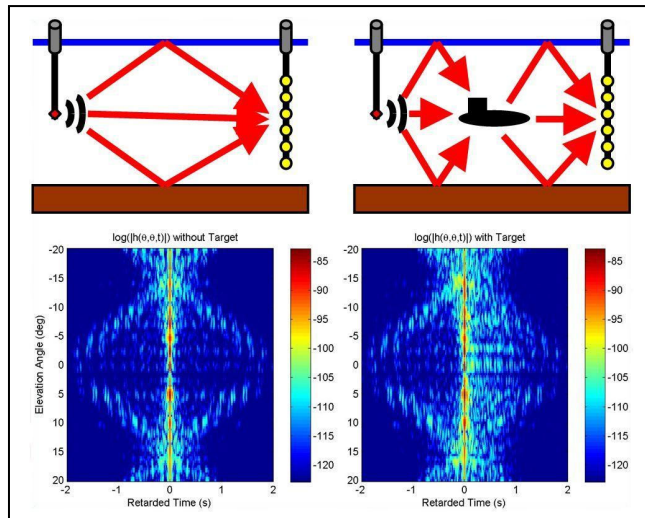


Sonobuoy System and Concept of Operations for Time-Reversal-Based Target Detection

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PROBLEM STATEMENT

With the development of stealthier submarines by our adversaries, the Navy Air-ASW community is researching more capable submarine detection systems. One major focus of this research has been the use of multistatic sonobuoys. Existing multistatic airborne ASW systems, however, are unable to exploit the significant forward scattering strength of a submarine target due to the blinding presence of the direct blast. Time reversal (TR) is a recent method for focusing acoustic energy at a point using pairs of source and receive arrays and offers the opportunity to exploit forward scattering, and near-forward scattering, from submarines. TR focusing provides a measure of propagation channel stability, allowing one to determine when the medium is disrupted as would occur when a scatterer such as a submarine passes between the two arrays.

The technology would provide a significant improvement in the detection capability of sonobuoy-based ASW systems. The time-reversal approach could improve the detection of underwater targets by taking advantage of the relatively large forward-scattered field. This is particularly important since adversary submarines continue to become stealthier with lower target strength and since operations in littoral environments, where transmission loss is high, are becoming more common.

WHO CAN BENEFIT?

The technology could significantly enhance the Navy's anti-submarine warfare capabilities. As a result, our commercialization efforts will primarily emphasize marketing the system and software to the air ASW community, in particular NAVAIR PMA 264.

In addition to air ASW, multi-static target detection has application to other defense related areas. For example, the Department in Homeland Security (DHS) is developing multi-static sonar systems for detecting unauthorized divers or submersibles in high-security shore areas like ports and nuclear power plants. APS would seek to transition the technology to other efforts through direct contact with DoD groups and through publication in relevant journals.

BASELINE TECHNOLOGY

For decades, sonobuoys have provided the principal means to conduct airborne anti-submarine warfare. Two basic concepts for conducting sonobuoy-based active sonar for ASW currently exist. First, source sonobuoys are deployed in small groups in the vicinity of a known or suspected target and independently operate as monostatic active sonars with coarse bearing receiver accuracy. The most commonly used monostatic active buoy is the DICASS SSQ-62. The second basic active sonar concept employed for Air-ASW uses low-frequency sources (either explosive or transducer based) deployed within a field of receive-only (ADAR) sonobuoys. The signal is reflected from local targets, detected and localized at one or more receivers, and then tracked and/or classified by an operator. This latter approach is often termed multistatic sonar. Key limitations of multistatic sonar are:

1. The specular target strength of a submarine is significantly stronger than the off-specular target strength and for the most part, detections are made only when the source-target-receiver geometry falls within the narrow specular beam of the target.
2. Although the forward scattering strength of a submarine is often even greater than the specular target strength, it is difficult to discriminate forward scattering from the incident 'direct blast' field from the source. This is often referred to as the 'looking into the sunlight' problem.

TECHNOLOGY DESCRIPTION

Time reversal (TR) is a recently demonstrated method for focusing acoustic energy at a point in the ocean. In the most basic form of TR, a transmission is made from one point on the first vertical line array (VLA) (often termed the "probe" array) and received at all points on the second VLA (termed the "time reversal mirror" array). The received signal at the second VLA is reversed in time, amplified and retransmitted. According to the principle of reciprocity, the signal received back at the first VLA is focused, in both time and space, at the original transmission point. This focus, however, will be disrupted if the medium between the two arrays is altered; as would occur when a large scatterer such as a submarine passes between the two arrays. Thus, time reversal techniques offer the opportunity to exploit target forward scattering, and near-forward scattering, through the coherent interaction of the direct blast and the forward scattered field. In this case, measures of the defocusing of the time reversed signal at the probe array serves as the detection stream. This target detection method has been termed a "time reversal barrier" (TRB) and is more clearly delineated from conventional monostatic and multistatic sonar in Figure 1.

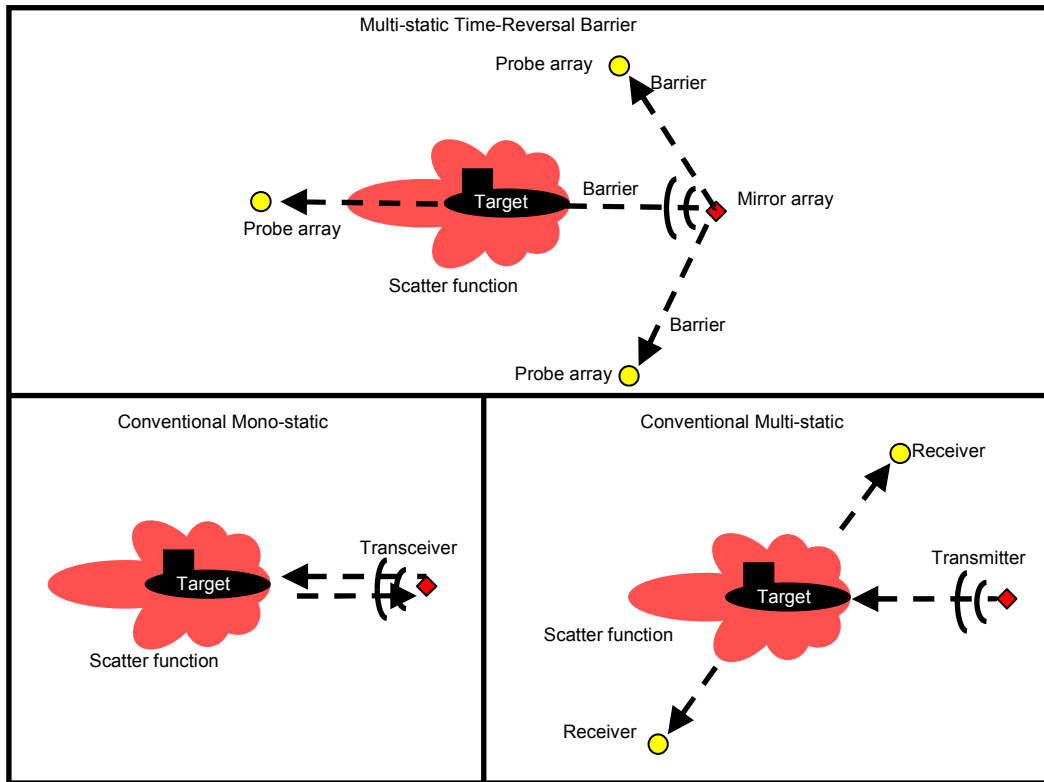


Figure 1: Comparison of the Time-Reversal Barrier (TRB) (top) with the more typical mono-static (lower left) and multi-static (lower right) target detection approaches. The mono-static system depends on back-scatter from the target where the scatter function is often relatively weak. The conventional multi-static approach takes advantage of a range of target scattering angles, potentially including specular scatters, but cannot easily detect forward scattering due to the ‘looking into the sunlight’ effect. The Time-Reversal Barrier, where the target passes between pairs of sensors, is able to discriminate the target’s forward-scattering, which is usually relatively strong, from the direct blast. Note that the strong forward scatter lobe has finite width such that the target does not have to be precisely on the barrier to be detected. Multiple pairs of sensors may be deployed resulting in many Barriers which could surround a target.

There are significant practical difficulties in a sonobuoy-based implementation of the ‘conventional’ TRB as described above. This is because the two buoys would require vertical arrays with both transmit and receive capability. Furthermore the mirror array needs to include a large number of source/receive elements to achieve the desired focusing; more than would be practical on a typical source sonobuoy. Due to the difficulty of implementing a conventional TRB, we have examined the usefulness of alternative ‘nonreciprocal’ TRB techniques. We find that, even though there are several variations to these techniques referred to by different names (Active Nonreciprocal TRB, Passive Nonreciprocal TRB, Matched-Signal Processing, and Passive Phase Conjugation), they are mathematically equivalent. The differences between these variations are in the mechanical or operational implementation and we find that we may choose the implementation that best fits within the limitations of a sonobuoy system.

In Phase I we determined the Passive Nonreciprocal Time-Reversal Barrier (Roux et al 2004), otherwise known as Passive Phase Conjugation (Dowling 1994), is most easily applied to a sonobuoys system. In this approach a signal is sent from a source array to a receiver array and recorded. Later the same signal is retransmitted by the source array and rerecorded by the receive array. The two separate recordings are then cross-correlated to determine their similarity. This technique is referred to as 'passive' because there is no need to retransmit a time-reversed signal. In Phase I we found that this nonreciprocal approach allows us to realize the advantages of time-reversal using already available Coherent Active Source and Digital Vertical-Line-Array Receive Sonobuoys.

CURRENT STATE OF DEVELOPMENT

Successful phase II demonstration of the time-reversal-barrier system will result in further development necessary for implementation of the system in the fleet. To this end, during Phase II, APS will present the results to PMA-264 and request joint funding to continue development for real-time implementation.

The source and receive sonobuoys used as part of the proposed TRB system have already been developed and flight tested by NAVAIR giving them a current Technology Readiness Level (TRL) of 9. The TRB algorithm developed in Phase I has been tested using realistic computational models for a TRL of 6. Successful completion of the Phase II sea-trial will place the TRB algorithm at a TRL of 7. The goal of the Phase III transition path is to bring the entire system to a TRL of 9.

Real-time implementation of an operational TRB system will require that the TRB algorithms be incorporated into the on-aircraft processing system. This will require further funding beyond Phase II, likely from NAVAIR, and a relationship with the ASW aircraft manufacturers.

REFERENCES

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ABOUT THE COMPANY

Applied Physical Sciences Corp. is a Research, Development and Engineering consulting firm specializing in Acoustics, Signal Processing, Marine Hydrodynamics and Electromagnetics. We provide services and innovative products to the National Defense R&D community, and also for the commercial market through direct commercial support and the Small Business Innovative Research (SBIR) program. Roughly half of our technical staff hold PhDs in Engineering, Physics and Mathematics.

APS is headquartered in Groton, CT and has regional offices in Lexington, MA, Arlington, VA, Suffolk, VA, and San Diego, CA. Originally incorporated in 2002, APS has been growing through a measured expansion of our technical staff, maintaining our focus on capability for innovative solutions to our customers' challenges. In September

2006, APS acquired Acoustech Corporation of Philadelphia, PA, establishing APS as an industry leader and innovator in the field of directional underwater transducers. In July 2007, APS acquired C&M Technology Inc of Old Saybrook, CT. For over 20 years, C&M Technology had developed and produced oceanographic data collection systems and special purpose underwater devices for government laboratories, universities, and industry. These acquisitions have boosted APS' capability for producing prototype systems for application of our innovative research and development concepts.

Applied Physical Sciences Corporation has a Secret level facility clearance granted by the Defense Security Service (DSS) on 8 July 2002 together with Secret storage capabilities and a computer system accredited for processing Secret information at Protection Level 1.