

DESCRIPTION

TITLE: METHOD FOR MONITORING A MARITIME AREA

5 **[0001]** The invention is in the field of sonars and more specifically of monitoring of maritime zones. More specifically, it relates to systems for monitoring underwater zones. These monitoring systems comprise submerged acoustic reception antennas.

[0002] These systems conventionally comprise a set of sonar devices, for example, buoys drifting at sea, each comprising one of the acoustic reception antennas
10 allowing acoustic measurements to be acquired and processing means configured to process the acoustic measurements in order to detect and classify noise generators in the maritime zone. A noise generator is understood to mean any underwater or surface sound source.

[0003] An aim of the invention is to improve the detection and/or location and/or
15 classification performance capabilities of this type of system.

[0004] To this end, the subject matter of the invention is a method for monitoring a maritime zone from a set of acoustic reception antennas, the acoustic reception antennas of the set each comprising a plurality of acoustic transducers, the reception antennas being reconfigurable so as to be able to be in several reception
20 configurations in which they are submerged, the method comprising a cycle of the following successive steps:

 - acquiring acoustic measurements by means of the set of acoustic reception antennas, the reception antennas of the set each being in a reception configuration;
 - detecting a set of noise generators of interest by forming sonar channels from the
25 acoustic measurements, each noise generator of interest being characterized by a set of at least one primary feature comprising a positioning zone of the noise generator defined in an overall reference frame common to all the noise generators of interest; and,

 when the set of noise generators of interest comprises at least one noise generator
30 of interest:

 - determining, from the set of at least one primary feature, an optimal configuration

set comprising an optimal reception configuration for each antenna of a subset of the reception antennas of the set of reception antennas, so that each reception antenna of the subset is capable of detecting, in the subsequent cycle, acoustic signals originating from a noise generator of interest of the set of noise generators of interest;

- 5 - reconfiguring each acoustic reception antenna of the subset according to the optimal reception configuration defined for this reception antenna, with the cycle of processing steps being repeated at least once.

[0005] Advantageously, the determination step comprises the following steps:

- forming sonar channels from acoustic measurements acquired by the set of
10 acoustic reception antennas during the acquisition step;
- detecting, from the formed channels, as a function of a predetermined detection criterion, a set of local noise generators, each local noise generator of the set of local noise generators being characterized by a set of at least one feature of a local noise generator comprising a positioning zone of the local noise generator in a reference
15 frame connected to the reception antenna;
- merging local noise generators in order to obtain a set of at least one noise generator of interest, each noise generator of interest being characterized by a set of features of the noise generator of interest comprising a positioning zone in an overall reference frame common to all the local noise generators.

- 20 **[0006]** Advantageously, the cycle of steps comprises a step of determining kinetic features of the set of at least one noise generator of interest.

[0007] Advantageously, the cycle of steps comprises a step of classifying the set of at least one noise generator of interest from the kinetic features of the set of at least one noise generator of interest and from the set of at least one primary feature.

- 25 **[0008]** Advantageously, the cycle of steps comprises a step of estimating an evolution of the set of at least one noise generator of interest in a subsequent cycle from the set of at least one primary feature, from the kinetic features and from the classification of the set of at least one noise generator of interest.

- [0009]** Advantageously, the step of determining the optimal configuration set
30 comprises, when the set of at least one noise generator of interest comprises a plurality of noise generators of interest, a step of determining an order of priority of

the noise generators of interest, from the features of the noise generators of interest, and a step of determining the optimal configuration set from features of the noise generators of interest and from the order of priority.

5 **[0010]** Advantageously, a first antenna of the subset is linear and comprises an elongated body that is elongated from a first end to a second end, determining the optimal configuration of the reception antenna of the first sonar device comprising determining an angle of elevation of the second end and/or determining an azimuth of the second end in a reference frame connected to a support with negative buoyancy connected to the first end of the first reception antenna, the reconfiguration
10 of the first reception antenna comprising adjusting the angle of elevation and/or the azimuth.

[0011] Advantageously, determining the optimal configuration set comprises determining the relative positioning of the acoustic transducers of at least one second reception antenna of the subset, the reconfiguration comprising adjusting the relative
15 positioning of the acoustic transducers of the second reception antenna.

[0012] Advantageously, determining the optimal configuration comprises determining a level of submersion of a third antenna of the subset, with the adjustment of the configuration of the third sonar device comprising adjusting the submersion of the antenna.

20 **[0013]** Advantageously, the reception antennas are independently reconfigurable.

[0014] The invention also relates to a sonar system comprising:

- a set of acoustic reception antennas, the reception antennas each comprising a plurality of acoustic transducers, the reception antennas of the set being reconfigurable so as to be able to be in several reception configurations, the set of
25 antennas being able to acquire acoustic measurements;
- adjustment means capable of reconfiguring the reception antennas as a function of the optimal configuration set;
- a processing device suitable for executing the steps of detecting and determining the optimal configuration set of the method according to the invention,
- 30 the sonar system being configured to implement the method according to the invention.

[0015] Advantageously, the sonar system comprises a set of sonar devices comprising a first sonar device comprising a support with negative buoyancy and a first acoustic reception antenna of the set of antennas, the first reception antenna being linear and comprising an elongated body that is elongated from a first end to a second end, the elongated body being connected by the first end at a connection point that is fixed relative to the support, the sonar device being able to be in a plurality of reception configurations, in which the antenna body and the support are fully submerged, the antenna body extending substantially vertically from the first end to the second end toward the seabed in at least one reception configuration, the first sonar device comprising orientation adjustment means for adjusting, when the first sonar device is in the operational configuration and the support is fixed relative to the terrestrial reference frame, an angle of elevation and an azimuth of the second end in the reference frame connected to the support centered on the connection point. The first acoustic reception antenna is one of the antennas of the set.

[0016] Advantageously, the system comprises means for adjusting the relative positioning of acoustic transducers of a second reception antenna of the set of antennas.

[0017] Advantageously, the system comprises a device for adjusting a level of submersion of a third reception antenna of the set of antennas.

[0018] Advantageously, the reception antennas are independently reconfigurable.

[0019] Further features and advantages of the invention will become apparent from reading the following detailed description, which is provided by way of a non-limiting example, and with reference to the appended drawings, in which:

[0020] [Fig. 1] figure 1 schematically shows a sonar system according to the invention;

[0021] [Fig. 2] figure 2 schematically shows the main steps of the monitoring method according to the invention;

[0022] [Fig. 3] figure 3 schematically shows the steps of the monitoring method according to the invention in more detail;

[0023] [Fig. 4] figure 4 schematically shows a conical surface obtained from channel formations from signals measured by a linear acoustic reception antenna;

[0024] [Fig. 5] figure 5 schematically shows a sonar device according to a first embodiment in two reception configurations;

[0025] [Fig. 6] figure 6 schematically shows part of the sonar device according to a second embodiment in a low vertical orientation, and two other reception

5 configurations;

[0026] [Fig. 7] figure 7 schematically shows an example of a buoyancy modification device.

[0027] The same elements are identified using the same reference signs from one figure to the next.

10 **[0028]** The invention relates to a method for monitoring a maritime zone. The sonar system SYS according to the invention comprises a plurality of sonar devices. Each of the sonar devices comprises a reconfigurable acoustic reception antenna. The monitoring method according to the invention uses the possibility of reconfiguring the acoustic reception antennas in order to improve the performance

15 capabilities for monitoring noise generators located in the maritime zone. It allows the spatial coverage zone of the sonar system to be increased.

[0029] The invention particularly applies to the underwater monitoring of private or military installations, to monitoring surface and underwater maritime traffic, and to studying the flow of underwater creatures.

20 **[0030]** An example of a sonar system according to the invention is shown in figure 1. It comprises a plurality of sonar devices DS_k , with $k = 1$ to K , where K is the number of sonar devices, with K being greater than 1. The whole number K is equal to 4 in the non-limiting embodiment of figure 1.

[0031] Each sonar device comprises an acoustic reception antenna A_k comprising

25 a plurality of acoustic transducers TA_{kj} , with $j = 1$ to N_k , where N_k is the number of acoustic transducers TA_{kj} of the acoustic reception antenna A_k . N_k is greater than 1. The antennas each comprise 3 transducers in the non-limiting example of figure 1.

[0032] An acoustic transducer TA_j is understood to mean a transducer able to convert an acoustic wave into an acoustic measurement, i.e. to acquire an acoustic

30 measurement. Acoustic measurement is understood to mean a signal representing

an acoustic intensity and an acoustic frequency as a function of time over an acquisition duration.

[0033] An acoustic transducer TA_j is, for example, an electro-acoustic transducer, for example, a hydrophone, converting an acoustic wave into an electrical signal representing an intensity and a frequency of the acoustic wave detected by the transducer as a function of time over an acquisition duration, or is even an opto-acoustic transducer converting an acoustic wave into an optical signal representing an intensity and a frequency of the acoustic wave detected by the transducer as a function of time over an acquisition duration.

[0034] Each sonar device comprises, for example, an acoustic reception antenna A_k , a floating main support F_k , a dive line LP_k , and a support S_k with negative buoyancy. The antenna A_k is connected to the floating main support F_k (i.e. with positive buoyancy) via the dive line LP_k connecting the support S_k to the main support F_k .

[0035] It should be noted that each sonar device comprises one or more acoustic reception antennas.

[0036] Each acoustic reception antenna A_k is able to be in different acoustic signal reception configurations in which it is intended to acquire acoustic measurements. In other words, the acoustic reception antenna is reconfigurable. In these reception configurations, the acoustic reception antenna is fully submerged.

[0037] Each reception configuration of the antenna A_k is characterized by a set of at least one configuration parameter representing a position of the antenna and/or of at least one configuration parameter representing an orientation of the antenna and/or of at least one configuration parameter representing a reception feature of the antenna.

[0038] The set of at least one reception parameter comprises, for example, a parameter representing an acoustic reception frequency of the antenna, such as, for example, a relative arrangement of the acoustic transducers of the antenna, such as, for example, a distance DI_k between the adjacent acoustic transducers TA_{kj} and TA_{kj+1} of the antenna A_k and/or a minimum frequency from which the acoustic reception antenna is sensitive and/or a maximum frequency from which the acoustic reception antenna is insensitive and/or a reception threshold comprising, for example,

a minimum sound intensity from which the acoustic reception antenna is sensitive and/or a processing feature connected to the processing chain of the antenna, such as, for example, a feature of a filter.

[0039] The set of at least one configuration parameter representing a position of the antenna comprises, for example, a level of submersion corresponding to the depth of the reception antenna and/or a horizontal position of the reception antenna in a reference frame common to all the reception antennas, such as the terrestrial reference frame, for example.

[0040] The set of at least one configuration parameter representing an orientation of the reception antenna in a predetermined reference frame comprises, for example, an angle of elevation αa_k of part of the antenna and/or an azimuth βa_k of the part of the antenna, with these angles being defined in a predetermined reference frame, for example, a reference frame connected to a support belonging to the sonar device DS_k .

[0041] In the case of a plurality of configuration parameters, said parameters can be independently adjusted by configuration parameter adjustment means comprising elementary adjustment means REG_k .

[0042] These parameters are referenced in figure 1 only for the antenna A_1 for the sake of greater clarity, but it is clear that in this figure the antennas are shown in different reception configurations.

[0043] The adjustment means comprise elementary adjustment means REG_k distributed over the different sonar devices DS_k .

[0044] The sonar system according to the invention also comprises processing and control means TRC configured to:

- process acoustic measurements J_k , with $k = 1$ to K , acquired by the acoustic reception antennas, in order to monitor the maritime zone and, in particular, to detect and locate noise generators in the maritime zone;
- generate reconfiguration commands OR_k intended for the adjustment means so that they reconfigure the antennas of the set by adjusting the parameters of the reception configurations of these antennas A_k ;

- and, optionally, generate acquisition commands OA_k so that the acoustic reception antennas A_k of the sonar devices DS_k acquire acoustic measurements.

[0045] The processing and control means TRC are remote, for example, i.e. not included in the sonar devices. They are installed, for example, in a processing unit

5 TER, located on land or on a seagoing vessel, which can be a surface ship or a submarine, and are connected in order to communicate, for example, by satellite, with the sonar devices DS_k in order to be able to receive the acoustic measurements J_k and send the adjustment commands OR_k and, optionally, the acquisition commands OA_k , to the sonar devices DS_k . As an alternative embodiment, the
10 processing means are distributed, for example, over sonar devices, i.e. mechanically connected to acoustic reception antennas of the sonar system.

[0046] Advantageously, the antennas can be reconfigured independently of each other. This allows the best performance capabilities to be achieved in terms of detection and location.

15 **[0047]** The invention relates to a method for monitoring a maritime zone from a sonar system according to the invention. The method according to the invention is implemented while the acoustic reception antennas are fully submerged and are each, in a reception configuration of the reception antenna, defined by a set of reception features.

20 **[0048]** The sonar devices are, for example, free in the water so as to drift under the effect of sea currents. This solution is light and has a certain amount of discretion relative to a threat due to the unpredictable nature of the positions of the sonar devices. As an alternative embodiment, the reception antennas are connected to a fixed support, for example, to the seabed or to a seagoing vessel or to an adjustment
25 device for adjusting the relative positions of the reception antennas in a horizontal plane substantially parallel to the surface of the water in calm sea conditions. This solution is heavier and more expensive, yet it does allow some control over the positions of the antennas and is suitable for monitoring port areas in which maritime traffic must not be disrupted.

30 **[0049]** Each reception antenna is intended to cover a spatial coverage zone. Acoustic noises generated by noise generators in this spatial coverage zone are able to be measured by the acoustic antenna. The reception antennas are arranged so as

to cover respective spatial coverage zones, at least some of which are able to partially overlap. Thus, acoustic reception antennas of the set, the spatial coverage zones of which partially overlap, are able to acquire acoustic measurements originating from the same noise generators in the overlapping zone of the spatial coverage zones, which allows additional acoustic measurements to be obtained that originate from the same noise generators.

[0050] The steps of the method according to the invention are shown in figure 2.

[0051] It comprises a cycle of the following successive processing steps:

- in a first step 100, acquiring acoustic measurements by the set of acoustic reception antennas A_k , with $k = 1$ to K , with the antennas each being in a predetermined reception configuration;

- in a second step 200, detecting a number NB of noise generators of interest B_b that is greater than or equal to 0; each B_b is characterized by a set of features of the noise generator of interest particularly comprising a positioning zone PO_b of the noise generator of interest B_b defined in an overall reference frame common to all the noise generators of interest B_b , the noise generators of interest B_b being particularly detected by forming sonar channels from the acoustic measurements J_k ;

- in a third step 300, determining optimal reception configurations of a subset of reception antennas of the set of reception antennas from the features of the NB noise generators of interest B_b , with $b = 1$ to NB, with NB being the number of detected noise generators of interest, with this step being implemented when the number NB of noise generators of interest is non-zero;

- in a fourth step 400, reconfiguring the reception antennas of the subset of antennas so that the antennas of the subset acquire the acoustic measurements in these respective optimal reception configurations during the subsequent cycle of steps.

[0052] The cycle of steps is repeated at least once. The repetition of the cycle of steps is stopped when a stopping criterion is met. The stopping criterion is, for example, a time criterion or the reception, by the processing and control means TRC, of a stopping command. The stopping criterion is met, for example, when the monitoring duration has reached a predetermined duration threshold.

[0053] Consequently, the method according to the invention uses the possibility of reconfiguring the reception antennas in order to optimize the reception configurations of a subset of reception antennas, so that each of the reconfigured antennas can obtain acoustic measurements originating from one of the detected noise generators.

5 This allows new features of this noise generator to be obtained, in the subsequent cycle, from the measurements acquired during the subsequent cycle, and/or allows the precision of the features of this noise generator to be improved. The method according to the invention thus allows better monitoring performance capabilities to be obtained such as, for example, performance capabilities related to the detection
10 and/or location and/or classification and/or tracking of noise generators, than by using reception antennas in a fixed reception configuration or for which variation is not controlled.

[0054] The method according to the invention will now be more specifically described with reference to figure 3.

15 **[0055]** The acquisition step 100 involves generating, by each antenna A_k of the set of acoustic reception antennas, a set of acoustic measurements J_k , with the acoustic reception antenna A_k being in a predetermined reception configuration. Each set of acoustic measurements J_k comprises a number N_k of elementary acoustic measurements that is greater than 1. Each elementary acoustic measurement is
20 provided by one of the acoustic transducers TA_{kj} of the reception antenna A_k .

[0056] Each acoustic transducer TA_{kj} of the antenna A_k implements, in each acquisition step, an elementary acquisition step, during which it measures an acoustic signal for a non-zero acquisition duration, with the antenna A_k being in a predetermined reception configuration for the entire acquisition duration.

25 **[0057]** Advantageously, the acquisition durations are the same for all the acoustic transducers.

[0058] Advantageously, during the same acquisition step, the elementary acquisition steps of the different transducers of the same antenna are implemented substantially simultaneously or simultaneously. In other words, they begin at
30 substantially the same initial instant and end at substantially the same final instant. Advantageously, the elementary acquisition steps of the acoustic transducers of the different reception antennas of the same acquisition step are also implemented

simultaneously. This simultaneity is managed, for example, by the processing and control means TRC generating acquisition commands sent to the different reception antennas A_k . As an alternative embodiment, this simultaneity is obtained, for example, by internal clocks of the different reception antennas so that, for example, each acoustic transducer implements an elementary acquisition step at identical regular time intervals for all the transducers, for an identical acquisition duration for all the transducers.

[0059] Each acoustic transducer TA_{kj} provides, during each elementary acquisition step, an acoustic measurement M_{kj} representing an acoustic intensity and an acoustic frequency as a function of time over the acquisition duration.

[0060] The acoustic measurement M_{kj} provided by an acoustic transducer comprises, for example, several series of elementary intensity measurements carried out over different elementary durations of the acquisition duration. Each series of elementary measurements is carried out at a predetermined acoustic frequency or in a predetermined acoustic frequency band distinct from the other frequencies/frequency bands of the other elementary series. The acoustic measurement provided by a transducer is, for example, in the form of a series of intensity-time matrices produced at different frequencies. Each matrix or elementary measurement comprises intensity values measured over different elementary durations at a determined frequency or in a determined frequency band. The different elementary measurements are obtained at different frequencies or in distinct frequency bands.

[0061] The acoustic measurements J_k , with $k = 1$ to K , are transmitted to the processing and control means TRC.

[0062] These acoustic measurements can undergo at least one pre-processing step using elementary pre-processing means included in the sonar devices before being transmitted to the processing and control means TRC and/or at least one pre-processing step using the processing and control means TRC before being used to implement step 200. The pre-processing steps can comprise, for example, filtering, coherent processing in order to correlate a received signal with a transmitted signal in the case of an active sonar system or normalization with a view to detecting noise generators.

[0063] The sonar system SYS comprises location means LOC_k , with $k = 1$ to K , shown in figure 1, allowing each sonar antenna to be located in the same overall reference frame, for example, a terrestrial reference frame, i.e. a reference frame connected to land, or a reference frame connected to one of the sonar devices or to the processing and control device TRC, in each cycle over the acquisition duration of the transducers of the antenna. The location means are satellite location means, for example, comprising satellite signal receivers LOC_k installed on the floating supports. This example is by no means limiting, other location means can be used. Inertial units connected to the main supports F_k can be provided, for example.

[0064] In one embodiment, the processing and control means TRC are configured to generate, in each cycle, acquisition commands OA_k sent to the reception antennas A_k in order for the transducers of the acoustic reception antennas A_k to implement, in each acquisition step, the acoustic measurement step over an acquisition duration. As an alternative embodiment, the antennas are configured to implement the measurement steps at regular time intervals, as previously specified.

[0065] The step 200 of detecting NB noise generators Bb , with $b = 1$ to NB, from the acoustic measurements comprises the subsequent steps that are described hereafter. NB is a number of noise generators detected during step 200. This number NB can be zero. In a step 201, sonar channels are formed from acoustic measurements acquired during step 100. More specifically, for each antenna A_k , at least one sonar channel v is formed from the set of acoustic measurements J_k acquired by the antenna A_k . A sonar channel is formed by applying a set of electronic delays to the different sets of acoustic measurements J_k provided by the different acoustic transducers A_k . The sets of applied delays are different for the different sonar channels. This allows an acoustic signal S_{kv} to be obtained for each channel v . The acoustic signal S_{kv} formed by a channel v represents an acoustic intensity as a function of the acoustic frequency along the listening direction representing the corresponding channel. On completion of step 201, a set of acoustic signals S_{kv} is obtained, with $v = 1$ to V_k , where V_k is a whole number greater than or equal to 1 of channels formed for the antenna k . This set is, for example, in the form of a frequency-channel directivity matrix comprising different acoustic signal intensity values S_k obtained for different frequency-channel directivity pairs.

[0066] In a particular embodiment, several sonar channels are formed from the set of acoustic measurements J_k acquired for each antenna A_k .

[0067] In the particular case of an orientable linear reception antenna, channels are formed by azimuth and/or by elevation.

5 **[0068]** If the antenna extends substantially linearly and substantially along a vertical z-axis, channels are formed only by elevation and if the antenna extends substantially linearly and substantially along a horizontal axis, channels are formed only by azimuth. If the antenna is in an intermediate orientation, channels are advantageously formed by azimuth and by elevation.

10 **[0069]** In a step 202 local noise generators B_{kl} are detected for each reception antenna A_k , L_k , with $l = 1$ to L_k when L_k is non-zero and is the number of detected local noise generators, from the sonar channel or channels formed for the reception antenna A_k , as a function of a predetermined detection criterion. As an alternative embodiment, no local noise generator is detected during step 202.

15 **[0070]** Each local noise generator B_{kl} detected during step 202 is characterized by a set of features CB_{kl} comprising:

- an acoustic signal SI_{kl} representing an acoustic intensity as a function of the acoustic frequency defined for the corresponding channel directivity;
- a positioning zone Z_{kl} , in which the local noise generator is located, the positioning
- 20 zone is defined (positioned and oriented) in a local reference frame connected to the antenna A_k ;
- identifying the reception antenna A_k at its source.

[0071] A linear antenna allows different listening directions to be obtained by forming several formations of channels by applying different sets of delays to the

25 same set of acoustic measurements simultaneously acquired by the different acoustic transducers of the antenna. Different channels can be formed along different respective channel directions (or channel directivities) forming different angles with the longitudinal axis I_k of the antenna A_k . However, without any directivity for the acoustic transducers, channels cannot be formed along directions forming different

30 angles around the longitudinal axis of the antenna. In other words, it is possible to deduce, from the acoustic measurements obtained by the antenna, a first conical surface C_{kl} with an axis corresponding to the longitudinal axis I_k of the antenna A_k , as

shown in figure 4, on which the local noise generator B_{lk} is located. In other words, it is possible to deduce an angle γ_{kl} formed between the axis l_k and a direction passing through the apex SO and comprising the noise generator, but it is not possible to deduce therefrom the direction in which it is located around the axis l_k , i.e. the angle β_{kl} formed by a projection of the t-axis, comprising the apex SO and the local noise generator B_{lk} , with a reference direction r_k perpendicular to l_k , around the axis l_k . There is ambiguity with respect to the position of the noise generator.

[0072] In practice, the positioning zone defined for a local noise generator B_{kl} detected from a channel having a direction (or channel directivity) forming an angle γ_{kl} with the longitudinal axis l_k of the antenna A_k corresponds to a generally conical local volume with an axis l_k and with an apex SO, comprising the first local conical surface C_{kl} and having an angular opening around the local angle γ_{kl} . The angular opening decreases with the angle γ_{kb} from 0 to $\pi/2$ because the angular positioning precision, due to the fineness of the channel, increases in this direction.

[0073] The detection 202 of the local noise generators B_{kl} is carried out from the channels formed as a function of a detection criterion.

[0074] The detection criterion can be predetermined or can depend on at least one reception configuration parameter of the antenna in the ongoing cycle and/or in a previous cycle and/or on channels formed in a previous cycle for the same antenna and/or on features of noise generators B_{kl} detected in a previous cycle and/or on the reception antenna in the ongoing cycle and/or in a previous cycle.

[0075] The detection criterion can comprise an intensity threshold, beyond which a noise generator is detected, which can be fixed or can depend on at least one of the aforementioned parameters and/or an acoustic frequency. The selection criterion can comprise a frequency criterion, which can comprise an acoustic frequency band, within which the acoustic frequency must be located. This frequency criterion can be fixed or can depend on at least one of the aforementioned parameters.

[0076] On completion of step 202, a set of local noise generators B_{kl} is obtained that can be empty. Each local noise generator is characterized by a set of features CB_{kl} comprising the positioning zone Z_{kl} in which the local noise generator is detected. The positioning zone Z_{kl} is defined in a local reference frame connected to the corresponding reception antenna A_k . The spatial coverage zones of the antennas

partially overlap, with some local noise generators detected by different antennas corresponding to the same noise generator.

[0077] Step 203 is a merging step comprising a step 203a of changing the reference point of the positioning zones Z_{kl} of the local noise generators B_{kl} defined in the respective local reference frames in order to define them in the overall reference frame and a step 203b of merging the local noise generators B_{kl} meeting a predetermined merging criterion. On completion of step 203, a number NB of noise generators of interest Bb is obtained, with $b = 1$ to NB, where NB is the number of noise generators of interest that is greater than or equal to 1. As an alternative embodiment, the number of noise generators is zero. The set of noise generators of interest Bb comprises a set of at least one noise generator of interest originating from the merging of local noise generators when said noise generators meet the merging criterion and/or a set of at least one local noise generator (when said noise generator is detected by a single antenna).

[0078] During step 203a, a positioning zone ZG_{kl} of each local noise generator B_{kl} in the overall reference frame is determined from its positioning zone P_{kl} in the local reference frame of the antenna A_k .

[0079] This step is carried out from the values of the parameters of the reception configurations of the reception antennas and from the positions of the reception antennas in the overall reference frame, during the acquisition step, and more specifically during the elementary measurement steps implemented by the different acoustic transducers.

[0080] This step is advantageously carried out from a probability of detection of the antenna or POD (Performance of the Day). The POD defines a probability of detecting a noise generator by means of measurements obtained by the antenna in the spatial coverage zone of the reception antenna. The probability of detecting a noise generator located outside the spatial coverage zone, using acoustic measurements acquired by the antenna, is zero. The shapes of the spatial coverage zones that are obtained are relatively complex and non-uniform due to the non-linearity of sound propagation in water. They are defined (position, orientation) in a reference frame connected to the antenna.

[0081] The method can then comprise a step of determining the POD of the antenna. The POD is determined, for example, using a method known to a person skilled in the art, from:

- at least one technical feature of the antenna taken from among a detection frequency band, a maximum range, a gain and an inherent noise;
- at least one environmental feature taken from among a temperature or a temperature curve around the sensor, a depth of the seabed, a type of seabed, sea noise related to traffic and/or the condition of the sea, a wave direction.

[0082] As an alternative embodiment, the POD is predetermined for the values of the configuration parameters of the reception antenna. The system comprises, for example, a database storing POD values for different reception configurations of the antenna.

[0083] The merging step 203b involves merging local noise generators B_{kl} , when the number of local noise generators detected during step 203a is greater than 1.

This step involves merging the local noise generators B_{kl} meeting a predetermined merging criterion, from the positioning zones ZG_{kl} of the local noise generators B_{kl} in the overall reference frame and from the other features of the local noise generators, such as the acoustic signals (intensity/frequency) Sl_{kl} associated with the respective local noise generators.

[0084] The merging criterion between local noise generators B_{kl} is a spatial and frequency matching criterion. Two local noise generators are merged in order to form a noise generator of interest if there is sufficient spatial matching of their respective positioning zones and optionally sufficient frequency matching of the signals associated with these local noise generators in an overlapping zone of the spatial coverage zones of the antennas.

[0085] For example, step 203b comprises, for each pair of local noise generators detected from different reception antennas, the respective spatial coverage zones of which at least partially overlap:

- a step of checking compliance with a spatial matching criterion between the two local noise generators in the overall reference frame involving checking whether there is an intersection between the positioning zones of the two local noise generators in an overlapping zone of the spatial coverage zones of the antennas

from which the two local noise generators were detected;

- and, if the spatial matching criterion is met between these two local noise generators, an optional step of checking compliance with a frequency matching criterion between these local noise generators.

5 **[0086]** The step of checking the spatial matching criterion involves, for example, checking whether the absolute value of the difference between the acoustic frequencies of the signals of the two local noise generators is less than or equal to a predetermined frequency difference threshold.

10 **[0087]** Only the local noise generators meeting the spatial matching and the optional frequency matching criteria are merged.

[0088] During step 203b, when noise generators are merged, a characterization CB_{lb} of the noise generator of interest is also built from the features of local noise generators from which the noise generator of interest B_b originates.

15 **[0089]** The noise generator of interest B_b is characterized by a set of primary features CB_b, when it is obtained from the merging of several local noise generators, by:

- a set ES_b of at least one acoustic signal comprising the acoustic signal of each local noise generator B_{kl} from which the noise generator of interest B_b originates;

20 - a positioning zone Z_b of the noise generator of interest B_b, defined in the overall reference frame;

- the list of each reception antenna behind the noise generator of interest.

25 **[0090]** The positioning zone Z_b of a noise generator of interest B_b originating from the merging of several local noise generators is obtained by determining an overlapping zone of the positioning zones of the local noise generators from which it originates.

[0091] The primary features of the noise generators of interest corresponding to local noise generators (not merged) are still the features of the local noise generators.

[0092] The following steps are implemented when at least one noise generator of interest is detected. When no noise generator of interest is detected, the acquisition

step is returned to directly, for example, without progressing through the subsequent steps.

[0093] The method advantageously, but not necessarily, comprises at least one of the following steps: determining 204 kinetic features of the noise generators of interest, classifying 205 the noise generators of interest, estimating 206 an evolution of the noise generators of interest, a step of constructing 207 a synthesis relating to the noise generators of interest.

[0094] During the step 204 of determining the kinetic features CCb of the noise generators of interest Bb, a direction of movement and/or a speed of each noise generator of interest Bb and/or an acceleration of the noise generator of interest is computed, for example.

[0095] This step is carried out, for each noise generator of interest Bb, from the set of primary features CBb of the noise generator of interest Bb.

[0096] This step can be carried out using a Doppler method or by a comparison with the previous cycle.

[0097] The Doppler method can be used for noise generators of interest obtained by merging local noise generators detected by at least two acoustic reception antennas, i.e. detected from channels formed for at least two acoustic reception antennas. This method is based on the frequency shift of the acoustic signals of the local noise generators that are merged relative to a reference frequency.

[0098] The “Doppler” effect indicates that an acoustic reception antenna, which has acquired, for the local noise generator behind the noise generator of interest, a signal that has a positive frequency shift relative to a predetermined reference frequency, perceives the noise generator approaching itself and that an acoustic reception antenna, which has acquired, for the local noise generator behind the noise generator of interest, a signal that has a negative frequency shift relative to the reference frequency, perceives the noise generator moving away from itself.

[0099] The reference frequency is normally the emission frequency of the noise generator of interest that is stationary relative to the antenna. However, since this frequency is not known, a reference frequency is randomly selected. This is, for example, a frequency of an acoustic signal from a local noise generator behind the noise generator of interest. This frequency is measured by one of the acoustic

reception antennas. This antenna is identified in the features of the noise generator of interest.

[0100] Step 204 therefore comprises:

- a step of determining a reference frequency taken from a frequency of an acoustic signal from one of the local noise generators behind the noise generator of interest;
- a step of comparing each of the frequencies of the acoustic signals of the other local noise generators behind the noise generator of interest with the reference frequency;
- a step of determining the orientation and the direction of the speed vector of the noise generator from the results of these comparisons and the positions of the reception antennas that detected the local noise generators behind the noise generator of interest.

[0101] The method “by a comparison with the previous cycle” involves, from positioning zones of a noise generator computed in two cycles (ongoing cycle and previous cycle) in the overall reference frame, computing the speed from the distance traveled between these cycles and the elapsed time between the acquisition steps of these two cycles. This step can be carried out before the classification step or after the classification step using the result of the step of classifying the noise generator of interest and optionally from a synthesis obtained in a cycle prior to the ongoing cycle.

[0102] The step 205 of classifying each noise generator of interest Bb is carried out from the primary features CBb of the relevant noise generator of interest Bb and optionally from the kinetic features CCb of the noise generator of interest.

[0103] The classification step 205 involves associating the noise generator of interest Bb with a type of noise generator Tb or identifying the noise generator, with the noise generator then being associated with an identity Ib, for example.

[0104] The step 205 of classifying the noise generator of interest Bb is advantageously implemented from known features of noise generators of different known types stored in a database, called classification database CLAS, belonging to the system SYS. Each type of noise generator is associated with different features, with which the features of the noise generator, and optionally its kinetic features, are compared. The type of noise generator associated with a noise generator of interest

is determined using a conventional comparison method, for example, by correlation or by a matching method.

[0105] For example, a noise generator of interest Bb can be associated with a type of seagoing or carrier vessel as a function of its acoustic frequency (obtained from the frequency of the acoustic signal of at least one local noise generator behind the noise generator of interest) and its speed and of frequency and speed features of known carriers, such as a cargo ship and an outboard vessel, for example. In particular, an outboard vessel will have a frequency signature and a speed that are different from those of a cargo ship.

[0106] The acoustic intensity of the acoustic signal from an antenna behind the noise generator of interest can be used for classification in combination with the positions of the antenna and of the acoustic noise generator and, optionally, a reception feature of the antenna.

[0107] The evolution of each noise generator of interest is estimated in a step 206, from:

- at least one of the primary features CBb of the noise generator of interest Bb;
- the kinetic features of the noise generator of interest,
- and optionally the classification of the noise generator of interest (type or identification).

[0108] This step involves estimating an evolution of the behavior of a noise generator of interest Bb in one or more subsequent cycles. It uses primary features CBb and the kinetic features CCB of the noise generator of interest Bb, and optionally the classification (type Tb or identity Ib) of the noise generator of interest and/or optionally at least one primary feature CBb and/or a kinetic feature CCB of a noise generator of the same type or of the noise generator of interest obtained during at least one previous cycle, in order to estimate at least one primary feature of the noise generator of interest and/or at least one kinetic feature of the noise generator in one or more subsequent cycles. On completion of this step, an estimate is obtained of a set of features of the noise generator ECIb in at least one subsequent cycle.

[0109] It is possible to estimate, for example, a position of the noise generator of interest Bb in a subsequent cycle from the positioning zone Zb of the noise generator

of interest Bb computed in the current cycle, i.e. the ongoing cycle, and its speed estimated during step 204.

[0110] It is possible to estimate a frequency and an intensity of an acoustic signal received by a reception antenna behind the detection of the noise generator of interest in the next cycle from the current speed of the noise generator of interest from its current position, from the current position of the reception antenna at its source and optionally from its position in one or more previous cycles. The estimate of the frequency can be particularly based on the Doppler effect. These computations are standard for a person skilled in the art.

[0111] The cycle of steps comprises a synthesis step 207. This step allows a synthesis Sb to be built, for each noise generator of interest Bb, of its features in accordance with the following inputs:

- at least one primary feature CBb of the noise generator of interest Bb;
- an optional kinetic feature CCb of the noise generator of interest Bb;
- and/or the optional classification (Ib or Tb) of each noise generator of interest Bb;
- and/or an optional estimation of a position of each noise generator of interest in the next cycle and/or of at least one other feature, for example, of at least one other primary feature of the noise generator of interest.

[0112] The synthesis Sb can be built, for example, in order to be able to be viewed by a user. It can represent positions (positioning zones) of different noise generators of interest on a three-dimensional map by associating, with each noise generator of interest, a speed vector and/or an optional estimate of a position of the noise generator of interest in the next cycle and/or a type.

[0113] The syntheses determined in the different cycles are advantageously stored in a syntheses database.

[0114] The method according to the invention comprises a third step 300 involving determining optimal reception configurations of reception antennas of a subset of antennas of the set from the features of the noise generators Bb, with $b = 1$ to NB.

[0115] This step comprises a step 301 of determining an order of priority of noise generators of interest Bb from features of the noise generators of interest or from the

synthesis when a synthesis is built. This order of priority is determined for a given mission.

[0116] This step involves establishing an order of priority, called order of priority of interest OP, of the noise generators of interest from a predetermined order of priority and from at least one feature of the set of features CBIb computed for each noise generator. This predetermined order of priority is, for example, stored in a database, called priority database PRIO.

[0117] This feature has, for example, an order of priority as a function of the type of noise generator. The step therefore involves establishing an order of priority of interest of the noise generators of interest as a function of the types of noise generators (obtained during the classification step) and of the predetermined order of priority.

[0118] For example, in the case of a drug trafficking detection mission, noise generators of the outboard vessel type will have priority over cargo ships, which will have priority over whales. A priority noise generator is, for example, an outboard vessel heading toward a predetermined zone, for example, a coast, and/or with a speed within a predetermined speed range.

[0119] For the prioritization of the noise generators, different weights can be associated with different features of noise generators in order to prioritize these noise generators.

[0120] Step 300 then comprises a step 302 of determining optimal reception configurations of a subset of reception antennas from the features of the noise generators of interest or from the synthesis, when a synthesis is built, and from the order of priority of interest of the noise generators of interest. It is also carried out from the adjustable configuration parameters of the different reception antennas of the subset. More specifically, this step is carried out from sets of possible reception configurations for each reception antenna of the subset. Each reception configuration is defined by a set of adjustable configuration parameter values. The set of possible reception configurations of an antenna corresponds to a set of possible sets of values of the possible adjustable configuration parameters.

[0121] The subset of antennas can comprise all or some of the antennas of the set.

[0122] The method can comprise a step 302a of determining the subset of antennas of the set of antennas to be reconfigured. This subset can be empty or can comprise one or more antennas. The subset of antennas to be reconfigured is determined from at least one feature of at least one noise generator of interest, for example, the noise generator of interest with the highest priority, or from several noise generators of interest, and optionally at least one other feature of the noise generator of interest. The subset is also determined from at least one technical feature of the reception antennas of the set, taken from among the antenna technical features listed above, from the current configurations of the reception antennas, from the positions of the different reception antennas at the time of the measurement.

[0123] This step 302a can involve determining, from among the antennas of the set, the antennas that are capable of measuring acoustic signals originating from the priority noise generator of interest or from at least one of the noise generators of interest of the set in the ongoing cycle or in the subsequent cycle.

[0124] This step 302a of determining the subset can comprise:

- a step of selecting reception antennas able to measure acoustic signals having frequency and/or intensity features representing the noise generator of interest.

Indeed, there is no need to reconfigure antennas that are unable to detect a frequency emitted by the noise generator of interest. In other words, only the antennas of the set able to detect at least part of the signal emitted by the noise generator of interest are selected;

- and/or a step of selecting the reception antennas of the set for which at least one of the possible PODs comprises an estimated position of the noise generator of interest in a subsequent cycle. Indeed, there is no need to reconfigure reception antennas that are unable to detect the noise generator of interest in the next cycle.

[0125] An antenna is selected if it meets one and/or the other of these selection criteria.

[0126] This method therefore can comprise a step of determining a set of possible PODs for each reception antenna from a set of possible configurations of the antenna, i.e. for different sets of values of the configuration parameters of the antenna.

[0127] As an alternative embodiment, the method does not comprise the step of selecting the subset of antennas to be reconfigured. The subset of antennas to be reconfigured is then the set of reception antennas. However, this solution is more computation intensive.

5 **[0128]** The method then comprises a step 302b of determining, for each reception antenna of the subset, an optimal set of values of the previously described adjustable configuration parameters. This optimal set of parameters defines the optimal configuration of the considered reception antenna in order to follow the noise generator of interest in the subsequent cycle and/or to improve the precision of at
10 least one feature of the noise generator of interest (for example, its positioning zone).

[0129] This step comprises, for example, for each reception antenna of the subset, the following series of steps:

- checking if the antenna is capable of detecting the priority noise generator of interest in the subsequent cycle, and,
- 15 if so, determining an optimal configuration of the reception antenna, taken from among a subset of configurations of the reception antenna, in which the antenna follows the noise generator of interest to the subsequent cycle and/or allows the precision of at least one feature of the noise generator of interest to be improved (for example, on its positioning zone),
- 20 if not, the noise generator of interest with the next priority becomes the priority noise generator.

[0130] Step 302b uses the POD of a reception antenna of the subset in order to determine the optimal configuration of this reception antenna.

[0131] The step of determining the optimal configuration involves, for example,
25 determining the configuration of the antenna in which the antenna has a maximum probability of detecting the noise generator of interest in one or more subsequent cycles, from among the subset of configurations. This step uses PODs of the antenna determined for a set of reception configurations of the antenna, an antenna position in the current cycle, an estimate of the antenna position, a position of the
30 antenna in the current cycle or in several cycles, for example, in the horizontal plane, and a position of the noise generator of interest in the current cycle and/or an estimate of a position of the noise generator in this or these subsequent cycles.

[0132] A database BPOD advantageously stores PODs of the antennas defined for different possible configurations of the antenna.

[0133] The optimal configuration is, for example, the one in which the probability of detecting the noise generator of interest, in a subsequent cycle or during several subsequent cycles, is maximal. As an alternative embodiment, the optimal configuration is that in which the probability of detecting the noise generator is non-zero during a maximum number of subsequent cycles. The optimal configuration is determined by simulation, for example.

[0134] If several antenna configurations of the subset of configurations exist with the same maximum probability of detecting the noise generator of interest, then the noise generator of interest becomes the noise generator with the next priority and the subset of configurations contains only the configurations with the same maximum probability of detection.

[0135] By selecting a configuration in which the reception antenna has a non-zero probability of detecting the noise generator of interest as a function of the estimate of the evolution of the noise generator, this allows information relating to the noise generator to be obtained by the reception antenna in the subsequent cycle and therefore allows the precision relating to features of the noise generator of interest to be improved and/or features determined in the previous cycle to be confirmed (confirmation of frequency/classification/positioning; and/or the positioning precision to be improved and/or an additional feature of the noise generator to be obtained (for example, the classification) and optionally allows kinetic features of the noise generator of interest to be supplemented by supplementing the path taken by the noise generator of interest during the subsequent cycles.

[0136] In the event of application to monitoring drug trafficking, an outboard vessel traveling toward the coast and moving only at night can potentially represent the presence of drug trafficking.

[0137] The subset of configurations of a reception antenna, among which the optimal configuration is determined, comprises, for example, a set of configurations checking a proximity criterion with the current configuration. As an alternative embodiment, the subset of configurations comprises all the possible configurations of the reception antenna. This latter solution is more computation intensive.

Furthermore, it can take a long time to modify the configuration of the antenna if the current configuration and the subsequent configuration are far apart from each other, which can limit the performance capabilities of the system in terms of monitoring by lengthening latency times between the acquisitions of two consecutive cycles.

- 5 Furthermore, a significant modification of the configuration of the antenna can be energy intensive.

[0138] The step 302 involving determining an optimal configuration for each reception antenna advantageously uses at least one environmental feature taken from among the environmental parameters listed above.

- 10 **[0139]** In addition, the synthesis determined in a cycle is compared, for example, with a previous cycle in order to allow learning with respect to the technical device (capacity, failure) and the strategy (mission) of the system and thus improve the subsequent cycles for the syntheses and assumptions made during the method (for example, when estimating the evolution).

- 15 **[0140]** The comparison can be a computation of the difference, for example, between the position that was predicted for a noise generator against the refined position obtained in the subsequent cycle. If the difference is too great it can be due to:

- poor anticipation as a result of making false assumptions (for example: speeds of the noise generator or direction) due to a lack of information concerning this noise generator;
- a malfunction of an antenna, for example, which therefore does not properly detect the noise generator.

- 25 **[0141]** The reconfiguration step 400 is then implemented by the adjustment means REG_k so that, during the subsequent implementation of the cycle of steps, the antennas of the subset acquire acoustic measurements in these optimal reception configurations during the cycle of subsequent steps. In other words, each of the reception antennas of the subset is in its optimal reception configuration during the acquisition step of the subsequent cycle.

- 30 **[0142]** The syntheses determined during the different cycles are, for example, transmitted to an operator, to assist decision making, or are used by the processing and control means TRC to build an overall synthesis of the behavior of the noise

generator of interest over several cycles, and optionally to trigger an alarm if suspicious behavior of a noise generator of interest is detected.

[0143] The system according to the invention forms a permanent or semi-permanent reconfigurable autonomous sonar monitoring system for improving its detection, location, and optional classification and/or tracking capabilities in a given maritime zone where the set of independent reception antennas is located.

[0144] An example of a sonar device comprising one of the reconfigurable acoustic reception antennas is shown in figure 5.

[0145] The sonar device D comprises a float F and a dive line LP connecting the float F to a support S. The support S has negative buoyancy. The support S connects the dive line LP to an acoustic reception antenna A.

[0146] The antenna A is one of the antennas A_k and comprises a plurality of acoustic transducers TA_j , with $j = 1$ to N , where N is an integer greater than 1 corresponding to the acoustic transducers TA_{kj} .

[0147] The antenna A comprises an antenna body C integrating the acoustic transducers TA_j of the antenna A_k . The antenna body C is an elongated body longitudinally extending from a first end E1 to a second end E2.

[0148] The antenna body C is connected to the support S.

[0149] As shown in figure 5, the antenna A is linear. It comprises a plurality of acoustic transducers distributed along a row of transducers that is able to be straight, i.e. rectilinear. The antenna body C is elongated along the row of transducers.

[0150] The acoustic transducers TA_j are arranged on different curvilinear abscissas along the row of transducers d. The antenna of the embodiment of figure 1 comprises a single acoustic transducer on each curvilinear abscissa. As an alternative embodiment, the antenna comprises a plurality of acoustic transducers on each curvilinear abscissa. Acoustic transducers are, for example, arranged around a row of transducers.

[0151] In the non-limiting embodiment of figure 5, this row of transducers is a straight line d.

[0152] The elongated body C is connected by the first end E1 to the support S and, more specifically, to a connection point PL that is fixed relative to the support.

[0153] In the non-limiting embodiment of figure 5, the antenna is connected to the support S by a ball joint. Thus, the first longitudinal end E1 is translationally fixed relative to the support S along three axes of an orthogonal reference frame connected to the support S. The connection point PL is the center of the ball joint in this embodiment.

[0154] The second end E2 of the antenna body C is free.

[0155] The sonar device D is configured to operate, i.e. to carry out acoustic measurements and to locate noise generators, when it is in a reception configuration. The sonar device D according to the invention is able to assume several reception configurations.

[0156] In each reception configuration, as shown in figure 5, the body of the antenna C and the support S are fully submerged and the antenna is in a reception configuration.

[0157] In the non-limiting case of the device of figure 5, the float F floats on the surface of the water and the dive line LP extends substantially vertically under the effect of the positive buoyancy of the float F and of the negative buoyancy of the support S. A vertical direction or a vertical axis is substantially perpendicular to the surface of the sea in calm sea conditions.

[0158] The acoustic reception antenna is connected to the support S and is configured so as to be able to occupy several orientations in a reference frame connected to the support centered on the connection point PL.

[0159] The antenna is able to be in a low vertical orientation OVB shown in figure 5, in which the antenna body C is suspended from the support S and extends substantially vertically from the first end E1 to the second end E2 toward the seabed.

[0160] The antenna body C is configured and connected to the connection point PL so that the second end E2 is movable relative to the support S and relative to the first end E1, and more specifically so that an angle of elevation and an azimuth of the second end E2, in an orthogonal reference frame (r ; x_1 ; z) connected to the support S and centered on the connection point PL, are variable.

[0161] Each reception configuration of the antenna is characterized by an angle of elevation and an azimuth (when it exists).

[0162] The sonar device D according to the invention also comprises means for adjusting the orientation of the antenna A, allowing an angle of elevation and an azimuth of the second end E2 to be adjusted relative to the support, i.e. in a reference frame connected to the support S centered on the connection point PL.

5 These orientation adjustment means allow the orientation of the antenna to be adjusted when the sonar device D is in a reception configuration or the antenna is in a reception configuration and the support S is fixed relative to the terrestrial reference frame. In other words, the orientation adjustment means allow a position of the second end E2 of the antenna body C to be adjusted relative to the support S along
10 the three directions of a three-dimensional reference frame connected to the support S when the support S occupies a fixed position in the terrestrial reference frame.

[0163] The orientation adjustment means allow this adjustment to be provided when the sonar device D is in a reception configuration and the support S is fixed relative to the terrestrial reference frame.

15 **[0164]** This allows an orientation of the antenna to be modified in a reference frame connected to the support S, i.e. it allows an orientation of the row of transducers to be modified when it is straight or more generally a straight line connecting the two ends E1 and E2 or the connection point PL and E2.

[0165] The angle of elevation of the second end E2 is the angle formed between a
20 horizontal plane ($r; x_1$) passing through the connection point PL and the straight line connecting the connection point PL to the end E2 and the azimuth of the second end E2 is the angle formed around a vertical z-axis of the reference frame ($r; x_1; z$) connected to the support S between a horizontal axis of reference r of this reference frame and the straight line connecting the connection point PL to the end E2. The
25 angle of elevation is positive when the second end is above the horizontal plane ($r; x_1$) and is negative when it is below said plane.

[0166] The orientation adjustment means, belonging to the elementary adjustment means REG_k , comprise drive means ENT allowing, when the support S is fixed, the second end E2 of the antenna body C to be moved relative to the support S along
30 the three directions of the reference frame connected to the support. These drive means ENT allow the second end E2 to be moved relative to the support S so as to vary its angle of elevation and its azimuth in the reference frame connected to the

support. This movement of the second end E2 relative to the support causes the second end E2 to move relative to the first end E1.

[0167] Thus, the drive means ENT allow the end E2 to be moved, even when the support S is fixed in the terrestrial reference frame, relative to the support S, from the position that it occupies when the antenna body C is in the low vertical orientation OVB to an inclined orientation OI, as shown by the dashed lines in figure 5. In the low vertical orientation OVB, the second end has an angle of elevation α_1 of $-\pi/2$, with the azimuth not being defined, i.e. not existing, for this angle of elevation.

[0168] The azimuth exists and is adjustable when the angle of elevation differs from $-\pi/2$ or $\pi/2$.

[0169] In the inclined orientation of figure 5, the second end has an angle of elevation α_2 that is negative and is greater than $-\pi/2$ and has an azimuth β_2 .

[0170] Advantageously, the drive means ENT allow the angle of elevation of the second end E2 to be continuously varied between $-\pi/2$ and a maximum angle of elevation. The maximum angle of elevation is greater than $-\pi/2$. It can be negative, zero or positive. It can be equal to $\pi/2$, for example.

[0171] Advantageously, the drive means ENT allow the azimuth of the second end E2 to be continuously varied between 0 and 2π exclusive when the angle of elevation differs from $-\pi/2$ and $\pi/2$.

[0172] The orientation adjustment means also comprise control means for controlling the drive means so that the drive means ENT adjust the angle of elevation of the second end E2 to a target angle of elevation and the azimuth of the second end E2 to a target azimuth, when the support S is fixed in the terrestrial reference frame, i.e. relative to land.

[0173] The antenna A of the sonar device D according to the invention thus can be dynamically oriented in space, even if the support S is fixed.

[0174] The possible adjustment of the angle of elevation and the angle of elevation of the second end E2 allows the antenna A to be reconfigured as a function of the features of the noise generators of interest, which allows the detection, location and classification capabilities of the sonar system according to the invention to be improved. It is possible, for example, to improve the positioning precision of the noise

generator of interest by modifying the orientation of the antenna for the subsequent cycle, and therefore the conical surface C1, during the subsequent cycle, which allows the precision of the positioning zone of a noise generator of interest detected in a previous cycle by the same antenna or by another antenna to be improved. This reorientation capability also allows the orientation of the antenna to be modified for the subsequent cycle, as a function of the movement of the noise generator of interest, in order to track it in the subsequent cycle.

[0175] The system according to the invention allows good performance capabilities to be obtained in terms of detection, location, classification and tracking of noise generators of interest from sonar devices having a linear antenna with simple geometry and that is economical in terms of acoustic transducers. Directive acoustic transducers no longer need to be provided in order to allow ambiguity to be removed.

[0176] The sonar device according to the invention is able to be implemented from a static support. It does not require the antenna to be towed by a seagoing vessel, which makes it economical and able to be used in a size-limited zone. It is also discreet.

[0177] In addition, this sonar device is easily deployable from a single attachment point (buoy).

[0178] In the particular embodiment of figure 5, the row of transducers d is a straight line. The antenna is configured so that the row of transducers has this linear shape in the reception configuration, irrespective of the position of the end E2.

[0179] In other words, the drive means ENT allow, as shown in figure 5, an incline of the antenna A to be varied, in particular of the straight row of transducers relative to a horizontal plane connected to the support S and relative to a vertical plane connected to the support S and containing the r-axis.

[0180] In an alternative embodiment shown in figure 6, the antenna AA differs from the antenna of figure 5 in that it is flexible. In other words, the transducers are distributed along a row of transducers that is able to be straight or rectilinear and is able to bend under the effect of a movement of the end E2 relative to the support S. This is permitted by virtue of the flexibility of the antenna body CC.

[0181] The acoustic transducers are arranged on different curvilinear abscissas along the row of transducers. The antenna of the embodiment of figure 6 comprises a

single acoustic transducer on each curvilinear abscissa. As an alternative embodiment, the antenna comprises a plurality of acoustic transducers on each curvilinear abscissa, with the acoustic transducers being distributed around a row of transducers.

5 **[0182]** The antenna AA is configured, for example, to extend in a substantially vertical straight line in the low vertical orientation OVB shown in figure 6 on the left-hand side and to be curved in inclined configurations, as shown in figure 6 in the middle and on the right-hand side. The antenna bends when the drive means ENT move the second end E2 away from its equilibrium position shown in figure 6 on the
10 left-hand side.

[0183] The end E2 is, for example, able to occupy the points of a surface SURF that is generally semi-spherical or spherical or is generally an ellipsoid or half-ellipsoid, as shown in figure 6.

[0184] The antenna A can be connected to the support S by a ball joint, as shown
15 in figure 5.

[0185] More generally, the antenna can be connected to the support S by a connection with three degrees of rotational freedom. A certain amount of travel can be allowed, for example, along one or more axes of translation.

[0186] To this end, the first end E1 of the flexible antenna AA or straight linear
20 antenna A, is connected, for example, to the support S by a connection body that is able to deform under the effect of the movement of the second end E2, by the drive means ENT, relative to its equilibrium position.

[0187] As an alternative embodiment, the antenna body CC is flexible and is directly fixed to the support S, in other words, the first end E1 and the connection
25 point PL occupy the same position.

[0188] The drive means ENT comprise, for example, as shown in figure 5, a propulsion unit PROP allowing the second end E2 to move relative to the support S (when the support is fixed in the terrestrial reference frame), at least along two orthogonal directions in a horizontal plane, and preferably, but not necessarily, along
30 a vertical z-axis.

[0189] In the non-limiting example of the figures, the propulsion unit PROP comprises turboprops configured and arranged around the second end E2 so as to allow the second end to move relative to the support S in three orthogonal directions, when the support is fixed in the terrestrial reference frame.

5 **[0190]** Advantageously, the drive means ENT comprise a buoyancy modification device MF mounted on the second end E2. This allows the energy that is consumed by the propulsion unit PROP in order to modify its angle of elevation to be limited, then allows it to be kept at a predetermined angle of elevation without using the propulsion unit and therefore limits the energy that is consumed. Furthermore, not
10 having to use the drive means ENT to keep the angle of elevation fixed avoids any pollution of the measurements acquired by the antenna by acoustic, electrical or magnetic noise that is likely to be generated by the drive means ENT.

[0191] To this end, the drive means ENT are configured to allow the angle of elevation to be kept constant over the entire angle of elevation range extending from
15 the minimum angle of elevation to the maximum angle of elevation.

[0192] The buoyancy modification device allows the reconfiguration of the antenna to be accelerated and therefore allows the latency time between two successive acquisitions to be limited.

[0193] Advantageously, but not necessarily, the low vertical orientation OVB is a
20 rest or equilibrium orientation of the antenna body C. This is, for example, the rest orientation of the antenna when buoyancy variation means MF have minimal buoyancy while a propulsion unit PROP, connected to the antenna, is off.

[0194] Advantageously, the antenna body C can have neutral buoyancy. As an alternative embodiment, the antenna body has negative or positive buoyancy.

25 **[0195]** As shown in figure 7, the buoyancy modification device MF comprises, for example, a ballast BAL with variable mass density, i.e. with a fixed volume and a variable mass or with a fixed mass and a variable volume, and controllable means allowing this mass or this volume to be varied.

[0196] For example, the ballast BAL has a fixed volume and a variable mass. It
30 comprises a housing BOIT containing a gas and a liquid, and a piston PS sealably separating a first sealed compartment CE1 of the housing BOIT containing the gas G and a second compartment CE2 of the housing BOIT containing the liquid L and

fluidly connecting with the external marine environment via an orifice OR. The buoyancy modification device MF comprises an actuator ACT allowing the piston PS to translationally move so as to modify the volumes of the compartments CE1 and CE2, with the volume of the compartment CE1 increasing when the volume of the compartment CE2 decreases. The translation movement of the piston PS thus modifies the amount of liquid in the second compartment CE2, which modifies the buoyancy of the ballast BAL, which also causes the volume occupied by the gas G in the first compartment CE1 to be modified.

[0197] Advantageously, the drive means ENT are arranged in the vicinity of the second end of the antenna A. This position is advantageous in terms of the length of the lever arm. In the case of a flexible antenna, it is also advantageous in terms of controlling the shape of the antenna when it moves and it allows a continuous evolution of the radius of curvature of the antenna to be obtained over its entire length.

[0198] As an alternative embodiment, the drive means ENT are arranged between the ends E1 and E2 or are even distributed along the antenna.

[0199] In the previous examples, the drive means ENT are mounted on the antenna.

[0200] As an alternative embodiment, the drive means ENT comprise, for example, an adjustable length cable connected to the antenna, for example, at the second end, and a winch allowing the length of the cable to be adjusted so as to allow the angle of elevation of the second end E2 to be adjusted, and a rotary actuator for adjusting the azimuth of the second end E2.

[0201] As an alternative embodiment, the sonar device comprises drive means ENT comprising an independent propulsion unit able to transiently cooperate with the antenna in order to move the second end of the antenna. The propulsion unit is of the underwater drone type, for example.

[0202] Advantageously, the sonar device comprises submersion adjustment means or a submersion adjustment device allowing the depth or the submersion IM of the antenna A to be adjusted. These means are then included in the elementary adjustment means of the sonar device. The submersion adjustment means allow, when the antenna is at a certain depth, acoustic measurements to be obtained that

originate from a zone that is a shadow zone for the antenna when said antenna is at another depth. A shadow zone is created by the underwater acoustic propagation defined by the bathymetry profile of the acoustic waves as a function of the depth.

Lowering the second antenna therefore allows a shadow zone to be moved and the

5 detection and/or the position of a noise generator to be confirmed or specified. These means therefore allow the capabilities for detecting noise generators to be improved and therefore allow the capabilities for locating noise generators to be improved. Varying the submersion of the antenna can also improve the “signal-to-noise” level of a noise generator detected by the antenna.

10 **[0203]** These submersion adjustment means comprise, for example, in a non-limiting manner, a winch T allowing the length of the dive line LP, and therefore the depth of the support S, to be adjusted. The winch T can be integrated into the float F, as in figure 5, or into the support S.

[0204] Advantageously, the sonar device comprises relative positioning adjustment
15 means allowing the relative positioning of the acoustic transducers TA_j of the antenna A to be adjusted when the antenna body C is fixed relative to the support S. In terms of detection, the variation of the relative positioning of the transducers determines the performance capabilities related to the detected frequency ranges and to the range of the antenna. A long antenna detects noise generators emitting at
20 very low frequency at very long distances, conversely a smaller antenna has a shorter range and allows noise generators to be detected that are emitting at medium and high frequency. This advantage of adjusting the relative positioning of the transducers therefore allows additional indications to be provided relative to the near/far location of the noise generators. The positioning adjustment means
25 comprise, for example, linear actuators able to linearly move the different transducers on the same straight line and position sensors allowing the positions of the different sensors to be detected on the straight line, with the sensors sending the detected positions to means for controlling the transducers. As an alternative embodiment, the transducers are kept spaced apart in pairs by compression springs, with end stops
30 allowing the springs to remain compressed. Linear actuators are provided to vary the distance between the end stops, so as to vary the spacing between the transducers. Of course, other solutions can be contemplated. The submersion adjustment means are then included in the elementary adjustment means.

[0205] Thus, in the particular embodiment of figures 5 and 6, each reception configuration of the reception antenna is characterized by a set of configuration parameters comprising an angle of elevation, an azimuth (when it exists), a level of submersion of the reception antenna and a relative position between the sensors.

5 These configuration parameters are independently adjustable by the elementary adjustment means.

[0206] The elementary adjustment means associated with the antenna Ak of a sonar device as described above therefore comprise the antenna orientation adjustment means, the positioning adjustment device and the submersion adjustment means.

10

[0207] The sonar system according to the invention can comprise a plurality of sonar devices with a reconfigurable reception antenna, as shown in figure 5.

[0208] More generally, the sonar system according to the invention comprises a plurality of sonar devices with a reconfigurable acoustic reception antenna each comprising at least one adjustment configuration parameter taken from among: a level of submersion (depth) of the reception antenna and/or an angle of elevation of the adjustable second end, and/or an azimuth of the adjustable second end, and/or an adjustable relative position between the transducers when the orientation and the submersion of the antenna are fixed, and the associated adjustment means.

15

[0209] In the embodiment of figure 5, the antenna is linear. As an alternative embodiment, the antenna is a two-dimensional antenna, with the transducers being distributed in a plane, or is a three-dimensional antenna, with the transducers being distributed over three dimensions.

20

[0210] The sonar system comprises sonar devices comprising at least one linear acoustic detection antenna and/or at least one two-dimensional acoustic detection antenna and/or at least one three-dimensional acoustic detection antenna.

25

[0211] In figure 5, the float F or main support is located above the support S along a vertical axis.

[0212] As an alternative embodiment, the main support is located above the surface of the water, such as a platform of a helicopter, or any partially submerged or fully submerged support located above the support S along a vertical axis in the operational configuration.

30

[0213] The buoy can be substantially fixed relative to the terrestrial reference frame or can be free floating at sea.

[0214] More generally, the sonar system according to the invention comprises a plurality of sonar devices each comprising an antenna connected to a main support.

5 The main supports are, for example, buoys free floating at sea or buoys that are substantially fixed relative to land or of the helicopter type (the sonar devices are then dipping sonars). The system can comprise sonar devices of the different types listed above.

[0215] The sonar system according to the invention is passive, for example, which
10 gives it a certain amount of discretion and a certain amount of energy autonomy, which allows long-term, or active, monitoring to be carried out; it then has a greater range but is then more expensive and more energy consuming.

[0216] Advantageously, the sonar system comprises means for determining an orientation and/or a position of the support in the terrestrial reference frame. These
15 means comprise, for example, an inertial unit or MEMS, allowing the movements of the support (acceleration and angular speed) to be integrated in order to estimate its position and/or its orientation (roll, pitch and heading angles) and/or its speed. The support can comprise a GPS receiver allowing satellite geolocation of the support. The orientation and/or position measurements of the support are advantageously
20 used when detecting noise generators of interest (change of reference frame and/or merging) and/or when determining optimal configurations.

[0217] Advantageously, but not necessarily, the means for adjusting the orientation of the antenna comprise means for monitoring the position of the second end. These
25 means can comprise, for example, MEMS allowing the movements of the second end of the antenna to be integrated. They can also use the measurements originating from the means for determining an orientation and/or a position of the support in the terrestrial reference frame to monitor the position of the second end E2.

[0218] The antenna can comprise sensors for determining a curvature of the reception antenna. This curvature is advantageously used when forming channels.
30 This allows the deformation of the antenna to be digitally compensated.

[0219] Advantageously, the reception antennas are configured so as to allow acoustic waves to be detected with a frequency ranging between 1 kHz and 10 kHz.

[0220] The processing and control means TRC and the control means can comprise one or more dedicated electronic circuits or a general purpose circuit. Each electronic circuit can comprise a reprogrammable computation machine (a processor or a microcontroller, for example) and/or a computer executing a program comprising

5 a sequence of instructions and/or a dedicated computation machine (for example, a set of logic gates such as an FPGA, a DSP or an ASIC, or any other hardware module).

CLAIMS

1. A method for monitoring a maritime zone from a set of acoustic reception antennas, the reception antennas of the set each comprising a plurality of acoustic transducers, the reception antennas being reconfigurable so as to be able to be in several reception configurations in which they are submerged, the method comprising a cycle of the following successive steps:
 - acquiring (100) acoustic measurements by means of the set of acoustic reception antennas, the reception antennas of the set each being in a reception configuration;
 - detecting (200) a set of noise generators of interest by forming sonar channels from the acoustic measurements, each noise generator of interest being characterized by a set of at least one primary feature comprising a positioning zone of the noise generator defined in an overall reference frame common to all the noise generators of interest; and,
 - when the set of noise generators of interest comprises at least one noise generator of interest:
 - determining (300), from the set of at least one primary feature, an optimal configuration set comprising an optimal reception configuration for each antenna of a subset of the reception antennas of the set of reception antennas, so that each reception antenna of the subset is capable of detecting, in the subsequent cycle, acoustic signals originating from a noise generator of interest of the set of noise generators of interest;
 - reconfiguring (400) each reception antenna of the subset according to the optimal reception configuration defined for this reception antenna, with the cycle of processing steps being repeated at least once.
2. The method as claimed in the preceding claim, wherein the detection step (200) comprises the following steps:
 - forming (201) sonar channels from acoustic measurements acquired by the set of acoustic reception antennas;
 - detecting (202), from the formed channels, as a function of a predetermined detection criterion, a set of local noise generators, each local noise generator of the set of local noise generators being characterized by a set of at least one feature of a local noise generator comprising a positioning zone of the local noise generator in a reference frame connected to the reception antenna;
 - merging (203) local noise generators in order to obtain a set of at least one noise generator of interest, each noise generator of interest being characterized by a set of features of the noise generator of interest comprising a positioning zone in an overall reference frame common to all the local noise generators.

3. The method as claimed in any one of the preceding claims, wherein the cycle of steps comprises a step of determining kinetic features of the set of at least one noise generator of interest.

5 4. The method as claimed in the preceding claim, wherein the cycle of steps comprises a step of classifying the set of at least one noise generator of interest from the kinetic features of the set of at least one noise generator of interest and from the set of at least one primary feature.

10 5. The method as claimed in the preceding claim, wherein the cycle of steps comprises a step of estimating an evolution of the set of at least one noise generator of interest in a subsequent cycle from the set of at least one primary feature, from the kinetic features and from the classification of the set of at least one noise generator of interest.

15 6. The method as claimed in the preceding claim, wherein the step (300) of determining the optimal configuration set comprises, when the set of at least one noise generator of interest comprises a plurality of noise generators of interest, a step (301) of determining an order of priority of the noise generators of interest, from the features of the noise generators of interest, and a step (302) of determining the optimal configuration set from features of the noise generators of interest and from the order of priority.

20 7. The method as claimed in any one of the preceding claims, wherein a first antenna of the subset is linear and comprises an elongated body that is elongated from a first end (E1) to a second end (E2), determining the optimal configuration of the reception antenna of the first sonar device comprising determining an angle of elevation of the second end and/or determining an azimuth of the second end (E2) in a reference frame connected to a support with negative buoyancy connected to the first end of the first reception antenna, the reconfiguration of the first reception antenna comprising adjusting the angle of elevation and/or the azimuth.

25 30 8. The method as claimed in any one of the preceding claims, wherein determining the optimal configuration set comprises determining the relative positioning of the acoustic transducers of at least one second reception antenna of the subset, the reconfiguration comprising adjusting the relative positioning of the acoustic transducers of the second reception antenna.

35 9. The method as claimed in any one of the preceding claims, wherein determining the optimal configuration comprises determining a level of submersion of a third antenna of the subset, with the adjustment of the configuration of the third sonar device comprising adjusting the submersion of the antenna.

10. The method as claimed in any one of the preceding claims, wherein the reception antennas are independently reconfigurable.

11. A sonar system comprising:

- a set of acoustic reception antennas, the reception antennas each comprising a plurality of acoustic transducers, the reception antennas being reconfigurable so as to be able to be in several reception configurations, the set of antennas being able to acquire acoustic measurements;

- adjustment means capable of reconfiguring the reception antennas as a function of the optimal configuration set;

- a processing device suitable for executing the steps of detecting and determining the optimal configuration set of the method as claimed in any one of claims 1 to 9,

the sonar system being configured to implement the method as claimed in any one of the preceding claims.

12. The sonar system as claimed in the preceding claim, comprising a set of sonar devices comprising a first sonar device comprising a support (S) with negative buoyancy and a first acoustic reception antenna of the set of antennas, the first reception antenna (A) being linear and comprising an elongated body that is elongated from a first end (E1) to a second end (E2), the elongated body (C) being connected by the first end (E1) at a connection point (PL) that is fixed relative to the support (S), the sonar device (D) being able to be in a plurality of reception configurations, in which the antenna body (C) and the support (S) are fully submerged, the antenna body (C) extending substantially vertically from the first end (E1) to the second end (E2) toward the seabed in at least one reception configuration, the first sonar device comprising orientation adjustment means for adjusting, when the first sonar device (D) is in the operational configuration and the support (S) is fixed relative to the terrestrial reference frame, an angle of elevation and an azimuth of the second end (E2) in the reference frame connected to the support (S) centered on the connection point (PL).

13. The sonar system as claimed in either one of claims 11 and 12, comprising means for adjusting the relative positioning of acoustic transducers of a second reception antenna of the set of antennas.

14. The sonar system as claimed in any one of claims 11 to 13, comprising a device for adjusting a level of submersion of a third reception antenna of the set of antennas.

15. The sonar system as claimed in any one of claims 11 to 14, wherein the reception antennas are independently reconfigurable.