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SEA TECHNOLOGY

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Low-Frequency Dipping Sonar on A Rigid-Hulled Inflatable Boat

A New Sonar-Based Surveillance System for Use in Shallow-Water Littorals

RHIB dipping sonar prototype 1 in the Gulf of Mexico.

(Below) Performance prediction results.

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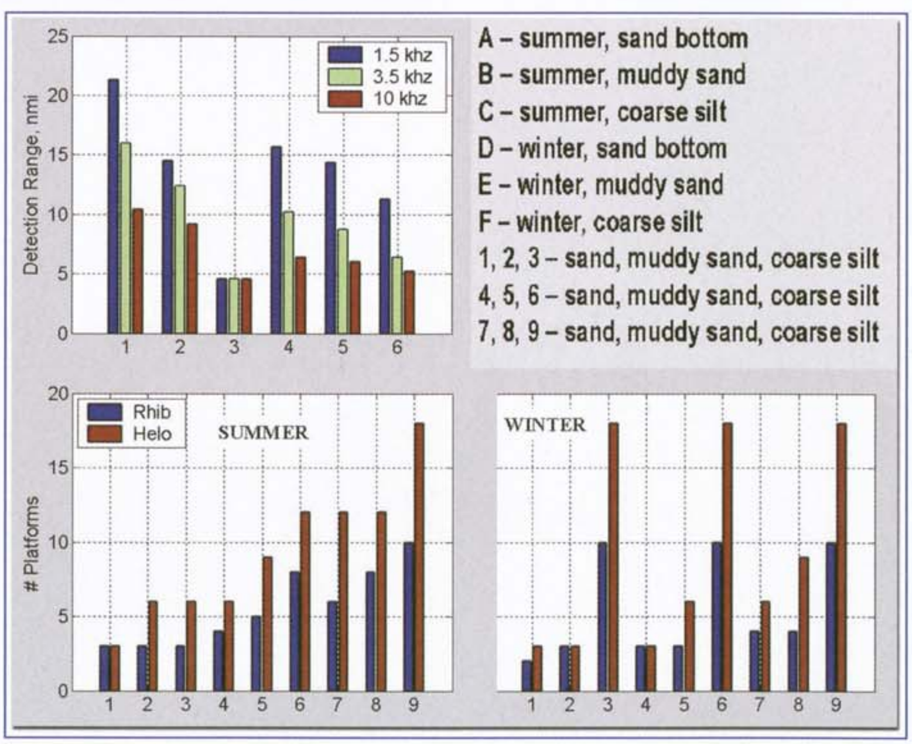
The shift of naval interest from blue-water fleet operations to flexible, rapid response operations in littorals, combined with the proliferation of diesel-powered submarines presents a difficult problem to nations operating surface forces. Variations in water depth, bottom types, salinity, currents and heavy shipping complicate the problem. Modern quiet diesel submarines patrolling in familiar home waters, air-independent propulsion that eliminates the need for frequent snorkeling and other modern technologies create a high-risk environment for fleet operators. Finally, rapidly changing geopolitical situations often require moving sea base operations long distances in short periods of time—hours rather than weeks, as has been the case in the past.

This article analyzes an innovative surveillance system comprised of existing technologies. The system consists of an unmanned 11-meter rigid-hulled inflatable boat (RHIB) equipped with a low-frequency dipping sonar.

This surveillance system has the ability to rapidly, safely and economically conduct antisubmarine warfare (ASW) operations from surface ships in littorals. Recent results from Task Force ASW Experimentation for Assured Access 2004 (TASWEX-04) proved the viability of the surveillance system.



Analysis Scenario

The analysis approach used in this article is scenario-neutral in that neither a particular political situation nor a particular strategic initiative applies. The environmental parameters chosen for this analysis are appropriate for western Pacific littorals. The tactical scenario focuses on an ASW search required to support a surface group transiting a distance of 400 nautical miles within 20 hours. The surface group track is through an area known to contain hostile diesel submarine operating areas. The operation is a barrier search moving ahead of the transiting surface group traveling at the speed of advance (SOA) of the surface group. The moving barrier search group consists of active dipping sonars deployed from an 11-meter RHIB. The surface group SOA is 20 knots.

The water depth is 250 meters, and the bottom composition is sand, muddy sand or coarse silt. Sonar operating depth is selected to maximize detection range, and targets operate at depths of 30 to 235 meters. The threat is a type 209-class SSK, a mid-capability modern diesel submarine.

Sonar Systems

There are several dipping sonar systems with design frequencies that fall in the 1.2 to 11-kilohertz range. Common characteristics for these dipping sonar systems include: omni-directional sources having power levels greater than 218 decibels, variable depth capability ranging from 10 to 750 meters, directivity against ambient noise greater than 14 decibels, directivity against platform noise sources greater than 35 decibels and a total weight of less than 750 pounds to enable helicopter-borne operations.

To the authors' knowledge, there are no dipping sonar systems specifically designed for unmanned surface vehicles. However, the 4,000-pound payload capacity of an 11-meter RHIB accommodates the significantly lighter dipping sonar designed for helicopters and the fuel required for extended on-station times, as demonstrated during TASWEX-04.

Measures of Effectiveness

The main result of the analysis is a determination of the number of platforms required to search a 30 by 400-nautical mile area within 20 hours using a moving barrier. The SOA of the moving barrier must be greater than the SOA of the surface group, which is 20 knots in this investigation. Sprint speed and detection range are driving parameters that determine the required number of platforms. Detection range is defined to be the range at which the signal excess changes from a positive to negative value.[1] In this investigation, the signal excess was computed using the Comprehensive Acoustic System Simulation, developed by the U.S. Naval Undersea Warfare Center.[2]

The leading environmental characteristic affecting detection range is the sound velocity profile (SVP). SVP characteristics depend on season, ocean currents and weather, and can amplify the effects of surface and bottom acoustic characteristics. The SVPs used in this analysis represent summer and winter conditions in shallow-water littorals in the western Pacific. The shallow water and downward refractive nature of SVPs amplify seafloor acoustic effects. Hence, three bottom types are considered: sand to represent benign conditions, muddy sand to represent moderately adverse conditions and coarse silt to represent adverse conditions.

Sonar and target operating depths affect performance. Average effective detection range (AEDR) is computed as an average over target operating depths ranging from 30 to 235 meters. Four sonar depths are considered: 50, 100, 120 and 245 meters. The sonar depth selected maximizes the AEDR.

Predicted Results

The low-frequency sonar out-performs the mid and high-frequency sonars in nearly all cases. Under benign acoustic conditions, there is an AEDR difference of a factor of two between the 10 and 1.5-kilohertz sonar systems. As the bottom conditions worsen, this factor (ratio) decreases such that the AEDRs are around the same—4.6 nautical miles—when operating over coarse silt during the summer. In addition, the strong downward refractive nature of the summer SVPs and shallow water accentuate the effects of bottom characteristics. AEDR significantly improves for winter SVPs. For example, AEDR increases from 4.6 to 11.3 nautical miles for the low-frequency sonar system under adverse bottom conditions.

As stated above, the number of platforms deployed must be sufficient to search a 30 by 400-nautical mile area in less than the surface group's transit time of 20 hours. The search platforms must have a maximum speed capability sufficient to maintain an SOA of 20 knots.

For example, if 50 percent of the time is spent dipping the sonar, a 40-knot sprint capability is required. The percent time spent dipping depends on sprint distance, which in turn depends on detection range. The shorter the detection range, the greater the required sprint speed.

These effects are included in the computations used to determine the required number of platforms. Any temporal gaps in the search must be short enough so that a moving target is unable to slip through the search barrier undetected.

With the exception of the most advantageous acoustic conditions with low-frequency sonars, the RHIB/dipping sonar combination required fewer platforms to complete the assigned search than the helicopter dipping sonar combination. This ratio held true regardless of the sonar frequency; but as the sonar frequency was reduced and sonar performance improved, the number of platforms required was reduced. Thus, the lowest number of platforms required to complete the mission was for a RHIB equipped with a low-frequency dipping sonar.

There are several additional advantages of the dipping sonar/RHIB system not considered in this analysis, but pertinent to system operations. Training for an unmanned RHIB operator is estimated to take less than week; one man in the loop for each re-motely controlled RHIB is adequate. Failures of remotely controlled RHIBs present little danger to human operators.

Platform Life-Cycle Cost

Cost implications of the above results related to the required number of platforms can be significant. A RHIB equipped with a dipping sonar, navigation radar, communications equipment and dynamic control system for unmanned operations is estimated to cost less than $4 million.

Total life-cycle costs for the RHIB are considerably lower than for helicopter platforms. Estimated 20-year life-cycle cost for the RHIB system is about $5.3 million. These total costs do not include crew and host platform costs.

Conclusions

The results presented in this article show an 11-meter RHIB equipped with low-frequency dipping sonar has an adequate capability to conduct surveillance in front of a surface group that is advancing at speeds greater than 20 knots.

The unmanned platform does not require the use of an onboard crew. Thus, surveillance operations present little risk to personnel. The proposed surveillance system is economical based on a life-cycle cost estimate that is less than one-tenth the cost of recently purchased helicopter-borne systems. /st/

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