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- (71) **Applicant (for US only):** **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).
- (71) **Applicant (for CA only):** **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).
- (71) **Applicant (for FR only):** **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) **Applicant (for all designated States except CA, FR, US):** **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89, NL-2514 JG The Hague (NL).
- (72) **Inventors:** **JARROT, Arnaud**; 36 Everett Avenue, Somerville, Massachusetts 02145 (US). **CONN, David Kirk**; 14330 Cindywood Dr., Houston, Texas 77079 (US).
- (74) **Agents:** **VEREB, John** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).
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(54) **Title:** OFFLINE SYNCHRONIZATION OF MWD/LWD LOGS

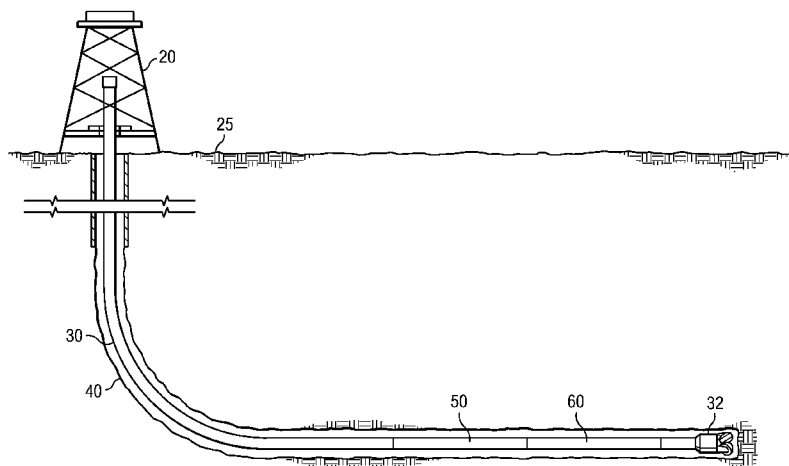


FIG. 1

(57) **Abstract:** A method for synchronizing downhole measurement data with a surface clock includes acquiring MWD/LWD data with a downhole tool and then processing the MWD/LWD measurements to obtain telemetry bits. The telemetry bits are transmitted to the surface and stored in downhole memory. The transmitted bits are received at a surface location and time stamped using a time obtained from a surface clock. Upon removing the drill string from the wellbore, the telemetry bits received at the surface are aligned with the telemetry bits stored to downhole memory to compute a time delay between the downhole and surface clocks. The time delay is then used to synchronize the downhole clock to the surface clock.



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OFFLINE SYNCHRONIZATION OF MWD/LWD LOGS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The current application claims priority to United States Provisional Application 62/173,407 filed June 10, 2015, the entirety of which is incorporated by reference.

FIELD OF THE INVENTION

[0002] The disclosed embodiments relate generally to synchronizing downhole and surface clocks and in particular to an offline synchronization method in which a telemetry signal received at the surface is correlated with a transmitted signal.

BACKGROUND

[0003] Typical subsurface drilling operations employ a number of techniques to gather information about the borehole and the formation through which it is drilled. Such techniques are commonly referred to in the art as measurement while drilling (MWD) and logging while drilling (LWD). MWD and LWD techniques may be used, for example, to obtain information about the well (e.g., information about the size, shape, and direction thereof) and the surrounding formation (e.g., the acoustic velocity, density, and resistivity thereof). These measurements may be evaluated, for example, to estimate the potential productivity of the well.

[0004] MWD and LWD data are commonly transmitted to the surface while drilling, for example, utilizing mud pulse telemetry or electromagnetic telemetry techniques. Obtaining accurate depth values for the MWD/LWD data has proven to be challenging technical problem (as the depth is measured at the surface). Downhole measurements

are generally time stamped using a downhole clock associated with the measurement tool. The time stamped data may then be compared with computerized surface clock measurements to obtain a depth at which the measurements were made.

[0005] The downhole clocks, however, are often subject to harsh downhole conditions (e.g., subject to extreme temperatures, pressures, and mechanical vibrations) that can cause a non-linear time drift with respect to the surface clock. The resulting depth errors can be significant depending on the drilling operation. In certain operations the downhole clock(s) may only run when the mud pumps are on (and a turbine generator is generating electrical power). There is a need for improved methods for depth matching downhole measurements and for correcting (or compensating) for the above described time drift of downhole clocks.

SUMMARY

[0006] A method for synchronizing downhole measurement data with a surface clock is disclosed. The method includes acquiring MWD/LWD data with a downhole tool and then processing the MWD/LWD measurements to obtain telemetry bits. The telemetry bits are transmitted to the surface and stored in downhole memory. The transmitted bits are received at a surface location and time stamped using a time obtained from a surface clock. Upon removing the drill string from the wellbore, the telemetry bits received at the surface are aligned with the telemetry bits stored to downhole memory to compute a time delay between the downhole and surface clocks. The time delay is then used to synchronize the downhole clock to the surface clock. The method may further include processing the telemetry bits stored in downhole memory to synthesize a telemetry signal and aligning the telemetry signal received at

the surface with the synthesized telemetry signal to compute a time delay between the downhole and surface clocks.

[0007] The disclosed embodiments may provide various technical advantages. For example, a method for calibrating downhole and uphole clocks is disclosed. The disclosed methods do not utilize an uplinked synchronization signal and are therefore viable even when the uplink communication channel fails (e.g. due to excessive noise). Moreover, since there is no need to create and transmit a synchronization signal valuable uplink bandwidth is preserved for other needs.

[0008] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a more complete understanding of the disclosed embodiments, and advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0010] FIG. 1 depicts a drilling rig on which the disclosed embodiments may be utilized.

[0011] FIG. 2 depicts a flow chart of one disclosed method embodiment.

[0012] FIG. 3 depicts a flow chart of another disclosed method embodiment.

[0013] FIG. 4 depicts a flow chart of a portion of the method embodiment disclosed on FIG. 2.

DETAILED DESCRIPTION

[0014] FIG. 1 depicts a drilling rig 20 suitable for using various method embodiments disclosed herein. The rig may be positioned over an oil or gas formation (not shown) disposed below the surface of the earth 25. The rig 20 may include a derrick and a hoisting apparatus for raising and lowering a drill string 30, which, as shown, extends into wellbore 40 and includes a drill bit 32 and MWD and LWD tools 50 and 60. Drill string 30 may further include substantially any other suitable downhole tools for example including a downhole drilling motor, a steering tool such as a rotary steerable tool, and various stabilizers. The disclosed embodiments are not limited in these regards.

[0015] It will be understood that drill string 30 may include substantially any suitable MWD and/or LWD tools 50 and 60. Measurement while drilling (MWD) tools are commonly used to measure the direction of wellbore propagation (referred to in the art as the wellbore attitude). They may also be used to measure the wellbore size and shape (commonly referred to as the calliper). MWD tool 50 may therefore include one or more navigation sensors, for example, including triaxial accelerometers, triaxial magnetometers, and/or triaxial gyroscopes. Suitable MWD tools may further include standoff sensors, for example, including ultrasonic transducers.

[0016] Logging while drilling (LWD) tools are often used to measure physical properties of the formations through which a borehole traverses. Formations having recoverable hydrocarbons typically include certain well-known physical properties, for example, resistivity, porosity (density), and acoustic velocity values in a certain range. LWD tool 60 may therefore include substantially any suitable downhole logging sensor, for example, including a natural gamma ray sensor, a neutron sensor, a density sensor, a resistivity electrode or antenna, a formation pressure sensor, an annular pressure sensor, an ultrasonic sensor, an audio-frequency acoustic sensor, and the like. LWD

tool 60 may further optionally include an energy source. For example, an LWD tool configured for azimuthal gamma measurements may include a gamma radiation source (such a device is typically referred to as a density measurement device). Likewise, LWD tools configured for azimuthal resistivity and acoustic velocity measurements may include one or more electromagnetic wave generators and acoustic transmitters, respectively.

[0017] As used in the art, there is not always a clear distinction between the terms MWD and LWD, however as described above, MWD often refers to measurements taken for the purpose of drilling the well (e.g., navigation) whereas LWD often refers to measurements taken for the purpose of analyzing the formation and surrounding borehole conditions. It will be understood that the disclosed embodiments are relevant to both MWD and LWD operations. As such they are referred to commonly hereafter as “MWD/LWD.” The MWD/LWD tool may also be referred to herein as a downhole measurement tool and the MWD/LWD measurements as downhole measurements.

[0018] MWD/LWD tools commonly further include one or more controllers configured to actuate the sensors thereby enabling the tool to make the appropriate measurements. The controller may include a processor configured to further process the sensor measurements to compute various MWD/LWD parameters values, which may in turn be saved in downhole memory located in the controller or elsewhere in the drill string.

[0019] Drill string 30 further includes a telemetry module (e.g., incorporated in one of the MWD/LWD tools 50 and 60) for transmitting digitized sensor measurements (or processed sensor measurements) to the surface while drilling. The telemetry module may include substantially any suitable telemetry system, for example, including a mud

pulse telemetry system, an acoustic telemetry system, or an electromagnetic telemetry system.

[0020] FIG. 2 depicts a flow chart of one disclosed method 100 for synchronizing MWD/LWD data with a surface clock. MWD/LWD data are acquired at 102. The data are indexed using a downhole clock and stored to downhole memory at 104. The data (or some portion of it) may be processed to obtain telemetry bits at 106 that may be recorded in downhole memory at 108 and transmitted to the surface (uplinked) using substantially any suitable telemetry technique (such as mud pulse telemetry or electromagnetic telemetry). The stored telemetry bits are the sequence of bits telemetered to the surface.

[0021] The received telemetry signal (e.g., the pressure wave received at the surface in a mud pulse telemetry operation) and the received telemetry bits may be time stamped using a surface clock and saved at the surface at 110. The surface time stamp may have substantially any suitable precision, for example, very high precision may be attained via synchronizing with global computerized clocks such as the network time protocol (NTP) or a global positioning system (GPS) clock. It will be understood that the transmitted data is not necessarily the raw MWD/LWD data acquired at 102. Rather the data may be sampled, averaged, compressed, and/or otherwise processed prior to the telemetry transmission. This processed data may then be further processed at 106 to obtain the telemetry bits. Such processing is known to those of ordinary skill in the art and need not be discussed further.

[0022] With continued reference to FIG. 2, the telemetry bits (stored in downhole memory at 108) may be retrieved from the downhole tool at 112 after it has been tripped out of the wellbore. In one embodiment a time shift may be obtained at 120 between the telemetry bits received at the surface at 110 (via telemetry) and the telemetry bits

retrieved at 112 (obtained from tool memory). The time shift may be obtained, for example, by finding the best alignment between the two sets of telemetry bits (e.g., by finding a maximum mathematical correlation between the telemetry bits obtained via telemetry and the telemetry bits obtained via tool memory).

[0023] In an alternative (or additional) embodiment, the telemetry bits obtained from downhole memory may be processed at 114 to synthesize the transmitted telemetry signal (e.g., the pressure pulses/waves transmitted through the drilling fluid for mud pulse telemetry). At 120 the time shift between the received telemetry signal (e.g., a digitized rendering of the received pressure pulses/waves) and the synthesized telemetry signal (the signal synthesized at 114) may be obtained. As described above the time shift may be obtained by finding the best alignment between the two signals (the received and synthesized signals).

[0024] With continued reference to FIG. 2, the time shift may be obtained, for example, by using the following mathematical equation:

$$\tau(t) = \underset{\tau(t)}{\operatorname{argmin}} \|T_t[n] - T_s(n - \tau(t))\| \quad (1)$$

where t represents the surface time, n represents the number of samples of the telemetry bits or telemetry signals, $\tau(t)$ represents the time shift, T_t represents the telemetry bits (or signal) received at the surface via the telemetry transmission, T_s represents the telemetry bits (or signal) retrieved from tool memory, and $\underset{\tau(t)}{\operatorname{argmin}} \|\cdot\|$ represents the

argument of the minimum function. It will be understood that Equation 1 may be solved using substantially any suitable mathematical techniques, for example, including local correlation, interpolation, inversion, or brute force.

[0025] With reference again to FIG. 2, the computed (or estimated) time shift $\tau(t)$ may be used at 122 to synchronize (align) the MWD/LWD data acquired at 102 with

the surface reference clock using the compensated time scale: $t_c = t - \tau(t)$, where t_c represents the compensated time scale and t and $\tau(t)$ are defined above with respect to Equation 1.

[0026] FIG. 3 depicts a flow chart of another disclosed method embodiment 150. The MWD/LWD data and the corresponding telemetry bits are indexed using a downhole clock and stored in downhole memory at 152. The received telemetry signal (e.g., pressure signal) and telemetry bits are time stamped using a surface clock and are stored in surface memory at 154. Upon removing the downhole tool from the wellbore, the telemetry bits may be used to reconstruct the telemetry signal at 156 (e.g., the pressure pulses transmitted in the drilling fluid) via passband modulation (to convert the telemetry bits to baseband). Likewise, the received telemetry signal may be filtered and converted to baseband (e.g., via sequential band pass and low pass filtering steps) at 158. The baseband signals (obtained at 156 and 158) may then be processed at 160 to obtain a time delay between the signals, for example, as described above with respect to Equation 1. Such processing may include, for example, a mathematical correlation as described in more detail below with respect to FIG. 4. The time shift and the time stamped surface data may then be processed to synchronize the MWD/LWD logs recorded in downhole memory at 162.

[0027] FIG. 4 depicts a flow chart of one example of method 200 for mathematically correlating the telemetry bits stored in downhole memory and the telemetry bits received at the surface via telemetry transmission. Such correlation may be conducted, for example, at 120 in FIG. 2 to correct for clock drift (drift correction) or absolute time discrepancies (absolute time correction). The telemetry bits received at the surface via telemetry transmission may be divided into multiple bit sequences at 202 (e.g., each having from about 50 to 200 bits, from about 75 to about 150 bits, or about 100 bits).

Each of the bit sequences may then be cross correlated with the telemetry bits stored in downhole memory at 204. When the normalized correlation is greater than a predetermined threshold (e.g., greater than about 0.98) and the total correction is less than a threshold (e.g., about 300 seconds) the computed time delay may be used to correct for drift at 206. In absolute correction mode, when the normalized correlation is greater than a threshold (e.g., greater than about 0.985), the computed time shift may be used to correct for absolute time differences at 208. In this example, a lower correlation threshold may be used for drift correction since clock drift generally results in small time adjustments (e.g., less than a few minutes). However, when making absolute corrections, a higher correlation threshold may be required as such corrections can be large (e.g., on the order of hours or even days in some operations) and a high degree of confidence may be required to make such significant corrections.

[0028] An offline synchronization method for MWD and LWD logs and certain advantages thereof have been described in detail. It should be understood that various changes, substitutions and alternations can be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims.

CLAIMS

What is claimed is:

1. A method for synchronizing downhole measurement data with a surface clock, comprising:

(a) deploying a drill string in a subterranean wellbore, the drill string including a measurement while drilling/logging while drilling (MWD/LWD) tool;

(b) causing the MWD/LWD tool to make MWD/LWD measurements in the wellbore;

(c) processing the MWD/LWD measurements with a downhole processor to obtain telemetry bits and storing the MWD/LWD measurements and the telemetry bits to downhole memory;

(d) transmitting the telemetry bits to the surface via telemetry transmission;

(e) receiving the telemetry bits at a surface location and time stamping the telemetry bits with a surface clock;

(f) removing the drill string from the subterranean wellbore;

(g) computing a time delay between the downhole clock and the surface clock by aligning the telemetry bits received at the surface location in in (e) with the telemetry bits stored to downhole memory in (c); and

(h) using the time delay to synchronize the downhole clock to the surface clock.

2. The method of claim 1, wherein the MWD/LWD measurements made in (b) are indexed using a downhole clock.

3. The method of claim 1, wherein the aligning in (g) comprises mathematical correlation.

4. The method of claim 1, wherein the time delay is computed in (g) according to the following mathematical equation:

$$\tau(t) = \underset{\tau(t)}{\operatorname{argmin}} \|T_t[n] - T_s(n.T - \tau(t))\|$$

wherein t represents surface time, n represents a number of samples of the telemetry bits, $\tau(t)$ represents the time delay, T_t represents the telemetry bits received in (e), T_s represents the telemetry bits stored in the downhole memory in (c), and $\underset{\tau(t)}{\operatorname{argmin}} \|\cdot\|$ represents an argument of the minimum function.

5. The method of claim 4, wherein $\tau(t)$ is solved using local correlation.

6. The method of claim 4, wherein the downhole clock is synchronized in (h) according to the following mathematical equation:

$$t_c = t - \tau(t)$$

wherein t_c represents a compensated time scale.

7. The method of claim 1, wherein (g) further comprises:

(i) dividing the telemetry bits received in (e) into multiple sequences bit sequences; and

(ii) aligning each of the multiple bit sequences with the telemetry bits stored to downhole memory in (c).

8. The method of claim 1, wherein the telemetry transmission in (d) comprises one of a mud pulse telemetry and electromagnetic telemetry.
9. The method of claim 1, wherein (h) comprises correcting for drift and absolute time differences between the downhole clock and the surface clock.
10. A method for synchronizing downhole measurement data with a surface clock, the method comprising:
- (a) deploying a drill string in a subterranean wellbore, the drill string including a measurement while drilling/logging while drilling (MWD/LWD) tool;
 - (b) causing the MWD/LWD tool to make MWD/LWD measurements in the wellbore;
 - (c) causing a downhole processor to process the MWD/LWD measurements to obtain telemetry bits and storing the MWD/LWD measurements and the telemetry bits to downhole memory;
 - (d) transmitting the telemetry bits to the surface via telemetry transmission;
 - (e) receiving a telemetry signal including the telemetry bits at a surface location and time stamping the telemetry signal with a surface clock;
 - (f) removing the drill string from the subterranean wellbore;
 - (g) processing the telemetry bits stored in downhole memory to synthesize a telemetry signal;
 - (h) causing a surface processor to compute a time delay between the downhole clock and the surface clock by aligning the telemetry signal received at the surface location in in (e) with the telemetry signal synthesized (g); and

(i) using the time delay to synchronize the downhole clock to the surface clock.

11. The method of claim 10, wherein the MWD/LWD measurements made in (b) are indexed using a downhole clock.

12. The method of claim 10, wherein the aligning in (h) comprises mathematical correlation.

13. The method of claim 10, wherein the time delay is computed in (h) according to the following mathematical equation:

$$\tau(t) = \underset{\tau(t)}{\operatorname{argmin}} \|T_t[n] - T_s(n.T - \tau(t))\|$$

wherein t represents surface time, n represents a number of samples of the telemetry signal, $\tau(t)$ represents the time delay, T_t represents the telemetry signal received in (e), T_s represents the telemetry signal synthesized in (g), and $\underset{\tau(t)}{\operatorname{argmin}} \|\cdot\|$ represents an argument of the minimum function.

14. The method of claim 13, wherein $\tau(t)$ is solved using local correlation.

15. The method of claim 13, wherein the downhole clock is synchronized in (i) according to the following mathematical equation:

$$t_c = t - \tau(t)$$

wherein t_c represents a compensated time scale.

16. The method of claim 10, wherein the telemetry transmission in (d) comprises mud pulse telemetry or electromagnetic telemetry.

17. The method of claim 10, wherein (i) comprises correcting for drift and absolute time differences between the downhole clock and the surface clock.

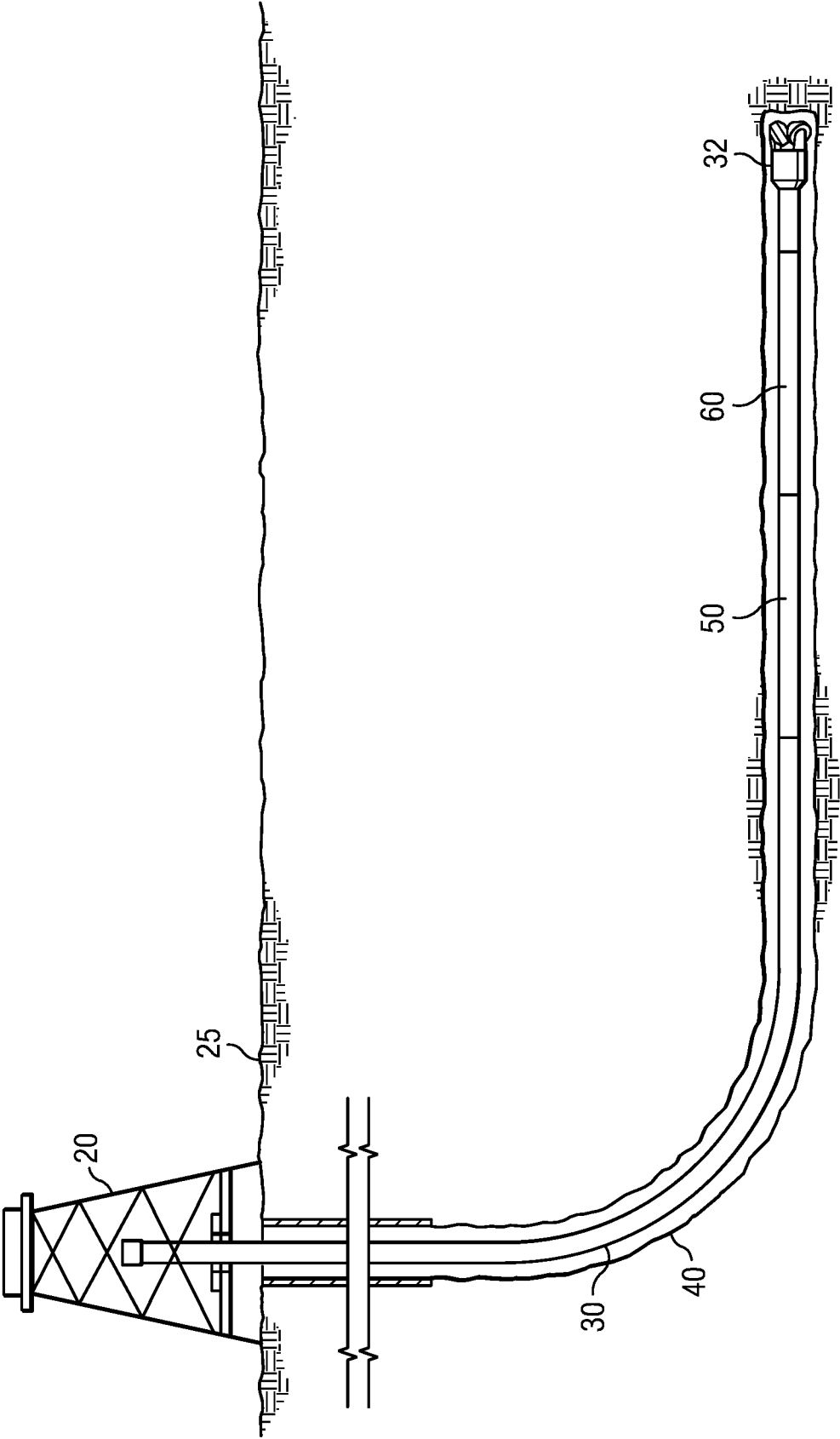


FIG. 1

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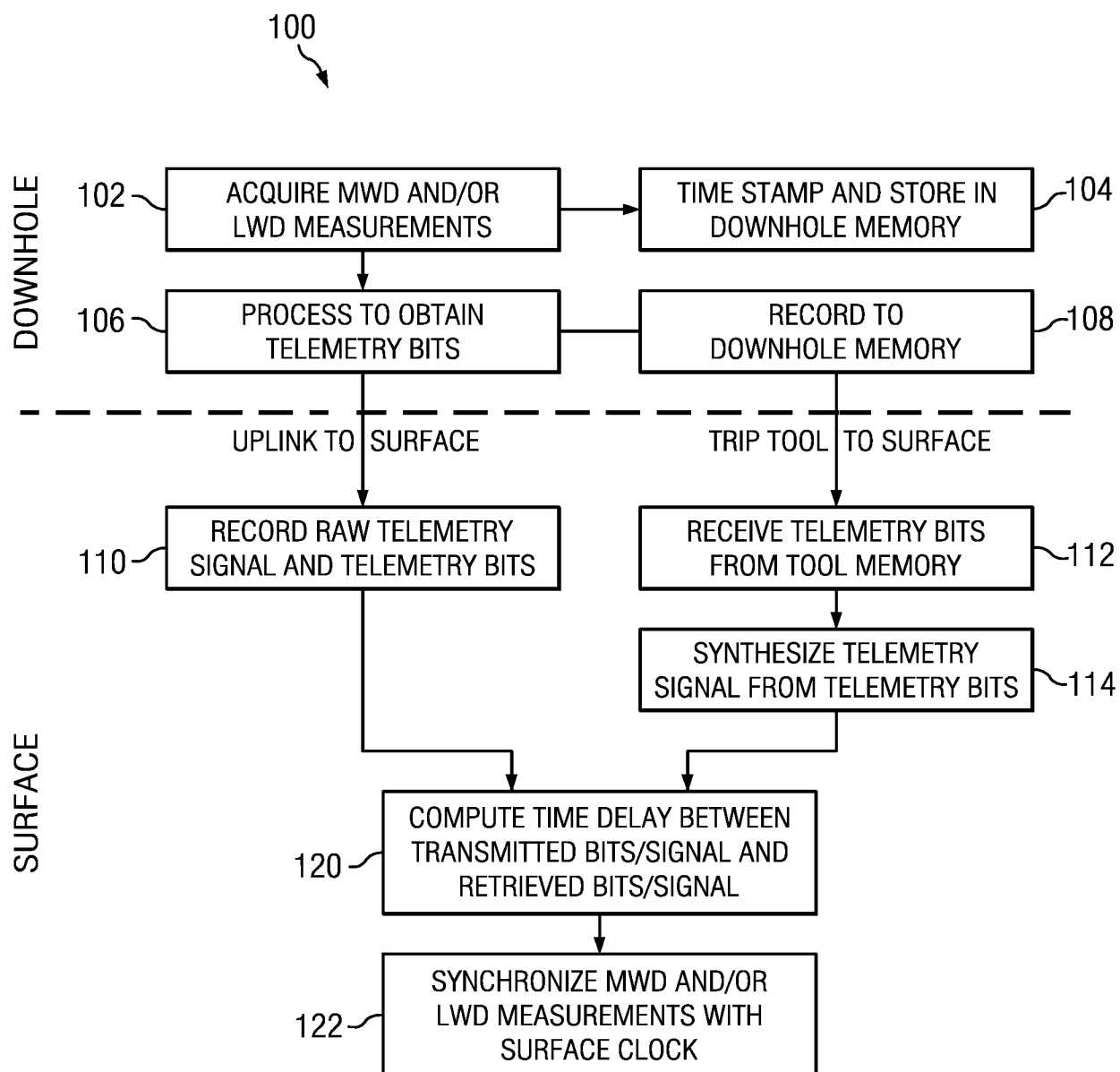
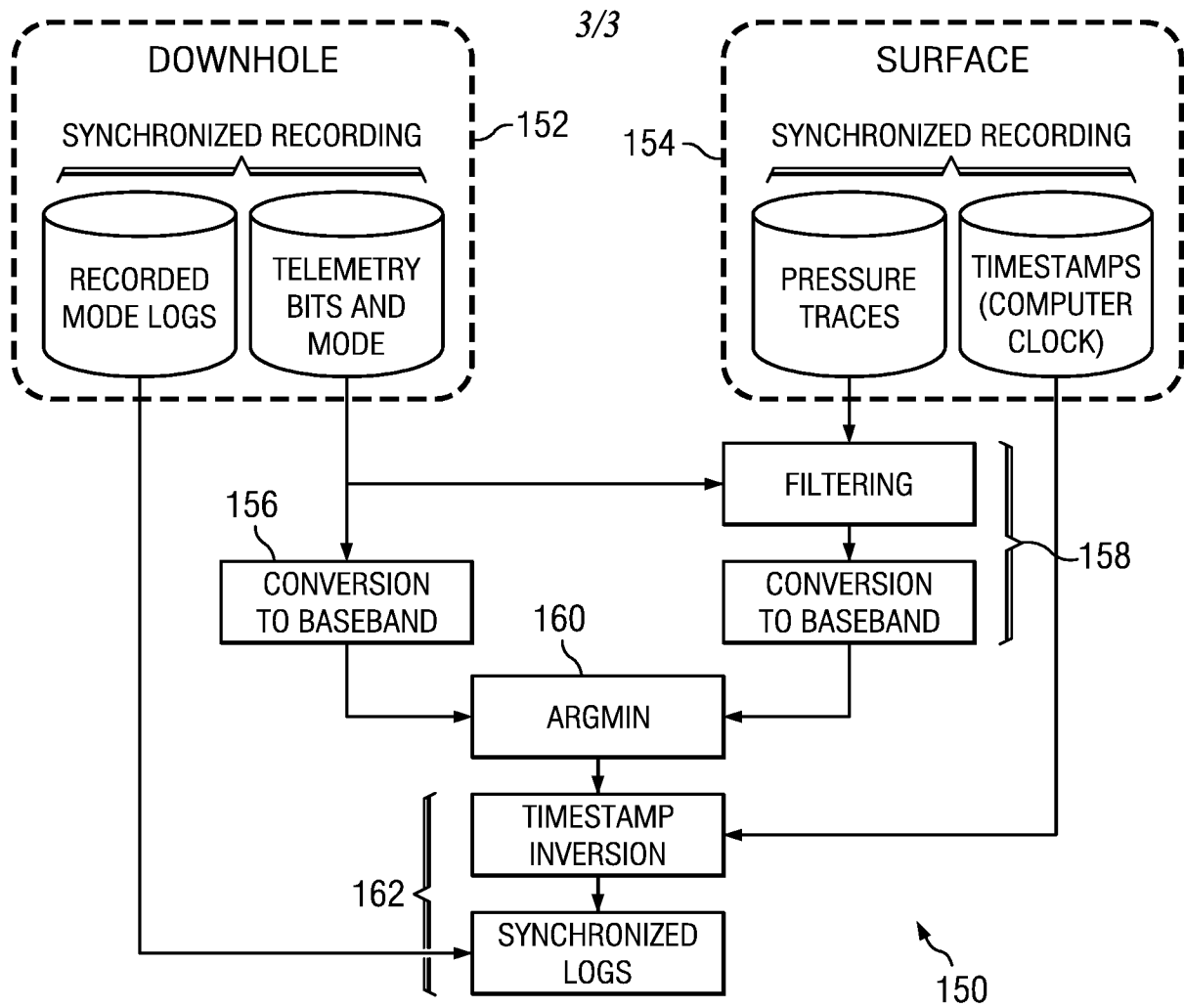
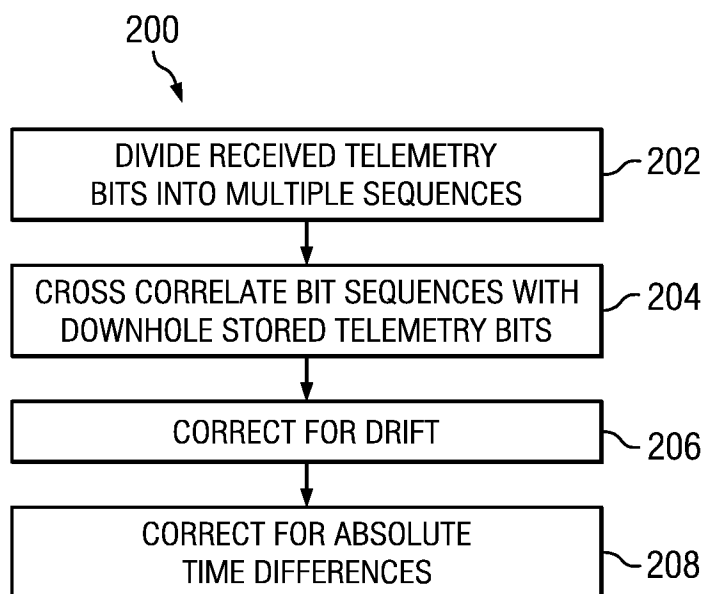


FIG. 2

*FIG. 3**FIG. 4*

A. CLASSIFICATION OF SUBJECT MATTER**E21B 47/00(2006.01)I, E21B 47/12(2006.01)I, E21B 41/00(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; G01V 3/00; E21B 45/00; G01V 1/40; E21C 7/06; G01V 1/50; E21B 47/12; E21B 41/00

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, MWD, LWD, downhole clock, surface clock, and time delay

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008-0137474 A1 (DASHEVSKIY et al.) 12 June 2008 See paragraphs [0010]-[0011], [0022], [0027]-[0031], [0035] and figures 1-5.	1-3, 7-12, 16-17
A		4-6, 13-15
A	US 2010-0313646 A1 (MEHTA et al.) 16 December 2010 See paragraphs [0037]-[0047] and figure 3A.	1-17
A	US 2010-0302060 A1 (MONTGOMERY et al.) 02 December 2010 See claim 1 and figures 1-3.	1-17
A	US 6424595 B1 (CHENIN, BERTRAND) 23 July 2002 See column 6, line 48 - column 7, line 57 and figure 2.	1-17
A	US 6308137 B1 (UNDERHILL et al.) 23 October 2001 See column 4, line 65 - column 5, line 53 and figures 1-3.	1-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"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

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"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

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International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

LEE, Dal Kyong

Telephone No. +82-42-481-8440



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/036144

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0137474 A1	12/06/2008	CA 2676377 A1 CA 2676377 C GB 2458424 A GB 2458424 B US 8902695 B2 WO 2008-070754 A1 WO 2008-070754 B1	12/06/2008 13/11/2012 23/09/2009 09/11/2011 02/12/2014 12/06/2008 24/07/2008
US 2010-0313646 A1	16/12/2010	US 8731837 B2	20/05/2014
US 2010-0302060 A1	02/12/2010	US 2013-0154844 A1 US 8378839 B2 US 8749398 B2	20/06/2013 19/02/2013 10/06/2014
US 6424595 B1	23/07/2002	CA 2300599 A1 GB 2348023 A GB 2348023 B NO 20001300 A	17/09/2000 20/09/2000 12/02/2003 18/09/2000
US 6308137 B1	23/10/2001	AU 6134300 A1 AU 748573 B2 CA 2320576 A1 CA 2320576 C CO 5290337 A1 GB 2355739 A	31/05/2001 06/06/2002 29/04/2001 29/04/2001 27/06/2003 02/05/2001