art documents, nor is it obvious to a person skilled in the art by the documents. Accordingly, claim 10 is novel and involves an inventive step under PCT Article 33(2) and

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(3).

Claims 11-13 are directly or indirectly dependent on claim 10 and therefore meet the requirements of PCT Article 33(2) and (3).

1.2.7 Concerning Claims 14-17

The additional feature of claim 14 is characterized in that a solid state pulse sequence portion includes a first ninety degree excitation pulse followed by a sub-sequence including a second ninety degree excitation pulse following the first ninety degree excitation pulse after a period of time  $\tau$ , which is followed after a period of  $4\tau$  during which time spin-locking  $+x$  and  $-x$  pulses are provided by another ninety degree excitation pulse. This feature is not disclosed in any of the prior art documents, nor is it obvious to a person skilled in the art by the documents. Accordingly, claim 14 is novel and involves an inventive step under PCT Article 33(2) and (3).

Claims 15-17 are directly or indirectly dependent on claim 14 and therefore meet the requirements of PCT Article 33(2) and (3).

1.2.8 Concerning Claim 18

The additional feature of claim 18 is characterized in that a pulse sequencer generates an NMR pulse sequence further including a T1 pulse sequence and a processor further processes data resulting from said T1 pulse sequence. This feature would be easily conceived from D2 considering that T1 is measured by using a sequence (see paragraph [0037]). Accordingly, claim 18 would have been obvious over D1 in view of D2. Therefore, claim 18 lacks an inventive step under PCT Article 33(3).

1.2.9 Concerning Claim 19

The additional feature of claim 19 is characterized in that a hydrogen content of a sample comprises the hydrogen content of a solid portion of the sample, and a processor determines an indication of the hydrogen content of the solid portion of the sample by using an echo resulting from a solid state sequence portion of a pulse sequence to establish a total organic hydrogen content of the sample, and by using the echoes resulting from the CPMG pulse

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sequence portion to establish a fluid organic hydrogen content, and by subtracting the fluid organic hydrogen content from the total organic hydrogen content to obtain the hydrogen content of the solid portion of the sample. This feature would be easily conceived from D1 considering that the FID signals are processed to obtain a measure of solid and liquid contents of the sample (see column 3, line 26 - column 4, line 67, claim 1, and figure 2). Accordingly, claim 19 would have been obvious over D1 in view of D2. Therefore, claim 19 lacks an inventive step under PCT Article 33(3).

1.2.10 Concerning Claim 20

The additional feature of claim 20 is characterized in that an NMR tool includes a body in which a magnetic, a transmitter and a receiver are located and a cable coupled to the body. This feature is merely a variation of the NMR apparatus comprising the magnet (3) and the coil (2) in D1 (see figure 1). Accordingly, claim 20 would have been obvious over D1 in view of D2. Therefore, claim 20 lacks an inventive step under PCT Article 33(3).

1.3 Independent Claim 21

D1, which is considered to be the closest prior art to the subject matter of claim 21, discloses a method for monitoring a sample having solid and liquid contents comprising the steps of: generating and subjecting a sample to an NMR field, the NMR field varying according to a pulse sequence including a 90° rf pulse signal in the x direction, a 90° rf pulse signal in the y direction, and 180° rf pulse signal; detecting signals resulting from an interaction of the NMR field with the sample, including an FID signal following the 90° rf pulse in the y direction, and an FID signal following the 180° rf pulse signal; and processing the FID signals to obtain a measure of solid and liquid contents of the sample (see column 1, lines 7-50, column 3, line 26 - column 4, line 67, claim 1, and figures 1, 2). Claim 21 differs from D1 in that a plurality of CPMG echoes between pulses of a CPMG pulse sequence portion are detected and processed. However, this feature would be easily conceived from D2 considering that a plurality of echoes between pulses of CPMG pulse sequence are detected for characterizing a sample (see paragraphs [0034]-[0040] and figure 1A). As D1 and D2 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of

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documents to arrive at the claimed invention. Accordingly, claim 21 would have been obvious over D1 in view of D2. Therefore, claim 21 lacks an inventive step under PCT Article 33(3).

1.4 Dependent Claims 22-27

1.4.1 Concerning Claim 22

The additional feature of claim 22 is identical to the 90° rf pulse signal in the x direction and the 90° rf pulse signal in the y direction in D1 (see figure 2). Accordingly, claim 22 would have been obvious over D1 in view of D2. Therefore, claim 22 lacks an inventive step under PCT Article 33(3).

1.4.2 Concerning Claim 23

The additional feature of claim 23 is identical to the 90° rf pulse signal in the y direction and the 180° rf pulse signal in D1 (see figure 2). Accordingly, claim 23 would have been obvious over D1 in view of D2. Therefore, claim 23 lacks an inventive step under PCT Article 33(3).

1.4.3 Concerning Claim 24

The additional feature of claim 24, concerning a two-dimensional line-narrowing sequence portion, is not disclosed either in D1 or in D2. However, this feature would be easily conceived from multipulse sequences to provide line narrowing for obtaining NMR imaging information from solid objects in D3 (see paragraph [0002], claim 1, and figure 1). As D1-D3 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of documents to arrive at the claimed invention. Accordingly, claim 24 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 24 lacks an inventive step under PCT Article 33(3).

1.4.4 Concerning Claim 25

The additional feature of claim 25 is characterized in the CPMG pulse sequence portion follows the two-dimensional line-narrowing sequence portion. This feature would be easily

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conceived from the 90° rf pulse signal in the y direction and the 180° rf pulse signal in D1 (see figure 2) and the multipulse sequences in D3 (see figure 1). Accordingly, claim 25 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 25 lacks an inventive step under PCT Article 33(3).

1.4.5 Concerning Claim 26

The additional feature of claim 26, concerning a two-dimensional line-narrowing sequence portion and a T1 pulse sequence, is not disclosed either in D1 or in D2. However, this feature would be easily conceived from multipulse sequences to provide line narrowing for obtaining NMR imaging information from solid objects in D3 (see paragraph [0002], claim 1, and figure 1) and T1 measured by using a sequence in D2 (see paragraph [0037]). As D1-D3 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of documents to arrive at the claimed invention. Accordingly, claim 26 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 26 lacks an inventive step under PCT Article 33(3).

1.4.6 Concerning Claim 27

The additional feature of claim 27 is characterized in that a processor determines an indication of the hydrogen content of a solid portion of a sample by using an echo resulting from a solid state sequence portion of a pulse sequence to establish a total organic hydrogen content of the sample, and by using the echoes resulting from the CPMG pulse sequence portion to establish a fluid organic hydrogen content, and by subtracting the fluid organic hydrogen content from the total organic hydrogen content to obtain the hydrogen content of the solid portion of the sample. This feature would be easily conceived from a processor (8) for processing the FID signals to obtain a measure of solid and liquid contents of the sample in D1 (see column 3, line 26 - column 4, line 67, claim 1, and figure 2). Accordingly, claim 27 would have been obvious over D1 in view of D2. Therefore, claim 27 lacks an inventive step under PCT Article 33(3).

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1.5 Independent Claim 28

D1, which is considered to be the closest prior art to the subject matter of claim 28, discloses a method for monitoring a sample having solid and liquid contents comprising the steps of: generating and subjecting a sample to an NMR field, the NMR field varying according to a pulse sequence including a 90° rf pulse signal in the x direction, a 90° rf pulse signal in the y direction, and 180° rf pulse signal; detecting signals resulting from an interaction of the NMR field with the sample, including an FID signal following the 90° rf pulse in the y direction, and an FID signal following the 180° rf pulse signal; and processing the FID signals to obtain a measure of solid and liquid contents of the sample (see column 1, lines 7-50, column 3, line 26 - column 4, line 67, claim 1, and figures 1, 2). Claim 28 differs from D1 in that an NMR pulse sequence includes a two-dimensional line-narrowing pulse sequence portion and a CPMG pulse sequence portion having a plurality of pulses and a series of echoes resulting from the two-dimensional line-narrowing pulse sequence portion and a train of CPMG echoes between pulses of the CPMG pulse sequence portion are detected and processed. However, this feature would be easily conceived from a plurality of echoes between pulses of CPMG pulse sequence detected for characterizing a sample in D2 (see paragraphs [0034]-[0040] and figure 1A) and multipulse sequences to provide line narrowing for obtaining NMR imaging information from solid objects in D3 (see paragraph [0002], claim 1, and figure 1). As D1-D3 are directed toward a similar subject matter, a person skilled in the art would, in seeking a solution to the problem being addressed, be motivated to combine the disclosures of each of documents to arrive at the claimed invention. Accordingly, claim 28 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 28 lacks an inventive step under PCT Article 33(3).

1.6 Dependent Claims 29-32

1.6.1 Concerning Claim 29

The additional feature of claim 29 is characterized in that the processing includes conducting a Laplace-Laplace inverse transform and finding line-narrowing T2 values from the series of echoes and finding CPMG T2 values from the train of CPMG echoes, the method further comprising: plotting a map the line-narrowing T2 values versus the CPMG T2 values; and identifying different hydrogen-containing species in the sample from the map. This feature is

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not disclosed in any of the prior art documents, nor is it obvious to a person skilled in the art by the documents. Accordingly, claim 29 is novel and involves an inventive step under PCT Article 33(2) and (3).

1.6.2 Concerning Claim 30

The additional feature of claim 30 is identical to the feature of D2 in that data analysis is performed by conducting a Fourier transform and a Laplace inversion for generating a two-dimensional spectrum with peaks identifying different molecules present in the sample, wherein the two-dimensional spectrum is optionally plotted on a graph utilizing chemical shift (ppm) as one axis and relaxation time T2 as the other axis (see paragraph [0013]). Accordingly, claim 30 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 30 lacks an inventive step under PCT Article 33(3).

1.6.3 Concerning Claim 31

The additional feature of claim 31 is identical to the feature of D1 in that a measure of solid and liquid contents of the sample is obtained by using nuclear magnetic resonance (see column 1, lines 7-50). Accordingly, claim 31 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 31 lacks an inventive step under PCT Article 33(3).

1.6.4 Concerning Claim 32

The additional feature of claim 32 is characterized in that the NMR pulse sequence further includes a T1 pulse sequence, and the method further comprises the step of plotting a map with T1 as one axis of the map. This feature would be easily conceived from D2 considering that T1 is measured by using a sequence (see paragraph [0037]) and the step of plotting a map comes within the customary practice followed by a person skilled in the art. Accordingly, claim 32 would have been obvious over D1 in view of D2, further in view of D3. Therefore, claim 32 lacks an inventive step under PCT Article 33(3).

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2. Industrial Applicability

Claims 1-32 are industrially applicable under PCT Article 33(4).