Calibrating the Time Drift of a Clock

Field of Invention

The present invention relates to the field of geophysical surveys in a marine environment with help of nodes. Specifically, the present invention relates to calibrating the time drift of a clock attached to such nodes.

Definitions

Signal

A “SIGNAL” shall henceforth be called a change in at least one property of Earth for a period of time, where said change, whether man-made or natural, is specifically used to probe Earth with the aim to characterise the geology, petrophysics, rock physics or similar of Earth, as a person skilled in the arts of geophysical processing and interpretation does. Said SIGNAL can be, for example but without limitation, pressure, velocity, acceleration, gravitational acceleration, electric field intensity, magnetic field intensity, and any similar property of Earth.

Ping

A “PING” shall henceforth be called a change in at least one property of Earth for a period of time, where said change is specifically designed to locate, interrogate or, in the invention disclosed herein, communicate a marker of time. Typically, such a PING is a change in pressure, with a change in the velocity and acceleration of water particles associated with said change in pressure. Such a change in pressure typically occurs with a frequency in a low kHz range.

Such a PING is generated by a device henceforth called a “PINGER SENDER”, a device well known simply as a pinger to a person skilled in the arts of locating devices on a seabed.

Such a PING is received by a device henceforth called a “PINGER RECEIVER.”

A device combining both the functions of PINGER SENDER and PINGER RECEIVER shall henceforth be called “PINGER”.

For the purpose of locating devices on a seabed, typically, a PINGER is deployed at the surface of a body of water, and a device henceforth called a “PINGER TRANSPONDER” is placed on the bottom of said body of water in the vicinity of said device to be located. Here, a PINGER TRANSPONDER is a special PINGER. It shall be capable of receiving a PRIMARY PING, which has been generated by said PINGER, and upon receiving said PRIMARY PING emitting itself a SECONDARY PING. Said PINGER TRANSPONDER shall typically emit said SECONDARY PING within a short period of time upon receiving said PRIMARY PING, that is within a period of time over which properties of said body of water do not change to such an extent that the time henceforth called “PRIMARY PING TRAVEL TIME” of a PRIMARY PING travelling from a PINGER SENDER to a PINGER TRANSPONDER and the time henceforth called “SECONDARY PING TRAVEL TIME” of a SECONDARY PING travelling from a PINGER TRANSPONDER to a PINGER SENDER change less than the accuracy required for the calibration of a NODE CLOCK, as defined below. Otherwise, that is if said PINGER TRANSPONDER does not emit said SECONDARY PING within said short period of time upon receiving said PRIMARY PING, said properties of said body of water shall be measured in sufficient detail such that at least one out of PRIMARY PING TRAVEL TIME and SECONDARY PING TRAVEL TIME can be corrected as if said PRIMARY PING and said SECONDARY PING have indeed been emitted within said short period of time. In fact, PRIMARY PING TRAVEL TIME and SECONDARY PING TRAVEL TIME could also be corrected as if both have been emitted within any other short period of time.

Obviously, correcting any PING TRAVEL TIME in this way requires another device capable of measuring said properties of said body of water: such properties are at least one out of pressure, temperature, conductivity, or salinity instead of conductivity. Suitable devices are for example but without limitation a CTD device, as a person skilled in the arts will know; and such devices are (a) passively lowered and raised between surface and bottom of said body of water or (b) mounted on an underwater vehicle actively moving between surface and bottom of said body of water or (c) similar, as a person skilled in the arts of oceanography will understand.

Registering

"REGISTERING" a signal shall henceforth mean one of the following two options: (1) a combination of (a) at least one sensor receiving at least part of said signal and (b) at least one clock providing a time at which or over which, as the case may be, said at least part of said signal is received; (2) a combination of (a) at least one sensor receiving at least part of said signal, (b) at least one computing device processing said at least part of said signal "on the fly" to provide partial or derivative information, as defined below, about said at least part of said signal, and (c) at least one clock providing a time over which or at which, as the case may be, said partial or derivative information about said at least part of said signal occurs. Here, said at least one computing device shall be capable of determining (a) any partial information about said at least part of said signal as for example but without limitation a start, an end, a maximum, a minimum, a zero-crossing, any other amplitude or any other characteristic feature or (b) any derivative information of said at least part of said signal as for example but without limitation its frequency content, energy loss or any other characteristic feature.

REGISTERING shall henceforth include recording said at least part of said signal, partial information about said signal, or derivative information about said signal, as the case may be. Said recording can occur within a PINGER, PINGER TRANSPONDER

Conventional Node

A "CONVENTIONAL NODE" shall henceforth be a device comprising (a) at least one sensor receiving said at least one GEOPHYSICAL SIGNAL, (b) at least one clock from which the arrival time or arrival times of said GEOPHYSICAL SIGNAL is read, (c) at least one processor REGISTERING said GEOPHYSICAL SIGNAL, and (d) at least one recorder.

Such a CONVENTIONAL NODE is well known simply as node or seabed node to a person skilled in the arts.

Node

A "NODE" shall henceforth be a device comprising (a) at least one sensor receiving said at least one GEOPHYSICAL SIGNAL, (b) at least one sensor receiving said at least one PING SIGNAL, (c) at least one clock, and (d) at least one recorder. Note, one function of a NODE is that of a CONVENTIONAL NODE, with at least that of a PINGER RECEIVER or, in some embodiments, that of a PINGER TRANSPONDER or that of a PINGER added.

Claims

Method

1. What is claimed is a method of correcting a SIGNAL ARRIVAL TIME of a SIGNAL, which is received by a NODE deployed in a body of water and comprising a NODE CLOCK, by a TIME DRIFT of said NODE CLOCK comprising the following steps:
    1. at least one NODE receiving at least one SIGNAL;

2. said at least one NODE reading at least one SIGNAL ARRIVAL TIME of said at least one SIGNAL from at least one NODE CLOCK;
3. at least one PINGER emitting at least one PRIMARY PING;
4. said at least one PINGER reading at least one PRIMARY EMISSION TIME of said at least one PRIMARY PING from at least one PINGER TIMER;
5. at least one NODE receiving said at least one PRIMARY PING;
6. said at least one NODE reading at least one PRIMARY ARRIVAL TIME of said at least one PRIMARY PING from said at least one NODE CLOCK;
7. said at least one NODE emitting at least one SECONDARY PING;
8. said at least one PINGER receiving said at least one SECONDARY PING;
9. said at least one PINGER reading at least one SECONDARY ARRIVAL TIME of said at least one SECONDARY PING from at leat least one PINGER TIMER;
10. determining at least one PING TRAVEL TIME based at least in part on said at least one PRIMARY EMISSION TIME and said at least one SECONDARY ARRIVAL TIME;
11. determining at least one TIME DRIFT of said at least one NODE CLOCK based at least in part on at least one set of action out of
    1. a set of action comprising
        1. said at least one PRIMARY EMISSION TIME,
        2. said at least one PING TRAVEL TIME, and
        3. said at least one PRIMARY ARRIVAL TIME

    and
    2. and a set of action comprising
        1. said at least one SECONDARY EMISSION TIME,
        2. said at least one PING TRAVEL TIME, and
        3. said at least one SECONDARY ARRIVAL TIME;
12. correcting said at least one SIGNAL ARRIVAL TIME by said at least one TIME DRIFT.

2. The method of claim 1. wherein said at least one NODE emits said at least one SECONDARY PING SIGNAL within a short period of time upon receiving said at least one PRIMARY PING.
3. The method of claim 1. wherein said at least one NODE emits said at least one SECONDARY PING SIGNAL within a short period of time after receiving one PRIMARY PING out of said at least one PRIMARY PING.
4. The method of claim 1. wherein at least one out of said at least one PRIMARY PING SIGNAL and said at least one SECONDARY PING SIGNAL is corrected for changes in at least one property of said body of water such as if
    1. at least one out of said at least one PRIMARY PING SIGNAL has been emitted

    and
    2. at least one out of said at least one SECONDARY PING SIGNAL has been emitted within a short period of time upon receiving said at least one out of said at least one PRIMARY PING SIGNAL.

5. The method of claim 1. wherein
    1. said at least one PING SIGNAL are at least two PING SIGNALS,
    2. steps 1.3. through 1.11. are performed for each one of said at least two PING SIGNALS such as to determine at least one TIME DRIFT for each one of said at least two PING SIGNALS,
    3. said at least one TIME DRIFT for each one of said at least two PING SIGNALS are interpolated or extrapolated, as the case may be, to determine at least one ESTIMATED TIME DRIFT for said at least one SIGNAL ARRIVAL TIME,

    and

    4. said at least one SIGNAL ARRIVAL TIME is corrected by one of said at least one ESTIMATED TIME DRIFT.
6. The method of claim 5. wherein one ESTIMATED TIME DRIFT is determined for each one ESTIMATED TIME DRIFT.
7. The method of claim 1. wherein said at least one PINGER TIMER is a time signal broadcast by a satellite.
8. The method of claim 1. wherein said at least one PINGER TIMER is a time signal broadcast by a clock not attached to said PINGER.
9. The method of claim 1. wherein said at least one PINGER TIMER is a time signal provided by a PINGER CLOCK attached to said PINGER.
10. The method of claim 9. wherein said PINGER CLOCK is calibrated at least once before emitting said at least one PRIMARY PING SIGNAL.
11. The method of claim 9. wherein said PINGER CLOCK is calibrated at least once after receiving said at least one SECONDARY PING SIGNAL.
12. The method of claim 9. wherein said at least one PINGER is mounted on at least one underwater vehicle.
13. The method of claim 12. wherein said at least one underwater vehicle is an autonomous underwater vehicle.
14. The method of claim 12. wherein said at least one underwater vehicle is a remotely operated underwater vehicle.
15. The method of claim 1. wherein said at least one NODE receives both said at least one SIGNAL and said at least one PRIMARY PING by means of at least one HYDROPHONE.
16. The method of claim 15. wherein said at least one PRIMARY PING and said at least one SIGNAL are separated by means of frequency filtering.
17. The method of claim 1. wherein said at least one NODE receives both said at least one SIGNAL and said at least one PRIMARY PING by means of at least one GEOPHONE.
18. The method of claim 17. wherein said at least one PRIMARY PING and said at least one SIGNAL are separated by frequency filtering.

System

1. What is claimed is a system of correcting a SIGNAL ARRIVAL TIME of a SIGNAL, which is received by a NODE comprising a NODE CLOCK, by a TIME DRIFT of said NODE CLOCK comprising the following devices:

1. at least one PINGER comprising
    1. at least one device providing time (“PINGER TIMER”),
    2. at least one device capable of emitting at least one PRIMARY PING (“PRIMARY PINGER SOURCE”) and reading at least one PRIMARY EMISSION TIME from said at least one PINGER TIMER,

    and

    3. at least one device capable of receiving at least one SECONDARY PING (“PRIMARY PINGER RECEIVER”) and reading at least one SECONDARY ARRIVAL TIME from said at least one PINGER TIMER;

and

2. at least one NODE comprising
    1. at least one device providing time (“NODE CLOCK”),
    2. at least one device capable of receiving said at least one PRIMARY PING (“SECONDARY PINGER RECEIVER”),
    3. at least one device capable of emitting at least one SECONDARY PING (“SECONDARY PINGER SOURCE”),

    and

    4. at least one device (“CONVENTIONAL NODE”) capable of receiving at least one SIGNAL and reading at least one SIGNAL ARRIVAL TIME from said at least one NODE CLOCK.

2. The system of claim 1. wherein at least one device (“PRIMARY PINGER”) comprises both at least one PRIMARY PINGER SOURCE and at least one PRIMARY PINGER RECEIVER.