(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 July 2014 (24.07.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/113554 A1

(51) International Patent Classification:
E21B 47/00 (2012.01) *E21B 47/022* (2012.01)

(21) International Application Number:
PCT/US2014/011824

(22) International Filing Date:
16 January 2014 (16.01.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/743,720 17 January 2013 (17.01.2013) US

(71) Applicant: BAKER HUGHES INCORPORATED [US/US]; PO Box 4740, Houston, Texas 77210-4740 (US).

(72) Inventor: MACPHERSON, John D.; 2929 Allen Parkway, Suite 2100, Houston, Texas 77019-2118 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:
— *with international search report (Art. 21(3))*

(54) Title: SYNCHRONIZATION OF DISTRIBUTED MEASUREMENTS IN A BOREHOLE

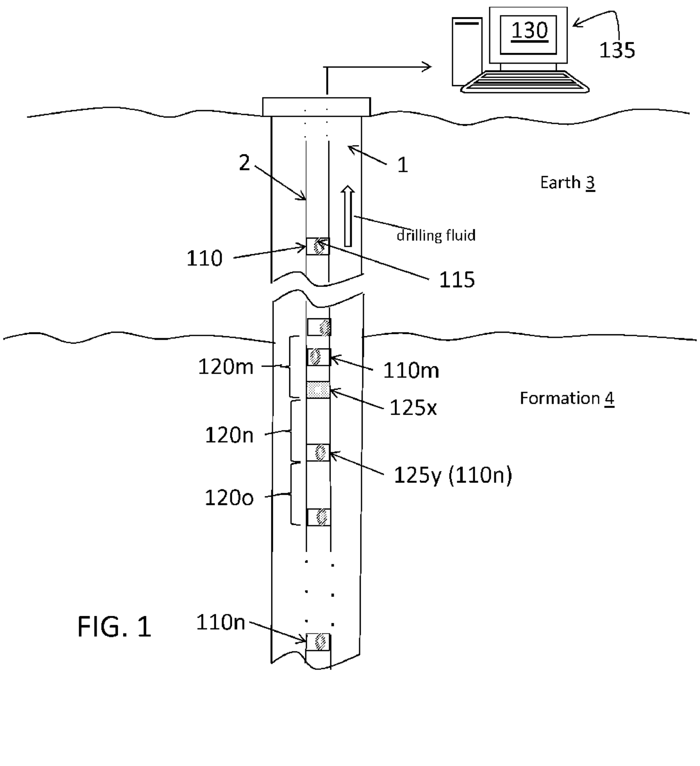

FIG. 1

(57) Abstract: A system and method to synchronize distributed measurements in a borehole are described. The system includes a plurality of wired segments coupled together by couplers and a plurality of nodes configured to measure, process, or relay information obtained in the borehole to a surface processing system, each of the plurality of nodes comprising a local clock and being disposed at one of the couplers or between couplers. The system also includes a surface processing system coupled to a master clock and configured to determine a time offset between the master clock and the local clock of an nth node among the plurality of nodes based on a downhole generated synchronization signal

WO 2014/113554 A1

SYNCHRONIZATION OF DISTRIBUTED MEASUREMENTS IN A BOREHOLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 13/743720, filed on January 17, 2013, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] During downhole exploration and formation excavation, a number of sensors and measurement devices may be used to characterize the downhole environment. Each measurement, or record of measurements, may be time-stamped, or associated with a known time, so that the measurements from the various devices may be processed together at the surface. However, each of the downhole measurement platforms operates with a respective local clock that is typically not synchronized with the surface master clock. Thus, before the various distributed measurements may be processed together, they must be synchronized to a common time. In prior systems, the surface processing system has undertaken the synchronization. For example, the master clock at the surface generates a synchronization signal, and the local clocks downhole use the signal to set their time in agreement with the master clock's time so that all time stamps are referenced to the same (master clock) time. As another example, the master clock generates a synchronization signal, and based on a response to that signal from each downhole device, the surface processing system stores a measured offset from the master clock for each device.

SUMMARY

[0003] According to one aspect of the invention, a system to synchronize distributed measurements in a borehole includes a plurality of wired segments coupled together by couplers; a plurality of nodes configured to measure, process, or relay information obtained in the borehole to a surface processing system, each of the plurality of nodes comprising a local clock and being disposed at one of the couplers or between couplers; and a surface processing system coupled to a master clock and configured to determine a time offset between the master clock and the local clock of an nth node among the plurality of nodes based on a downhole generated synchronization signal.

[0004] According to another aspect of the invention, a method of synchronizing distributed measurements in a borehole includes disposing a known number of wired segments coupled together by couplers in the borehole; disposing nodes along the wired segments, the nodes being disposed at two or more of the couplers or between couplers and each node comprising a local clock and configured to measure or relay information obtained in the borehole to a surface processing system; generating a time-stamped signal at an nth node based on the local clock of the nth node; receiving the time-stamped signal at the surface processing system; and the surface processing system computing a time offset between a master clock associated with the surface processing system and the local clock of the nth node.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Referring now to the drawings wherein like elements are numbered alike in the several Figures:

[0006] FIG. 1 is a cross-sectional illustration of a borehole including nodes with local clocks according to an embodiment of the invention; and

[0007] FIG. 2 is a flow diagram of a method of synchronizing distributed measurements in a borehole according to an embodiment of the invention.

DETAILED DESCRIPTION

[0008] As noted above, prior systems have synchronized local clocks of downhole devices with a master clock at the surface by using a synchronization signal generated by the master clock or some other form of synchronization initiated by the master clock. Embodiments of the invention described herein use the fact that the time at a local clock need not be synchronized and reset as long as its offset from the master clock is determined and accounted for. Accordingly, embodiments described herein include downhole initiation of a synchronization process rather than synchronization by the master clock.

[0009] FIG. 1 is a cross-sectional illustration of a borehole 1 including nodes 110 with local clocks 115 according to an embodiment of the invention. Nodes 110 are disposed in the borehole 1 penetrating the earth 3, which may include a formation 4. The formation 4 represents any subsurface material of interest that the nodes 110 may help to characterize. The nodes 110 may be conveyed through the borehole 1 by a carrier 2. The carrier 2 may be a wireline used in wireline logging after drilling has ceased. In this case, the nodes 110 are disposed along the wireline. In alternate embodiments, the carrier 2 may be a drill string used in Logging While Drilling (LWD) with the nodes 110 disposed in a bottomhole assembly. In general, the nodes 110 with local clocks 115 may be part of any system for obtaining downhole measurements in a borehole 1 in which the nodes 110 are distributed along the borehole 1, and in which the nodes 110 transfer data along the borehole 1. That is, a given node 110 may obtain downhole data (act as a sensor measuring data) for transmission to the surface, relay downhole data sent from another node 110 without any additional processing, or may process measured data or data received from another node 110. The data transfer by the nodes 110 may be via signals including, for example, mud pulse, acoustic, electro-magnetic, electrical, or optical.

[0010] In the embodiment shown in FIG. 1, the carrier 2 is a wired pipe system composed of multiple wired segments 120 with interspersed couplers 125. These couplers 125 are used to transfer data between sections of tubular elements that make up the carrier 2 (e.g. drill string). The wired segments 120 may, therefore, all be of approximately the same length and, therefore, periodic. The couplers 125 may be nodes 110, though not all couplers 125 may be nodes 110, and. a node may lie between couplers 125 (see e.g., 110m). For example, coupler 125x is not a node 110 while coupler 125y is a node 110 that measures or senses some information downhole. Each of the nodes 110 relays information from another node 110 farther from the surface. Each node 110 includes a local clock 115 so that information provided by each node 110 is time-stamped with the local time at which the information was obtained. Information relayed to the surface may be processed by a surface processing system 130 that includes one or more processors and memory devices. The surface processing system 130 also includes or is coupled to the master clock 135.

[0011] The local clocks 115 of the nodes 110 may be relatively simple crystal oscillators that are intended to work in an asynchronous manner (i.e., independent of any other timing device in the borehole 1). The local clocks 115 are intended to ensure that inter-sample time periods are accurate to a specified amount, but a local clock115 at a node 110m may experience time drift with respect to a local clock 115 at another node 110n over the long term. Local clocks 115 are used to time-stamp individual measurements, or records of measurements, with a local time. In general, the master clock 135 may be a very accurate time keeping system, possibly synchronized to a remote timing system, such as that supplied by a Global Positioning System (GPS).

[0012] The couplers 125, wired segments 120, and nodes 110 operate in a time-varying thermal environment and are also subject to vibration. As a result, the local clocks 115 of the nodes 110 drift with respect to one another. In addition, signal propagation speeds vary with temperature because, for example, material properties of the wired segments 120 change with temperature. The signal propagation delay includes time delay through the multiple wired segments 120, time delay through the multiple couplers 125, and time delay at each of the nodes 110 encountered by the signal prior to reaching the surface processing system 130. Each of these is discussed in turn.

[0013] With regard to the wired segments 120, when these are coaxial segments, then signal propagation velocity is approximately 180 m/μs, assuming a velocity factor of 60% for the dielectric. If each coaxial segment is 10 m in length, then the delay over each segment is 1/18 μs. Over an exemplary borehole 1 of length 10 km, the resulting delay over the combined coaxial segments is 0.056 ms. Because seismic recording rates are 1000 s/s, a clock accuracy (offset accuracy) to 0.5 ms is needed. As illustrated by the exemplary case, this accuracy is apparently achievable by at least a factor of 10, even with this conservative estimate of the coaxial velocity factor. Thus, delays through the wired segments 120 may be ignored, although they may be compensated for if needed. The delay through the wired segments 120 may be modeled to account for temperature effects, for example. With regard to the couplers 125, their cumulative effect may be significant. However, because there are a relatively large number of couplers 125 within a carrier 2 (e.g., wired pipe), the delay introduced by the couplers 125 may be measured experimentally and handled statistically. The surface processing system 130 has knowledge of the number of couplers 125 between itself and a given node 110 and can, therefore, estimate the delay resulting from the couplers 125. If the coupler 125 delay is found to be affected by temperature, then periodic temperature measurements along the carrier 2 may be used to correct the delay values. With regard to the nodes 110, the delay associated with each may be more problematic because nodes 110 are computation points and may read and write messages, as well. As such, the delay at each node 110 is unlikely to be the same from one transmission to the next. Further, the delay at a given node 110 is likely to be different from the delay at another node 110. However, the delay at a node 110 may be made deterministic by delaying a time synchronization signal a specified amount of time at each node 110. That is, as long as the specified amount of time that is assumed as the delay is greater than the actual computation, read/write time taken by any node 110, the actual delay at the node 110 need not be known. For example, if the longest delay at any node 110 is x, a forced delay of x + some margin may be imposed on all the nodes 110 in order to make the delay related to the nodes 110 deterministic. In alternate embodiments, a processing delay (x + some margin) may be imposed on those nodes 110 that process data but not on nodes 110 that merely relay data. In alternate embodiments, the delay at each node 110 may also be determined statistically.

[0014] The offset associated with a particular node 110 n may then be calculated as:

$$B[n] = C[n] + da[n] + dc[n] + dr[n] - C_M \qquad \text{[EQ. 1]}$$

where B[n] is the offset for the nth node 110;

C[n] is the local clock time of the nth node 110;

$da[n]$ is an aggregate of the delay associated with every acquisition platform or node 110 from the surface to the nth node 110;

$dc[n]$ is an aggregate of the delay associated with every wired segment 120 from the surface to the nth node 110;

$dr[n]$ is an aggregate of the delay associated with every coupler 125 from the surface to the nth node 110; and

C_M is the master clock 135 time.

As noted above, the delay associated with every node 110 (da[n]) may be an artificial delay that is introduced at each node 110 (or each processing node 110) and ensured to be greater than the actual processing time at every node 110. Also, a node 110 may not be disposed at every coupler 125 but may also be disposed between couplers 125. Thus, the number of couplers 125 between the nth node 110 and the surface may be greater or less than the number of nodes 110 between the nth node 110 and the surface. Once the offset (B[n]) is determined, the timestamp of a data point received from the nth node 110 may be standardized to the time of the master clock 135 as follows:

$$\text{master timestamp} = \text{timestamp from nth node} - B[n] \qquad \text{[EQ. 2]}$$

Once all the data points from all the nodes 110 are adjusted to have timestamps standardized to the master clock 135 according to EQ. 2, measurements taken at different nodes 110 at the same time may be matched up and used in the analysis of the downhole environment.

[0015] In one embodiment, node 110 n is the farthest node 110 in the borehole 1 from the surface processing system 130. A time-stamped signal originates at node 110 n and is relayed to the surface processing system 130 by each node 110 between node 110 n and the surface processing system 130. By having each node 110 add its local timestamp to the relayed signal, the offset associated with each node 110 from the farthest (node 110 n) to the closest to the surface processing system 130 may be determined. As such, the node 110 n would have generated the synchronization signal. In alternate embodiments, any node 110 may generate the synchronization signal for the surface processing system 130 to determine its offset and the offset of nodes 110 between the node 110 generating the synchronization signal and the surface processing system 130.

[0016] FIG. 2 is a flow diagram of a method 200 of synchronizing distributed measurements in a borehole 1 according to an embodiment of the invention. Disposing a known number of couplers 125, nodes 110, and wired segments 120 in the borehole 1 (block 210) may be as shown in FIG. 1, for example. Generating a time-stamped signal at a node 110 (block 220) includes generating the synchronization signal at the node 110 n that is farthest from the surface processing system 130. The method 200 also includes receiving the signal at the surface processing system 130 at block 230. Computing the offset at block 240 may be for one or more nodes 110. For example, as discussed above, in one embodiment, a synchronization signal generated at the farthest node 110 n is used to determine offsets for every node 110 from the farthest node 110 to the closest node 110 to the surface processing system 130.

[0017] While one or more embodiments have been shown and described, modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

CLAIMS:

1. A system to synchronize distributed measurements in a borehole, the system comprising:

a plurality of wired segments coupled together by couplers;

a plurality of nodes configured to measure, process, or relay information obtained in the borehole to a surface processing system, each of the plurality of nodes comprising a local clock and being disposed at one of the couplers or between couplers; and

a surface processing system coupled to a master clock and configured to determine a time offset between the master clock and the local clock of an nth node among the plurality of nodes based on a downhole generated synchronization signal.

2. The system according to claim 1, wherein the surface processing system determines a time offset associated with every node between the nth node and the surface processing system.

3. The system according to claim 1, wherein the wired segments are part of a wired pipe.

4. The system according to claim 1, wherein the surface processing system determines the time offset associated with the local clock of the nth node as follows:

$$B[n] = C[n] + da[n] + dc[n] + dr[n] - C_M$$

where B[n] is the time offset for the nth node;

C[n] is the local clock time of the nth node;

da[n] is an aggregate of a delay associated with every node from the surface processing system to the nth node;

dc[n] is an aggregate of a delay associated with every wired segment from the surface processing system to the nth node;

dr[n] is an aggregate of a delay associated with every coupler from the surface processing system to the nth node; and

C_M is the master clock time.

5. The system according to claim 4, wherein the delay associated with every coupler is based on a statistical analysis of experimental results.

6. The system according to claim 4, wherein the delay associated with every wired segment is the same based on a length of each of the plurality of wired segments.

7. The system according to claim 4, wherein the delay associated with each wired segment is determined based on a model.

8. The system according to claim 4, wherein the delay associated with every node that performs processing is an artificial delay greater than a processing delay at any node.

9. The system according to claim 4, wherein the delay associated with each node is determined statistically.

10. The system according to claim 1, wherein the surface processing system determines a synchronized time stamp from a time stamp associated with data from the nth node based on the time offset associated with the local clock of the nth node from the time stamp.

11. A method of synchronizing distributed measurements in a borehole, the method comprising:

disposing a known number of wired segments coupled together by couplers in the borehole;

disposing nodes along the wired segments, the nodes being disposed at two or more of the couplers or between couplers and each node comprising a local clock and configured to measure or relay information obtained in the borehole to a surface processing system;

generating a time-stamped signal at an nth node based on the local clock of the nth node;

receiving the time-stamped signal at the surface processing system; and

the surface processing system computing a time offset between a master clock associated with the surface processing system and the local clock of the nth node.

12. The method according to claim 11, further comprising the surface processing system computing a time offset between the master clock and the local clock of every node between the nth node and the surface processing system.

13. The method according to claim 11, wherein the surface processing system computing the time offset for the nth node is as follows:

$$B[n] = C[n] + da[n] + dc[n] + dr[n] - C_M$$

where B[n] is the time offset for the nth node;

C[n] is the local clock time of the nth node;

$da[n]$ is an aggregate of a delay associated with every node from the surface processing system to the nth node;

$dc[n]$ is an aggregate of a delay associated with every wired segment from the surface processing system to the nth node;

$dr[n]$ is an aggregate of a delay associated with every coupler from the surface processing system to the nth node; and

C_M is the master clock time.

14. The method according to claim 13, wherein the delay associated with every coupler is based on a statistical analysis of experimental results.

15. The method according to claim 13, wherein the delay associated with every wired segment is the same based on a length of each of the wired segments.

16. The method according to claim 13, wherein the delay associated with each wired segment is determined based on a model.

17. The method according to claim 13, wherein the delay associated with every node that performs processing is an artificial delay greater than a processing delay at any node.

18. The method according to claim 13, wherein the delay associated with each node is determined statistically.

19. The method according to claim 11, further comprising the surface processing system determining a standardized time stamp from the time stamp associated with data from the nth node based on the time offset associated with the local clock of the nth node from the time stamp.

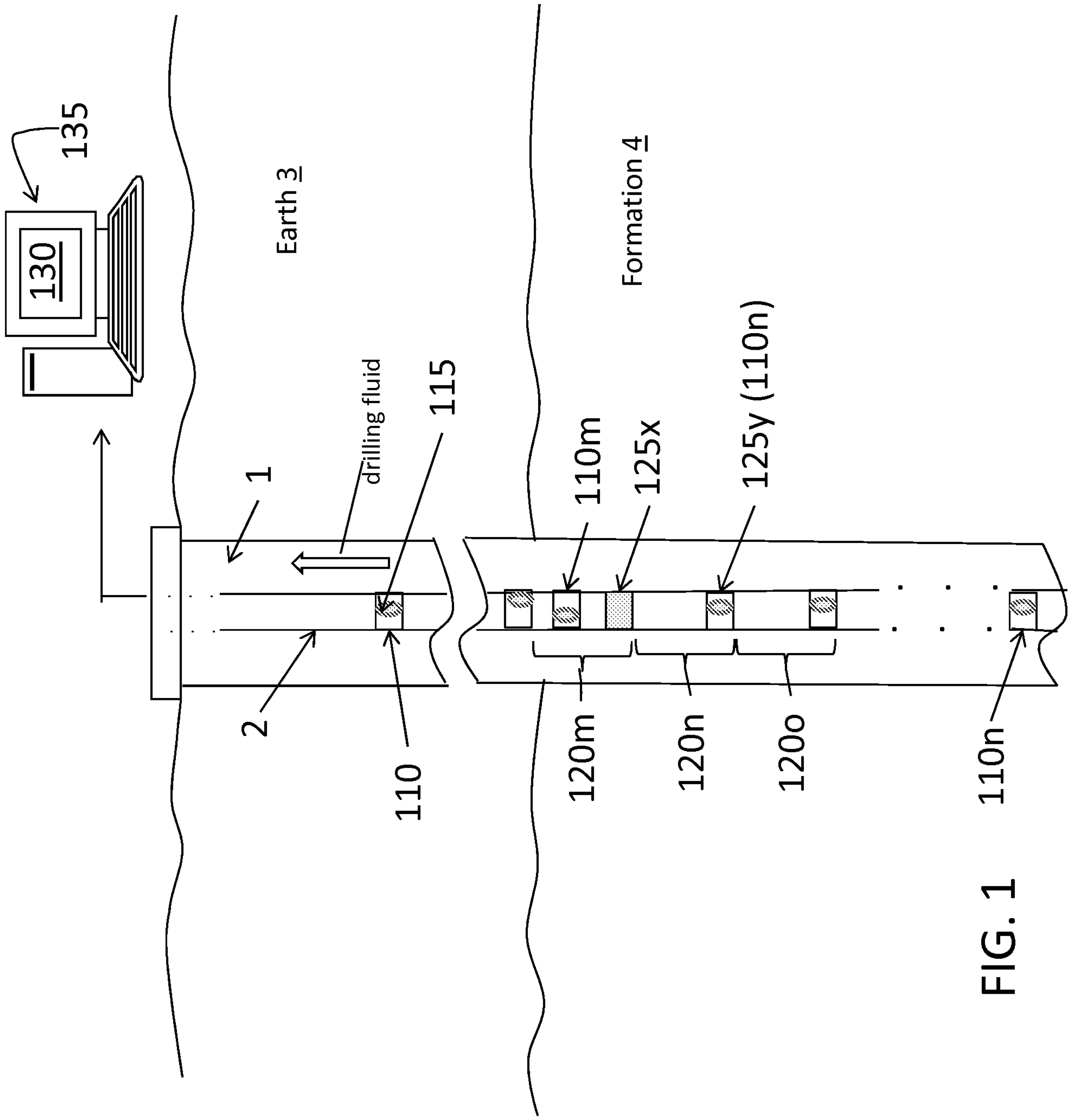
135
130
Earth 3
Formation 4
drilling fluid
1
2
115
110
110m
125x
125y (110n)
120m
120n
120o
110n

FIG. 1

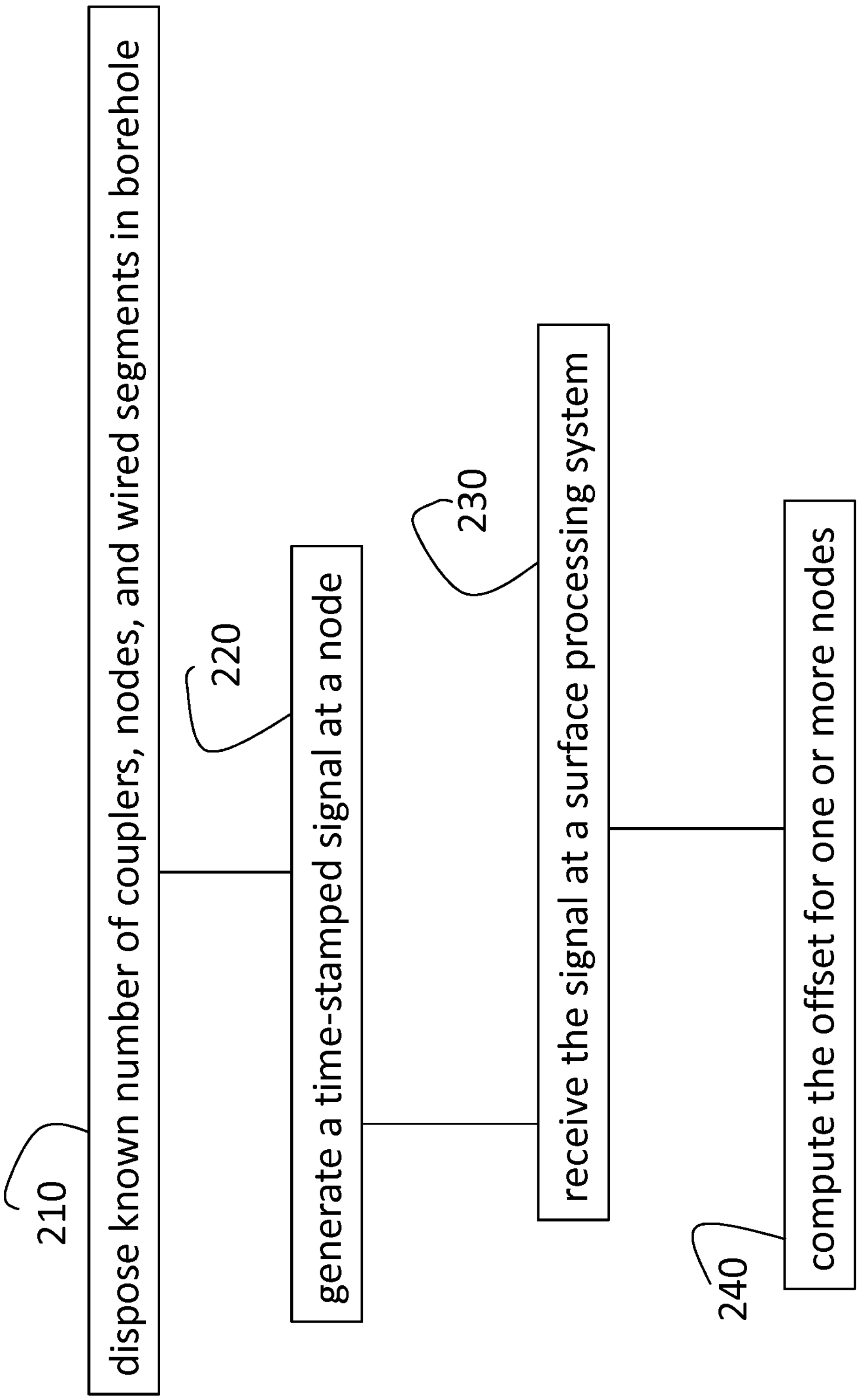
210
dispose known number of couplers, nodes, and wired segments in borehole
220
generate a time-stamped signal at a node
230
receive the signal at a surface processing system
240
compute the offset for one or more nodes

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/011824

A. CLASSIFICATION OF SUBJECT MATTER

E21B 47/00(2006.01)i, E21B 47/022(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B 47/00; E21B 47/04; H03B 9/14; E21B 47/12; G01V 1/40; G01V 11/00; E21B 47/022

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: synchronization, measurement, clock, time offset, and time stamp

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0313646 A1 (MEHTA, SHYAM et al.) 16 December 2010 See claims 1-2, 4, 22; paragraphs [0020]-[0063]; and figures 1-2.	1-3,10-12,19
A		4-9,13-18
A	US 2009-0187345 A1 (BLANZ, MARTIN) 23 July 2009 See paragraphs [0019]-[0045] and figure 1.	1-19
A	EP 2385396 A2 (SAUDI ARABIAN OIL COMPANY) 09 November 2011 See abstract and claims 1-18.	1-19
A	US 6079505 A (PIGNARD, GUY et al.) 27 June 2000 See column 3, line 43 - column 6, line 46 and figure 1.	1-19
A	US 2009-0038392 A1 (ALFRED, WALTER et al.) 12 February 2009 See paragraphs [0007]-[0020] and figure 1.	1-19

☐ Further documents are listed in the continuation of Box C.　　☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 April 2014 (18.04.2014)	**21 April 2014 (21.04.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
KIM, Jin Ho
Telephone No. +82-42-481-8699

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0313646 A1	16/12/2010	None	
US 2009-0187345 A1	23/07/2009	AU 2005-295209 A1	27/04/2006
		AU 2006-272755 A1	01/02/2007
		AU 2007-235543 A1	18/10/2007
		AU 2007-254366 A1	29/11/2007
		AU 2007-328463 A1	12/06/2008
		AU 2008-229323 A1	25/09/2008
		AU 2008-304661 A1	02/04/2009
		AU 2009-206038 A1	23/07/2009
		AU 2009-206041 A1	23/07/2009
		AU 2009-206042 A1	23/07/2009
		AU 2009-206044 A1	23/07/2009
		AU 2009-212432 A1	13/08/2009
		CA 2582118 A1	27/04/2006
		CA 2616197 A1	01/02/2007
		CA 2650223 A1	18/10/2007
		CA 2652134 A1	29/11/2007
		CA 2652447 A1	12/06/2008
		CA 2682180 A1	25/09/2008
		CA 2700324 A1	02/04/2009
		CA 2711273 A1	23/07/2009
		CA 2711761 A1	23/07/2009
		CA 2711959 A1	23/07/2009
		CA 2712461 A1	23/07/2009
		CA 2714096 A1	13/08/2009
		CA 2721898 A1	18/12/2009
		CA 2723880 A1	20/11/2008
		CN 100483365 C	29/04/2009
		CN 101784996 A	21/07/2010
		CN 101939737 A	05/01/2011
		CN 101959580 A	26/01/2011
		CN 102046260 A	04/05/2011
		CN 1867902 A	22/11/2006
		CN 1997972 A	11/07/2007
		EP 1654659 A2	10/05/2006
		EP 1683028 A1	26/07/2006
		EP 1802240 A2	04/07/2007
		EP 1909663 A2	16/04/2008
		EP 2018124 A2	28/01/2009
		EP 2018126 A2	28/01/2009
		EP 2049028 A2	22/04/2009
		EP 2142119 A1	13/01/2010
		EP 2174225 A1	14/04/2010
		EP 2194897 A2	16/06/2010
		EP 2235640 A2	06/10/2010
		EP 2237851 A1	13/10/2010
		EP 2237862 A1	13/10/2010
		EP 2249727 A2	17/11/2010

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		EP 2252219 A2	24/11/2010
		EP 2320815 A2	18/05/2011
		GB 201012206 D0	08/09/2010
		GB 2468621 A	15/09/2010
		GB 2468621 B	07/03/2012
		JP 2007-527572 A	27/09/2007
		JP 2010-532538 A	07/10/2010
		JP 2011-509760 A	31/03/2011
		JP 2011-510302 A	31/03/2011
		JP 2011-510405 A	31/03/2011
		JP 2011-510454 A	31/03/2011
		JP 2013-176682 A	09/09/2013
		JP 5334997 B2	06/11/2013
		KR 10-0890573 B1	25/03/2009
		KR 10-2006-0080239 A	07/07/2006
		KR 10-2010-0113086 A	20/10/2010
		US 2005-0071392 A1	31/03/2005
		US 2005-0108486 A1	19/05/2005
		US 2005-0193235 A1	01/09/2005
		US 2006-0084982 A1	20/04/2006
		US 2006-0084984 A1	20/04/2006
		US 2006-0084987 A1	20/04/2006
		US 2007-0043359 A1	22/02/2007
		US 2007-0100341 A1	03/05/2007
		US 2007-0112896 A1	17/05/2007
		US 2007-0167949 A1	19/07/2007
		US 2007-0219556 A1	20/09/2007
		US 2007-0225712 A1	27/09/2007
		US 2007-0225713 A1	27/09/2007
		US 2007-0239159 A1	11/10/2007
		US 2008-0016131 A1	17/01/2008
		US 2008-0082310 A1	03/04/2008
		US 2008-0097441 A1	24/04/2008
		US 2008-0183215 A1	31/07/2008
		US 2008-0262554 A1	23/10/2008
		US 2008-0275911 A1	06/11/2008
		US 2009-0030465 A1	29/01/2009
		US 2009-0125047 A1	14/05/2009
		US 2009-0172326 A1	02/07/2009
		US 2009-0177661 A1	09/07/2009
		US 2009-0182150 A1	16/07/2009
		US 2009-0182789 A1	16/07/2009
		US 2009-0186495 A1	23/07/2009
		US 2009-0186534 A1	23/07/2009
		US 2009-0187232 A1	23/07/2009
		US 2009-0228045 A1	10/09/2009
		US 2009-0282980 A1	19/11/2009
		US 2010-0036423 A1	11/02/2010
		US 2011-0089318 A1	21/04/2011
		US 2011-0144701 A1	16/06/2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 7146476 B2	05/12/2006
		US 7430647 B2	30/09/2008
		US 7629469 B2	08/12/2009
		US 7740488 B2	22/06/2010
		US 7935134 B2	03/05/2011
		US 7998175 B2	16/08/2011
		US 8025680 B2	27/09/2011
		US 8034161 B2	11/10/2011
		US 8075595 B2	13/12/2011
		US 8162985 B2	24/04/2012
		US 8195397 B2	05/06/2012
		US 8200924 B2	12/06/2012
		US 8226690 B2	24/07/2012
		US 8267969 B2	18/09/2012
		US 8280926 B2	02/10/2012
		US 8523865 B2	03/09/2013
		US 8535352 B2	17/09/2013
		US 8551142 B2	08/10/2013
		US 8620640 B2	31/12/2013
		US 8686353 B2	01/04/2014
		WO 2005-017686 A2	24/02/2005
		WO 2005-017686 A3	14/04/2005
		WO 2005-033945 A1	14/04/2005
		WO 2006-045091 A2	27/04/2006
		WO 2006-045091 A3	26/05/2006
		WO 2007-014119 A2	01/02/2007
		WO 2007-014119 A3	27/09/2007
		WO 2007-117366 A2	18/10/2007
		WO 2007-117366 A3	12/09/2008
		WO 2007-136612 A2	29/11/2007
		WO 2007-136612 A3	26/06/2008
		WO 2008-069835 A2	12/06/2008
		WO 2008-069835 A3	27/11/2008
		WO 2008-115549 A1	25/09/2008
		WO 2008-140756 A2	20/11/2008
		WO 2008-140756 A3	08/01/2009
		WO 2008-153747 A2	18/12/2008
		WO 2008-153747 A3	05/03/2009
		WO 2009-006278 A1	08/01/2009
		WO 2009-042489 A2	02/04/2009
		WO 2009-042489 A3	22/05/2009
		WO 2009-091955 A1	23/07/2009
		WO 2009-091956 A2	23/07/2009
		WO 2009-091956 A3	22/10/2009
		WO 2009-091957 A2	23/07/2009
		WO 2009-091957 A3	15/10/2009
		WO 2009-091958 A1	23/07/2009
		WO 2009-091959 A2	23/07/2009
		WO 2009-091960 A2	23/07/2009
		WO 2009-091960 A3	15/10/2009

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/011824

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		WO 2009-091961 A1	23/07/2009
		WO 2009-091962 A1	23/07/2009
		WO 2009-091963 A1	23/07/2009
		WO 2009-100190 A2	13/08/2009
		WO 2009-100190 A3	22/10/2009
		WO 2010-019791 A2	18/02/2010
		WO 2010-019791 A3	14/05/2010
EP 2385396 A2	09/11/2011	CN 102197319 A	21/09/2011
		EP 2344910 A1	20/07/2011
		EP 2385396 A3	18/04/2012
		EP 2385396 B1	09/01/2013
		US 2010-0050017 A1	25/02/2010
		US 8312320 B2	13/11/2012
		WO 2010-027786 A1	11/03/2010
US 6079505 A	27/06/2000	CA 2090586 A1	28/08/1993
		CA 2090586 C	10/04/2007
		EP 0558379 A1	01/09/1993
		EP 0558379 B1	15/05/1996
US 2009-0038392 A1	12/02/2009	CA 2540648 A1	14/04/2005
		CA 2540648 C	30/10/2012
		EA 007837 B1	27/02/2007
		US 2004-124012 A1	01/07/2004
		US 7128167 B2	31/10/2006
		US 8181510 B2	22/05/2012
		WO 2005-033473 A1	14/04/2005