Claims

1. An acoustic detection system (100) for detecting at least partly submerged targets in a sensitive area defined with respect to an infrastructure, characterized in that the detection system comprises at least one multistatic detection group, each multistatic detection group (3) defining a detection area, and comprising:

- A submerged transmitter (31) transmitting at low frequencies;
- A plurality of submerged receivers (32) comprising at least two receivers, each receiver of a given group forming, with the transmitter of said group, a bistatic pair, each bistatic pair generating an elementary detection area (320) surrounding a blind zone (321), the blind zone associated with each bistatic pair corresponding to a non-detection zone, the detection area of said group being formed by all of the elementary detection areas of said receivers of the group,

and in that the blind zone (321) of each receiver in a given detection group is at least partly covered by the elementary detection areas of the neighbouring receivers of the detection system.

2. The acoustic detection system as claimed in claim 1, characterized in that the receivers of a given group describe at least one piecewise linear form, and in that the receivers of a given group comprise at least one reference pair, said reference pair comprising receivers that are adjacent and equidistant from the transmitter (31), the rectilinear segment linking the receivers of said reference pair being situated at a distance D from the transmitter, called reference transmitter-receiver distance, the distance of a given receiver of the group from the axis of symmetry of the reference pair, from among the receivers of the group other than the receivers of the reference pair, depending on the reference transmitter-receiver distance D and on the distance $(2x_1)$ between the receivers of the reference pair.

3. The acoustic detection system as claimed in claim 2, characterized in that the distance ($2x_1$) between the receivers of the reference pair is a function of the reference transmitter-receiver distance (D) and of the minimum range R_{mono} of an equivalent monostatic sonar on all of the possible targets.

4. The system as claimed in either of claims 2 and 3, characterized in that the receivers of each group are arranged in at least one layer, and in that, for at least one group of the system, the receivers of at least one layer of said group describe a piecewise linear form, the receivers of the reference pair being symmetrical about an axis of symmetry passing through the transmitter.

5. The system as claimed in claim 4, characterized in that the distance x_i between a given receiver RX_i, other than the receivers of the reference pair, and the axis of symmetry of the form depends on the distance x_{i-1} between the adjacent receiver RX_{i-1} and the axis of symmetry (33), said adjacent receiver being situated between said given receiver and the axis of symmetry, and in that the distance of the $i-th$ receiver from the reference receiver, situated on the same side as the $i-1th$ receiver with respect to the axis, depends on the index i of the receiver and on the distance x_1 of the receiver of said reference pair from the axis of symmetry.

6. The system as claimed in either of claims 4 and 5, characterized in that said distance x_1 between a receiver of said reference pair and the axis of symmetry of the group is at least equal to a minimum threshold value $x_{1_{min}}$:

$$x_{1_{min}} = \frac{D}{\sqrt{2}} \cdot \sqrt{\sqrt{1+\left(\frac{R_{mono}}{D}\right)^4} - 1}$$

.

7. The system as claimed in claim 6, characterized in that, for a linear layer of a given group such that the distance x_1 is equal to the minimum threshold value, the surface area $Aire(T_i)$ of a triangle T_i formed by a point coinciding with the transmitter (31) of the group and two points coinciding with two adjacent receivers (32) of said layer, divided by the cosine of an angle θ_i denoting the angle of insonification of the receiver RX_i with respect to the axis of symmetry, is equal to half the surface area $Aire(S)$ of a square S having a side equal to the minimum range of the equivalent monostatic sonar R_{mono}:

$$Aire(T_i)/\cos(\theta_i) = Aire(S)/2 = R_{mono}^2/2$$

8. The system as claimed in either of claims 4 and 5, characterized in that said distance x_1 of a receiver of said reference pair from the axis of symmetry is at most equal to a maximum threshold value $x_{1_{max}}$:

$$x_{1_{max}} = R^2_{mono}/D.$$

9. The system as claimed in claim 8, characterized in that, for a linear layer of a given group, the surface area $Aire(T_i)$ of a reference triangle T_i formed by a point coinciding with the transmitter (31) of the group and two points coinciding with two adjacent receivers (32) RX_{i-1} and RX_i of said layer, divided by the cosine of the angle θ_{Mi} between the axis of symmetry, on the one hand, and the axis passing through the transmitter TX and through a point M_i situated in the middle of the segment defined by said adjacent receivers, is equal to the surface area $Aire(S)$ of a square S having a side equal to the minimum range of the equivalent monostatic sonar R_{mono}:

$$Aire(T_i)/cos(\theta_{Mi}) = Aire(S) = R^2_{mono}.$$

10. The system as claimed in claims 6 and 8, characterized in that the value of said distance x_1 of a receiver of said reference pair from the axis of symmetry is between said minimum threshold value $x_{1_{min}}$ and said maximum threshold value $x_{1_{max}}$.

11. The system as claimed in claim 10, characterized in that the position of each receiver RX_i is such that the surface area $Aire(T_i)$ of a triangle T_i is less than or equal to $R^2_{mono}.cos(\theta_{Mi})$ and greater than or equal to $R^2_{mono}cos(\theta_i)/2$, the triangle T_i being formed by a point coinciding with the transmitter (31) of the group and two points coinciding with two adjacent receivers (32) of said layer, the angle θ_i denoting the angle of insonification of the receiver RX_i with respect to the axis of symmetry and the angle θ_{Mi} denoting the angle between the axis of symmetry (33), on the one hand, and the axis passing through the transmitter (31) and through the point M_i corresponding to the middle of the segment defined by the receiver RXi and the previous adjacent receiver RX_{i-1}, on the other hand.

12. The system as claimed in either of claims 2 and 3, characterized in that the receivers of each group are arranged in at least one layer, and in that, for at least one group of the system, the receivers of at least one layer of said group describe a curved form, and in that the position of each receiver RX_i is such that the surface area $Aire(T_i)$ of a triangle T_i is less than or equal to $R^2_{mono}.cos(\theta_{Mi})$ and greater than or equal to $R^2_{mono}cos(\theta_i)/2$, the triangle T_i being formed by a point coinciding with the transmitter (31) of the group and two points coinciding with two adjacent receivers (32) RX_i and RX_{i-1} of said layer, the angle θ_i denoting the angle of insonification of the receiver RX_i with respect to the axis passing through the transmitter and perpendicular to the straight line passing through the receivers RX_i and RX_{i-1}, the angle θ_{Mi} denoting the angle between said axis, on the one hand, and the axis passing through the transmitter (31) and through the point M_i corresponding to the middle of the segment defined by the receiver RXi and the previous adjacent receiver RX_{i-1}, on the other hand.

13. The detection system as claimed in one of the preceding claims, characterized in that it comprises at least one group having at least two layers of receivers, the layers of receivers being arranged at different reference transmitter-receiver distances.

14. The detection system as claimed in any one of the preceding claims, characterized in that each layer is configured so as to detect a target of minimum given index, and in that the product of the distance $2.x_1$ between the two reference receivers of the reference pair of a layer and the distance D_{TRX} between the transmitter and a reference receiver of said pair is determined as a function of the square R^2_{mono} of the detection radius of the equivalent monostatic sonar for a target of minimum given index to be detected at least by said layer.

15. The detection system as claimed in either of claims 13 and 14, characterized in that it comprises linear layers of receivers and/or circular layers of receivers, a linear layer comprising receivers that are substantially aligned in a line, a circular layer comprising receivers describing an at least partly circular form, some receivers being able to be shared between any two groups.

16. The detection system as claimed in claims 14 and 15, characterized in that said group comprises at least one first linear layer arranged between the transmitter and the infrastructure and at least one second linear layer, the transmitter being arranged between the second linear layer of receivers and the first linear layer of receivers.

17. The detection system as claimed in claim 2, characterized in that each layer is configured so as to detect a target of minimum given index, and in that at least some of the receivers of all of the groups are arranged in at least two main lines of receivers, the adjacent receivers of the first line being separated from one another by a distance d_{inter_1} and the reference transmitter-receiver distance of the first line being denoted by D_{TRX1}, the adjacent receivers of at least one other line of receivers being separated from one another by a distance d_{inter_2} and the reference transmitter-receiver distance of said other line being denoted by D_{TRX2}, the first line being arranged between the infrastructure and the other lines, and in that, for propagation losses equal to K times the logarithm of the distance of the propagation paths TL, the ratio between the product $d_{inter1}.D_{TRX1}$ corresponding to the first line and the product $d_{inter2}.D_{TRX2}$ of said other line is determined as a function of the maximum detection index deviation $\Delta(TS)$ of the possible targets:

$$2K log\left((d_{inter_2}.D_{TRX2})/(d_{inter_1}.D_{TRX1})\right) = \Delta(TS).$$

18. The detection system as claimed in one of the preceding claims, characterized in that each receiver is configured so as to receive signals in a frequency band lower than 30 kHz.

19. The detection system as claimed in one of the preceding claims, characterized in that the elementary detection areas of at least some of the end receivers of a given detection group at least partly overlap with the end receivers of an adjacent detection group.

20. The detection system as claimed in claim 19, characterized in that the distance between the end receiver of a given group and the point of intersection of two groups situated in the middle of the segment linking the two adjacent end receivers between the two groups is a function of the square of the detection radius of the equivalent monostatic sonar R^2_{mono}, and of the distance D_{TRXI} between said point of intersection and the transmitter of the given group (D_{TRXI}).

21. The detection system as claimed in one of the preceding claims, characterized in that it comprises at least one sensor chosen from among the group consisting of a magnetic sensor, an acoustic sensor, a non-acoustic sensor, and in that it comprises a classification unit configured so as to use information derived from the signals of the sensor or sensors to classify the target.

22. The detection system as claimed in claim 21, characterized in that the signals of at least some of the receivers are used by said classification unit to classify the detected targets, and in that each receiver is configured so as to operate at least acoustically simultaneously in passive and active mode, each receiver in passive mode processing frequencies lower than the frequencies processed in active mode, a passive acoustic classification being performed by slaving it from the active tracking, the acoustic or non-acoustic classification range being at least equal to half the maximum distance between two neighbouring receivers, so as to perform classification at least when the target passes between them.

23. The detection system as claimed in one of the preceding claims, characterized in that it comprises a processing unit implementing coherent and adaptive processing of the receivers (32) in order to receive echoes of targets on a receiver, including during the direct reception of the transmission of pulses ("Rx as Tx").

24. The detection system as claimed in one of claims 3 to 23, characterized in that it comprises a group whose transmitter (31) is not omnidirectional, the detection radius of the equivalent monostatic sonar used to determine the positioning of each receiver RXi of the group being a function of the angle θi denoting the angle of insonification of

the transmitter toward said receiver RX_i with respect to the direction of maximum transmission of the transmitter.

25. The detection system as claimed in one of the preceding claims, characterized in that at least some of the adjacent groups are configured so as to transmit orthogonal codes in the same frequency band, and have shared common receivers, said shared receivers using the multistatic echoes of the targets coming simultaneously from the transmitters of said adjacent groups, the receivers being configured so as to distinguish the received echoes between two transmitters.