Anti-Submarine Warfare With Continuously Active Sonar

TNO Tests the Principle of Continuously Active Sonar With the Interim Removable Low-Frequency Active Sonar System

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Exterior (above) and interior (right) views of the SOCRATES tow-fish source. The tow-fish has a free-flooded ring transducer covering the frequency band between one and two kilohertz. (Photo credit: Paul van Walree)

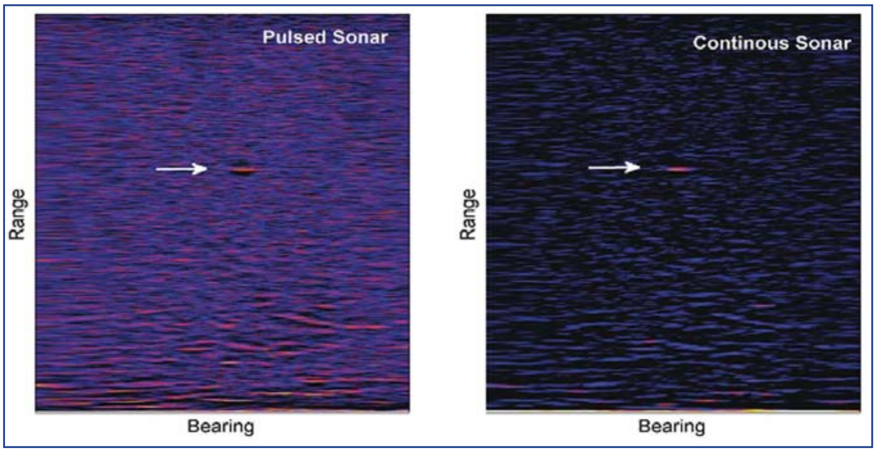
Existing surveillance sonar systems for anti-submarine warfare (ASW) use a pulsed sonar deployed at a low duty cycle. A short signal is transmitted, followed by a long listening time. The short pulse is used because sonar systems with a limited dynamic range are saturated during the transmission. The long listening time is needed to detect objects at a greater distance. As a consequence, a potential target is illuminated only during a short period of the time, and the operator needs to wait for a complete cycle for a new detection opportunity.

Today, state-of-the-art sonar systems have a larger dynamic range that solves the saturation problem. Therefore the duty cycle can be increased to 100 percent, allowing for continuous sonar transmission as an alternative to pulsed sonar. Continuously active sonar (CAS) is of special interest since the technique could provide better detection performance than conventional pulsed sonar, and it will provide the operator a continuous track.

Motivation for CAS

Several potential benefits have been identified for CAS. Continuous transmission leads to continuous illumination of a target. It provides more detection opportunities and is therefore likely to increase the probability of detection. For maneuvering targets, for example, a broadside glint could appear only during a short period during a maneuver. It is therefore likely to be missed with pulsed sonar, whereas the probability of detection increases in the case of continuous illumination. Another advantage of continuous illumination is that there are no gaps of information. With pulsed sonar, the operator only sees new information for the period of time the target is illuminated, whereas the update rate with CAS can be continuous. One can assume this will provide opportunities for improving the tracking performance. Furthermore, it is expected that CAS can be used for the suppression of false alarms, one of the main problems in shallow-water ASW.

In addition to continuous illumination, there are also environmental considerations. With CAS, the same amount of



Sections of range-bearing images from conventional pulsed sonar (left) and with CAS (right). The arrow indicates the target. CAS yields the highest contrast.

energy can be transmitted into the water at a much lower peak source level compared to pulsed sonar. In CAS experiments conducted by TNO, for example, the peak source level was reduced by 11 decibels compared to pulsed sonar. The environmental impact of CAS needs to be carefully assessed, and it is anticipated that peak source level and total transmitted energy will need to be considered.

The IRLFAS System

TNO has more than 20 years of practical experience with low-frequency active sonar (LFAS) for ASW. The efforts on this topic were started in 1990 with the development of the experimental ALF system for the benefit of the Dutch Ministry of Defense, in collaboration with Thales Underwater Systems (Templecombe, England).

TNO has developed the interim removable low-frequency active sonar (IRLFAS) system demonstrator for the Royal Netherlands Navy, which uses the system onboard its operational platforms to gain operational experience.

IRLFAS is based on hardware from Ultra Electronics Maritime Systems (Dartmouth, Canada). This system—comprised of the Sonar Calibration and Testing (SOCRATES) sonar source (developed by TNO and the Defence Materiel Organisation), a receive array and containerized processing.

TNO's philosophy is that sonar research can only be successful through intense experimentation at sea, so LFAS experiments are conducted every year at sea in close collaboration with the Defence Materiel Organisation and Royal Netherlands Navy. This enables TNO to test and evaluate new concepts and algorithms at sea.

Experimental Verification of CAS

A CAS experiment was executed during the IRLFAS 2009 trial in the Western Approaches area, southwest of the U.K., to determine the feasibility of CAS and to gain insight into its performance. The source of the IRLFAS system is a free-flooded ring transducer with one-kilohertz bandwidth, centered at 1.5 kilohertz. The receiver module is a 32-wavelength QUAD array, developed by Ultra Electronics Maritime Systems. This is an array in which each nest is comprised of four sensors that provide intrinsic port/starboard ambiguity resolution. The trial area was a shallow-water environment, where water depth was between 100 and 200 meters.

To test the feasibility and performance of CAS, operators defined a transmit schedule. First, a conventional short-duration linear frequency modulation (LFM) signal was transmitted to serve as reference. The subsequent pings were three long-duration CAS signals, lasting 90 percent of a ping repetition interval. The sequence was finished with a window of time without transmission, enabling the team to investigate whether the recordings deteriorate during the transmission.

The peak source level of the CAS pings was reduced by 11 decibels relative to the reference transmit signal, and the duration was roughly six times longer than the reference signal. As a result, the total amount of energy transmitted by the CAS signal was roughly two times lower than the energy transmitted by the reference signal.

The data processing and analysis revealed no performance differences between the subsequent CAS pings. This indicates that meaningful data can be recorded during transmission. With transmit signal design and tailored processing, the received signal can be separated from the transmit signal.

For the comparison between the performance of the CAS and LFM reference transmit signals, the results that are obtained within individual ping repetition intervals need to be assessed. The results indicate that a good detection performance is obtained with both the reference transmit signal and with the CAS signal. The target was detected using both approaches. This demonstrates that the principle of CAS is feasible. Moreover, the number of contacts that are observed in the CAS range-bearing images is smaller than the number observed in the reference data. This suggests that the application of CAS could reduce the false alarm rate.

Conclusions and Future Applications

The feasibility of CAS has been successfully demonstrated with the IRLFAS system at sea in a shallow-water environment. The technique is of special interest because it provides more detection opportunities than conventional pulsed sonar. Potential targets are namely continuously illuminated. It is anticipated that CAS will improve the detection and tracking performance. For the detection, CAS provides more opportunities to distinguish targets from clutter contacts. Data collected during the IRLFAS 2009 experiment suggest the false alarm rate can be reduced using CAS. Concerning the tracking, pulsed sonar results in gaps in the information on contacts and their positions. These gaps may result in ambiguities in tracking. With continuous illumination, there are, in the case of a good detection performance, no gaps in the information, resulting in an improved tracking performance.

It is therefore anticipated that in ASW applications, CAS will yield new opportunities not possible with conventional pulsed sonar. To achieve this, hardware needs to be adapted and processing and analysis tools need to be further developed. These include data acquisition systems, waveform design, data fusion for detection and reduction of false alarms, and tracking techniques for CAS.

References

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Acknowledgments

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