Claims

1. An offshore GNSS reference station apparatus comprising:

a processing resource;

an underwater acoustic communications unit comprising an underwater acoustic transducer, the underwater acoustic communications unit being arranged to cooperate with the processing resource in order to calculate, when in use, a position;

a GNSS antenna site; and

an orientation determination unit operably coupled to the processing resource, the orientation determination unit being arranged to determine an orientation associated with the GNSS antenna site and the acoustic transducer of the underwater acoustic communications unit.

2. An apparatus as claimed in Claim 1, further comprising:

a wireless communications module operably coupled to the processing resource.

3. An apparatus as claimed in Claim 2, wherein

the calculated position is a position of the underwater acoustic transducer; and

the processing resource is arranged to calculate a vector extending between the underwater acoustic transducer and the GNSS antenna site, the vector being calculated using a predetermined lever arm offset and the orientation determined by the orientation determination unit.

4. An apparatus as claimed in Claim 3, wherein the processing resource is arranged to translate the calculated position of the underwater acoustic transducer using the calculated vector in order to yield a position of the GNSS antenna site, the position of the GNSS antenna site being a three-dimensional position of the GNSS antenna site with respect to a seabed reference frame.

5. An apparatus as claimed in any one of the preceding claims, further comprising:

a GNSS receiver arranged to make GNSS signal observations comprising a pseudorange measurement and a carrier phase measurement; wherein

the processing resource is arranged to store data generated by the GNSS receiver representing the GNSS signal observations as GNSS observation data.

6. An apparatus as claimed in one of the preceding claims, wherein

the underwater acoustic communications unit is arranged to make range-related measurements.

7. An apparatus as claimed in Claim 5, wherein the processing resource is arranged to modify the data generated by the GNSS receiver representing the GNSS signal observations so as to correspond to measurements made from a predetermined static pseudo-observation position, and to store the modified data as the GNSS observation data.

8. An apparatus as claimed in any one of the preceding claims, wherein the processing resource is arranged to support a reference frame translation unit, the reference frame translation unit being arranged to receive the position of the GNSS antenna site and to translate the position from expression in a first reference frame to a second reference frame.

9. An apparatus as claimed in Claim 5, when dependent upon Claim 2, wherein the wireless communications module is arranged to broadcast the GNSS observation data.

10. An apparatus as claimed in Claim 4, wherein the wireless communications module is arranged to broadcast the position of the GNSS antenna site.

11. An apparatus as claimed in Claim 7, when dependent upon Claim 2, wherein the wireless communications module is arranged to broadcast the modified data and the predetermined static pseudo-observation position.

12. An apparatus as claimed in Claim 2, wherein the wireless communications module is arranged to receive other GNSS observation data and other position data from other base stations.

13. An apparatus as claimed in Claim 5, when dependent upon Claim 2, wherein the GNSS receiver is arranged to receive Precise Point Positioning (PPP) data; and

the processing resource is arranged to support a precise point positioning processing unit, the precise point positioning processing unit being arranged to receive the precise point positioning data and to use the precise point positioning data to calculate a GNSS-derived position of the GNSS antenna site.

14. An apparatus as claimed in Claim 5, when dependent upon Claim 4, wherein the GNSS receiver is arranged to receive precise point positioning data; and

the processing resource is arranged to support a precise point positioning processing unit, the precise point positioning processing unit being arranged to receive the precise point positioning data and to use the precise point positioning data to calculate a GNSS-derived position of the GNSS antenna site; and

the processing resource is arranged to calculate an offset between the GNSS-derived position of the GNSS antenna site calculated using the precise point positioning data and the position of the GNSS antenna site.

15. An apparatus as claimed in any one of the preceding claims, wherein the processing resource is arranged to estimate an average speed of sound in water, the average speed of sound being tracked over time.

16. An apparatus as claimed in Claim 15, wherein the processing resource is arranged to calculate a depth of the underwater acoustic transducer; and the

processing resource is arranged to estimate refraction corrections to the speed of sound in a water column from a predetermined approximate sound speed profile.

17. An offshore GNSS positioning system, comprising:

the offshore GNSS reference station apparatus as claimed in any one of Claims 1 to 16; and

a plurality of underwater acoustic reference transponders; wherein

the underwater acoustic communications unit is arranged to measure a respective two-way travel time with respect to each of the plurality of underwater acoustic reference transponders.

18. A system as claimed in Claim 17, wherein the processing resource is arranged to cooperate with the underwater acoustic communications unit in order to estimate the position of the acoustic transducer with respect to the plurality of underwater acoustic reference transponders.

19. A system as claimed in Claim 17 or Claim 18, when dependent upon Claim 4, further comprising:

a roving GNSS apparatus arranged to receive the GNSS observation data and the position of the GNSS antenna site with respect to the reference frame defined by the plurality of subsea acoustic reference transponders; and

the roving GNSS apparatus is arranged to calculate a relative position vector associated with a position of a GNSS antenna site of the roving GNSS apparatus relative to the position of the GNSS antenna site of the GNSS reference station.

20. A method of generating positioning reference data offshore, the method comprising:

determining a position acoustically through water of an offshore GNSS reference station;

making a GNSS observation in respect of the offshore GNSS reference station;

determining an orientation associated with a GNSS antenna site of the offshore GNSS reference station and the position determined acoustically.

21. A method of determining a position, the method comprising:

the method of generating positioning reference data offshore as claimed in Claim 20;

broadcasting the GNSS observation and the position;

receiving the broadcast GNSS observation and the broadcast position at a position to be determined;

making a local GNSS observation in respect of the position to be determined; and

using the received broadcast GNSS observation and the broadcast position with the local GNSS observation data to estimate a relative position vector.