acoustic signal having a second propagation path for the purposes of the calculation to be performed in this example.

[0042] Upon receipt of the second reply message, the offset calculator of the transponder 116 is able to calculate the time offset between the first clock 115 of the transponder 116 and the second clock 119 of the transceiver 114 in the following manner.

[0043] One way time-of-flight, T_{FAB2}, is calculated using the following equation:

$$T_{FAB2} = (T_{B3} – T_{B2} – F_{TAT})/2 \quad (1)$$

[0044] Once the one way time-of-flight has been calculated, the offset is calculated using the following equation:

$$Offset_{BA} = T_{B3} – T_{A3} - T_{FAB2} \quad (2)$$

[0045] The above calculations are based upon an inverted model for calculating the offset between the first clock 115 and the second clock 119, namely the calculation is performed in respect of a communication originating from close to the seabed 118 and a reply thereto as opposed to a communication originating from beneath but close to the sea surface, for example from a surface vessel-mounted underwater transceiver, and a reply thereto. In this regard, and as mentioned above, the transceiver 114 is dynamic and so moves under the influence of motion of the sea. Consequently, measurements made are influenced by the opportunity for the transceiver 114 to move. This can occur during the turnaround time, but also during the propagation (times-of-flight) of the signals between the transceiver 114 and the transponder 116 if the offset calculation is to be based upon a two-way communication originating from the top side. In contrast, the inverted model requires measurements to be made that are only influenced by movement of the transceiver 114 during the second turnaround time, F_{TAT}. Hence, inaccuracy caused by movement of the transceiver 114 during the times-of-flight of communications between the transceiver 114 and the transponder 116 is mitigated.

[0046] In another embodiment (Figures 4 to 6), Doppler shift data is used to improve accuracy of the offset calculated above. Referring to Figure 4, the offset calculation unit 200 supported by the PC 110 initiates, via the navigation sensor hub 102, an offset calculation session by sending a TIME command message to the transceiver 114 to set (Step 300) the time of the internal clock 115 of the transceiver 114 based upon time data provided by way of receipt of the date and time data stream 106 from the source of GPS-derived signals 104. Thereafter, the transceiver 114 sets the internal clock to the time received from the navigation sensor hub 102 and then sends another TIME message (Step 302) to the navigation sensor hub 102 confirming the time set by the transceiver 114. The PC 110 then sends, via the navigation sensor hub 102, a TSYNC command

Claims

1. An aquatic time synchronisation system comprising:

an aquatic first acoustic communications apparatus capable of communicating acoustically with a dynamic aquatic second acoustic communications apparatus, the aquatic first acoustic communications apparatus comprising a first time source and the dynamic aquatic second acoustic communications apparatus comprising a second time source; and

an offset calculator; wherein

the aquatic first acoustic communications apparatus is arranged to communicate a first acoustic signal to the dynamic aquatic second acoustic communications apparatus and the dynamic aquatic second acoustic communications apparatus is arranged to communicate a second acoustic signal to the aquatic first acoustic communications apparatus in reply to the first acoustic signal; and

the offset calculator is arranged to use data associated with the first and second acoustic signals in order to determine a time offset between the first and second time sources; wherein

the aquatic first acoustic communications apparatus is substantially static.

2. A system as claimed in Claim 1, wherein

the first acoustic signal has a first acoustic propagation path associated therewith; and

the dynamic aquatic second acoustic communications apparatus is arranged to calculate a Doppler shift observed thereby in respect of propagation of the first acoustic signal along the first acoustic propagation path.

3. A system as claimed in Claim 2, wherein

the second acoustic signal has a second acoustic propagation path associated therewith; and

the aquatic first acoustic communications apparatus is arranged to calculate another Doppler shift observed thereby in respect of propagation of the second acoustic signal along the second acoustic propagation path.

4. A system as claimed in Claim 3, wherein an average Doppler shift is calculated using the calculated Doppler shift and the another calculated Doppler shifts.

5. A system as claimed in any one of the preceding claims, wherein the second acoustic signal is communicated in reply to the first acoustic signal after a predetermined period of time.

6. A system as claimed in Claim 5, when dependent upon Claim 4, wherein a translation distance in respect of movement of the dynamic aquatic second acoustic communications apparatus is calculated using the average Doppler shift calculated and the predetermined period of time.

7. A system as claimed in Claim 6, wherein a time shift is calculated using the translation distance calculated and an acoustic signal propagation speed in respect of water.

8. A system as claimed in Claim 7, wherein the data associated with the second acoustic signals comprises the time shift calculated.

9. A system as claimed in any one of the preceding claims, wherein the second acoustic signal comprises first time data.

10. A system as claimed in Claim 9, wherein the first time data comprises transmit time data in respect of the second acoustic signal.

11. A system as claimed in any one of the preceding claims, wherein the dynamic aquatic second acoustic communications apparatus is a transceiver.

12. A system as claimed in any one of the preceding claims, wherein the dynamic aquatic second acoustic communications apparatus is located, when in use, remote from a seabed.

13. A system as claimed in any one of the preceding claims, wherein the aquatic first acoustic communications apparatus is located, when in use, substantially adjacent the seabed or tethered to the seabed.

14. A system as claimed in Claim 13, wherein movement of the aquatic first acoustic communications apparatus is substantially immune to surface wave motion.

15. A system as claimed in any one of the preceding claims, wherein the aquatic first acoustic communications apparatus is a transponder.

16. A system as claimed in any one of Claims 1 to 10, wherein the dynamic aquatic second acoustic communications apparatus is a transponder.

17. A system as claimed in any one of the preceding claims, wherein the dynamic aquatic second acoustic communications apparatus is operably coupled to a surface vessel and, when in use, is immersed in water.

18. A system as claimed in any one of the preceding claims, further comprising a submersible vehicle comprising the dynamic aquatic second acoustic communications apparatus.

19. A system as claimed in Claim 18, wherein the submersible vehicle is an autonomous underwater vehicle or a remote operated vehicle.

20. A system as claimed in any one of the preceding claims, wherein the aquatic first acoustic communications apparatus comprises an output port and is arranged to communicate, when in use, time data associated with the determined time offset via the output port.

21. A system as claimed in Claim 20, further comprising a processing node coupled to the output port and arranged, when in use, to receive the time data.

22. A system as claimed in Claim 21, wherein the processing node is a seabed recoding node.

23. A system as claimed in any one of the preceding claims, wherein the aquatic first acoustic communications apparatus comprises the offset calculator.

24. A system as claimed in any one of Claims 1 to 22, wherein the dynamic aquatic second acoustic communications apparatus comprises the offset calculator.

25. A system as claimed in any one of Claims 1 to 22, further comprising a surface-side computing apparatus comprising the offset calculator.

26. A method of determining a time offset, the method comprising:

an aquatic first acoustic communications apparatus communicating a first acoustic signal to a dynamic aquatic second acoustic communications apparatus;

the dynamic aquatic second acoustic communications apparatus communicating a second acoustic signal to the aquatic first acoustic communications apparatus in reply to the first acoustic signal; and

an offset calculator determining a time offset between the first and second time sources using data associated with the first and second acoustic signals; wherein

the aquatic first acoustic communications apparatus is substantially static.