

SYSTEM FOR THE PASSIVE LOCATING OF A MOBILE UNDERWATER CRAFT.

5 The present invention relates to systems for locating mobile craft moving under the sea or in proximity to the surface of the latter.

 It is more particularly useful in the field of underwater combat when a surface boat or a submarine has detected a torpedo with its sonar listening means, in particular with the aid of its torpedo alert device. This
10 device being passive, it only makes it possible to obtain the direction corresponding to that of the directional beam, or "channel", pointing at the torpedo, as well as the time signal allowing its classification.

 There are currently 3 means of estimating the distance:

 - telemetry by wavefront curvature, which is implemented on
15 submarines whose tonnage allows the installation of 3 distributed antennas on each flank, 2 at the ends and 1 at the center. Such a system is described in particular in French patent No. 89 06662 filed by the applicant on May 22 1989, published on November 23 1990 under No. 2 647 224, and granted on April 30 1992. Surface vessels and small submarines are not equipped with
20 this expensive system. Moreover, the range of this system is limited, the curvature having to be sufficient, and it does not work at very low frequency, the wavelength being too large;

 - triangulation between a hull antenna and a towed linear antenna. Not many surface vessels and submarines have towed linear
25 antennas. Furthermore, when the towing vessel maneuvers, the position of the towed antenna is no longer known with sufficient accuracy, thereby rendering the measurement uncertain;

 - telemetry by multipaths, which requires the use of antennas that are highly directional in terms of elevation and hence vertically extended
30 in order to separate the paths. This technique therefore requires means that do not exist on surface vessels and that are expensive on submarines. Furthermore, it does not perform well in shallow waters since the paths are then difficult to separate and the first measurement is available only after a lengthy time lag.



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Airborne means of detection are also known, consisting in releasing several passive acoustic buoys from an aircraft in order to detect and track submarines or to protect sensitive sites.

Finally, systems for decoying torpedoes launched from a surface vessel are known, such as for example that described in French patent No. 90 04809, filed by the applicant on 04/13/90 published on 10/18/92 under No. 2 660 907 and granted on 7/21/95. Described therein is a means making it possible to decoy and destroy a torpedo, this means consisting of a buoy furnished with an active sonar. In this way, telemetry could be applied to the torpedo. The major drawback of this system lies in the fact that it would have to emit considerable acoustic power omnidirectionally on account of the low reflexion index of a torpedo (and in general of any craft having the size of a torpedo).

To alleviate these drawbacks, the invention proposes a system as claimed in the appended claims.

Other features and advantages of the invention will become clearly apparent in the following description, presented by way of nonlimiting example with regard to the appended figures which represent:

- figure 1, a depiction explaining the invention;
- figure 2, a depiction of a series of measurements;
- figure 3, a schematic of the system;
- figure 4, an exemplary embodiment for a surface vessel;
- figure 5, a first exemplary embodiment for a submarine;
- figures 6 and 7, a first exemplary embodiment of the buoy;
- figure 8, a second exemplary embodiment of the buoy;
- figure 9, a second exemplary embodiment for a submarine, and
- figure 10, a third exemplary embodiment of the buoy.

The invention consists in releasing from a surface vessel or a submarine a buoy furnished with at least one hydrophone and with means of linkage with the naval vessel. When the buoy is stationary, the distance from the craft is estimated by measuring the delay time between the acoustic signals received by the hydrophone of the buoy on the one hand, and by the passive sonar of the vessel on the other hand.

The naval vessel (surface or underwater), situated at B in figure 1, releases an acoustic buoy that can be detached at an instant t_0 recorded by the naval vessel with the position x_0, y_0 of the buoy. In a known manner, the buoy deploys an omnidirectional hydrophone which picks up the noise radiated by the craft M when moving and transmits it back to the naval vessel. The latter has detected the craft by means of the passive sonar and moves away from it so as to be at A in figure 1 at an instant t . The sonar and the hydrophone have a common frequency band in reception. The 2 signals emanating respectively from the channel of the sonar on the one hand, and received by the hydrophone of the buoy on the other hand, are sampled, and hence dated, with reference to the instant t_0 . These two signals are correlated over sufficiently long time spans and, in a known manner, the measurement of the instant corresponding to the maximum of the intercorrelation function between these signals provides the value of the gap in arrival time of the signal between A and B, through the formula $\tau_{AB}(t) = (|MA(t)| - |MB(t)|)/C$, where C is the speed of sound in water.

The location of the craft M at the instant t is then obtained simply by calculating the coordinates in the plane AMB of the point of intersection between the hyperbola with foci A,B and of constant $C\tau_{AB}(t)$ (locus of equal delays) and the straight line AM of azimuth $AZ_A(t)$, the position of the buoy (x_0, y_0) being known. This angle AZ_A corresponds to the bearing $G_A(t)$ of the sonar channel in which the maximum of the signal (radiated noise) originating from the craft is received, corrected for the angle of heading of the naval vessel, which is known at each instant.

Thus, the operator is furnished with a series of points in a Cartesian distance-time reference frame making it possible also to estimate the speed of the craft in a known manner with the aid of a kinematic model. On the basis of this set of points, the measurement is improved by calculating the mean curve, for example by the method of least squares, such as represented in figure 2.

According to a variant embodiment, the passive buoy is a buoy of DIFAR type (Directional Frequency Analysis and Recording) providing a relatively coarse measurement of the azimuth $AZ_B(t)$ of the craft on the basis of two crossed dipoles. It is thus possible to calculate the coordinates of the 2

additional points of intersection with the isodelay hyperbola and the line $AZ_A(t)$, thereby improving the location fix.

The location fix can also be improved, when the buoy is furnished with a GPS receiver and continually transmits its position $x_B(t)$, $y_B(t)$ back to the naval vessel.

Figure 3 represents the complete system in schematic form.

From the alert module 301, the releasing of the buoy, or of 2 buoys so as to have a redundancy in the event of a fault, is triggered at 302 either manually or automatically.

On the basis of the set of measurements obtained over time of $AZ_A(t)$ at 303 and $\tau_{AB}(t)$ (intercorrelator 302), a conventional optimal procedure of passive trajectography is implemented in the module 305 for example of the type using the maximum likelihood. To do this, in a known manner, an uncertainty, inversely proportional to the signal-to-noise ratio, is associated with each instantaneous measurement of AZ_A et Γ_{AB} , and the trajectory of the craft in a Cartesian reference frame is obtained with a kinematic model by minimizing 2 criteria relating to AZ_A and to τ_{AB} , using for example a gradient type algorithm, initialized on the basis of the instantaneous location fixes in the module 306. The greater the distance AB, the greater the accuracy of each instantaneous location fix. By way of example, for a naval vessel moving away at 20 knots after releasing the buoy, after two minutes the distance equals 1200 meters, this being much bigger than the customary distance for towing a linear antenna or a fish, which is typically 200 meters.

Figure 4 diagrammatically represents the configuration of the system for a surface vessel. According to an exemplary embodiment, the buoy 401 is formed of a cylindrical container 411 comprising in its simplest version a hydrophone 402, a radio emitter and electronics for recording and processing the acoustic signals picked up by the hydrophone (amplification, filtering the band of the passive sonar, analog/digital conversion, etc.). It is also furnished with a cell that can last for around 15 to 30 minutes and which is activated on launch. The buoy is for example released by means of a simple mechanical device 403, such as a tube furnished with a holding electromagnet, or else pincer-forming tongs. The cable 404 of the hydrophone is coiled in the bottom of the buoy body which is closed by

means of a plate in such a way that the latter detaches at the moment of impact with the water, as described for example in French patent No. 79 19968 filed on August 3 1979 by the applicant, published on 02.13.1981 under No. 2 462 335 and granted on 05.30.1983.

5 According to the simplest procedure, at the moment of release, the instant t_0 and the position x_0, y_0 of the buoy, taken as being that of the naval vessel at this moment, are recorded by the latter.

 According to a variant, the buoy is furnished with a GPS receiver and its position is then transmitted back to the vessel by VHF.

10 In the case where the buoy is of the DIFAR type, it comprises a compass so as to obtain the azimuth of the craft from the measurement of the bearing.

 Figure 5 diagrammatically represents the configuration of the system for a submarine 500, according to a first embodiment.

15 In this first embodiment, the buoy 501 is designed to sit on the bottom of the sea 502. When the depth of water is small, typically less than 100 meters, this first embodiment is the preferred one. Launch is effected from a known device such as a decoy launcher situated either in the keel or in a housing accommodated at the front between the thick hull and the thin
20 hull. If a watertight passage is made, the buoy can be launched via the garbage-chute airlock. The buoy then remains connected to the submarine by an electric cable or by an optical fiber 504 that are similar to those used for wire-guided torpedoes. In the case of bow launch, a lightweight depressor 505 ensures the downward distancing of the wire. A float 506 ensures that
25 the hydrophone 517 is held under water.

 Figures 6 and 7 represent an exemplary embodiment of the buoy.

 The latter is launched while the underwater vessel is proceeding at a relatively high speed, the craft being supposedly a threat.
30 The buoy is therefore designed to sail with the current, quasi-horizontally, and for this purpose it is furnished with a floating anchor 701 consisting of 2 or 3 articulated vanes held along the body 411 of the buoy by a hood 601 during storage. The buoy comprises 2 compartments and its center of gravity is displaced so as to have a quasi-horizontal posture. For this, half of the
35 body of the buoy is weighted with a heavy material 602 and forms the first

compartment in which is placed the power supply cell 702, the reception electronics 703, and the transmission wire 704 wound on a reel, whereas the second compartment, formed of a lightweight material 603, contains the hydrophone, the float, and the linking wire 705 wound on a tapered spool.

5 The hood is held in place in storage by a device, for example a pyrotechnic device, the opening of which is deferred with respect to the instant of release until there is no longer any risk of tangling of the wire. The control signal for the hood release device is either sent by the transmission wire, or preprogrammed.

10 Figure 8 represents another embodiment in which the buoy is ballasted from the bottom by means of a ballast 801, the transmission wire 802 being wound around the upper part 803 of the body of the buoy. The releasing of the hood is triggered once the buoy has touched the bottom so that the wires do not tangle.

15 Figure 9 diagrammatically represents the configuration of the system for a submarine according to a second embodiment. According to this configuration, the buoy 901 is released toward the surface.

20 Figure 10 represents a third exemplary embodiment of the buoy. It is furnished with a float balloon 506 in such a way that it rises to the surface of the sea as soon as it is cast off from the buoy launcher. The hydrophone 507 and its connection wire 705 are situated at the bottom of the buoy in a housing closed by a removable plate 902, the opening of which is delayed as above.

25 According to a variant, the float balloon is stored folded in the upper part of the buoy and with the aid of a compressed-gas capsule triggered at the appropriate moment, the buoy is released and the float is inflated.

30 Other embodiments may be implemented without departing from the scope of the invention. In particular, in the case of an underwater vessel, the transmission of the signal $S_B(t)$ is effected in an acoustic manner, the buoy then comprising a transducer. Likewise, in the case of a surface vessel, and if the target is supposedly dangerous, the buoy is furnished with acoustic decoy means emitting in a frequency band distinct from that corresponding to the noise radiated by the target.

CLAIMS

1 – A system for the passive locating of a mobile underwater craft, from a surface vessel (400) or from a submarine (500) equipped with a passive sonar, characterized in that the vessel comprises means (403) for releasing at least one buoy 401 in response to the detection by said sonar of said underwater craft, that said buoy comprises means for listening (402) for acoustic signals emitted by said craft and means for transmitting the signals thus detected to the release vessel, and in that this vessel comprises means of calculation for determining the coordinates of said craft from the estimate of the delay between the acoustic signals received on the channel of the sonar which is pointed at the craft and the same acoustic signals received on said listening means.

2 – The system as claimed in claim 1, characterized in that said means of calculation comprise means of intercorrelation (304) between said signals received by the sonar and by the buoy, means for determining the isodelay hyperbola of these signals, and means for determining the point of intersection between this isodelay hyperbola and the azimuth line of the target with respect to the vessel, which is itself determined by the sonar.

3 – The system as claimed in either of claims 1 and 2, characterized in that several successive instantaneous location fixes of said underwater craft are determined and that its trajectory is reconstructed in a passive manner by associating these instantaneous location fixes with the aid of a kinematic model.

4 – The system as claimed in any one of claims 1 to 3, characterized in that the buoy release vessel (400) sails on the surface, that said buoy (401) floats on the surface of the water and that the link with the vessel is effected by radioelectric channel.

5 – The system as claimed in any one of claims 1 to 3, characterized in that said buoy release vessel is a submarine (500), that said buoy (501) rests on the bottom of the sea (502), that the reception hydrophone of this buoy (507) is held under water by way of a float (506) cast

off by the buoy when it contacts the bottom, and that the transmission between the buoy and the submarine is effected by a wire link (504).

- 5 6 – The system as claimed in any one of claims 1 to 3, characterized in that the buoy release vessel is a submarine (500), that the buoy (901) floats on the surface of the sea and that the link between the buoy and the submarine is of the wire type (504).