Small Parametric Sonars for AUV Undersea Reconnaissance

H.C. Woodsum
Sonetech Corporation
10 Commerce Park North, Unit 1
Bedford, NH 03110

Abstract

Autonomous Undersea Vehicles (AUV's) have great potential utility, especially for applications involving remote undersea inspection and reconnaissance, however, the severe size constraints of the platforms dictate that novel, space efficient sensors be utilized. In the case of active and passive acoustic sensors, existing designs derived prior research on parametric sonar, are presented as a potential solution to meet AUV acosutic sensing requirements. Specific characteristics of existing hardware are identified and matched to particular applications and AUV designs, suggesting a mission dependent sensor suite.

Background

Mission capabilities of AUV's allow the emplacement of sensors that are mobile for potentially long periods of time. Such applications as bottom mapping/survey, coastal defense / port security, and detection sea mines / unexploded ordinance (UXO), require active sonars which have both high resolution and small size. The "targets" of these new detection systems can be characterized as being physically small, with low active sonar target strength. As a result, sonar detection range is normally limited by <u>reverberation</u>, (rather than by ambient noise) and classification is limited by the capability of the sonar to discriminate real target echoes from those of target-like "clutter. Desirable properties of such a sonar are: narrow beams with low pattern sidelobes to achieve reduction of reverberation, increase signal coherence, and to achieve high cross-range resolution; large bandwidth for FM/coded-pulse operation to mitigate reverberation and produce high down-range resolution; a relatively low sonar frequency, for reduced transmission loss , reduced reverberation backscattering coefficient, and sediment penetration for detection of buried targets; high duty cycle, to achieve a large search rate and high contact update rate for tracking; and the potential for use of long transmit pulses, when required, to achieve high figure of merit. In addition, a sonar which achieves the above characteristics can be shown to have potential for a degree of covertness, which could, result in additional applications or reserve modes of operation. One example of this might be covert collision avoidance sonar for AUV navigation. In addition, covertness implies less environmental impact on marine mammals and other living things, which could be affected by sonar operation. Two approaches have been suggested in the literature, which allow small system size with low sonar frequency while maintaining high spatial resolution. These techniques, Synthetic Aperture Sonar (SAS), and Parametric

Array Sonic Echo Ranging (PASER^{TM}) technology are often viewed as competitive, but in fact are not mutually exclusive. In fact, PASER^{TM} sonars can be designed for monostatic echo ranging, multi-static echo ranging, and spotlight synthetic aperture modes of operation.

The basis of the PASER^{TM} is the use of a *steerable parametric virtual source array* as the sonar transmitter, with simultaneous transmit and receive operation by design*. The virtual source array* is created by the nonlinear mixing of two co-propagating (steerable), high frequency acoustic beams, using a conventional phased array acoustic projector. The result of this nonlinear transduction process, is a narrow, nearly side-lobe free, low-frequency acoustic beam, at the difference, or "beat" frequency of the two high frequencies. The source generation mechanism provides broad bandwidth with relative ease, and thus, all of the desirable active sonar characteristics above. For a given size constraint on the source array, an optimized parametric source achieves a smaller beam width by a factor of 5-25. This beamwidth reduction produces an approximate 7-35 dB increase in signal-to-reverberation ratio, since surface and bottom reverberation are proportional to beamwidth, and volume reverberation is proportional to roughly the square of beamwidth. In addition, the small beamwidth which can be achieved offers extremely high data rate, point to point underwater communications potential for control of AUV's and for telemetry/data linking, and potentially networking. Data rate is improved via multi-path reduction, due to narrower beams and elimination of sidelobes.

By way of contrast, SAS allows the creation of narrow beams, at the expense of having to physically move the sonar. The use of parametric arrays in combination with synthetic aperture processing is not precluded by the physics of the virtual source, and in fact, Sonetech's technology and current system design could support a "spotlight" synthetic aperture mode. An optimized system, where source motion *is* possible, could offer a purely parametric active sonar mode for long-range search, and a parametric spotlight synthetic aperture mode for added value in target imaging and classification. This would be a natural approach, for example, in operation against buried mine and UXO targets. While the phenomenon of the parametric array was discovered and explained by Dr. Peter Westervelt in the 1960's, the opportunity for widespread application has only recently appeared, as a result rapid advances in the required enabling technologies. These enabling technologies include maximally efficient beamformers, artificial cognition for target classification, receiver technology for simultaneous transmission and reception, gyroscopic electronic beam stabilization, Expert System, AI technology for automated search control, algorithms for precise signal generation and control of the nonlinear transduction process, as well as compact, extremely efficient solid state driver modules

Status of the Technology

We have in completed and tested several advanced prototype systems of increasing complexity, which have demonstrated the principles required for real-world application. A new evolution has been designed, with all major subsystem components validated. Currently, the new generation system is being completed, with “to be determined” follow-on experiments being proposed, to be described in the oral presentation, to explore and demonstrate the value of this technology for applications to potentially include Unmanned Surface and Underwater Vehicles.

A set of AUV payloads can be identified, based on the prototypes we have developed thus far, and described in the oral presentation associated with this paper, which can be hosted on existing AUV’s to achieve the benefits described above. Sensor size, weight, and power can be shown to readily fits within the envelope of current AUV design. A number of experiments can be envisioned which could prove out the advantages of the technology for both underwater sensing, and for underwater data link / networking applications. Such experiments can support the development of new operational concepts, such as the Advanced Littoral Acoustic Remote Monitoring (ALARM), distributed AUV sensor system, which could be use solar-powered AUV’s as its primary platform of choice.