Compact, Isolating Elastomeric Suspension for Vehicle Acoustic Vector Sensor

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LONG-TERM GOALS

The miniature acoustic vector sensor (AVS) incorporates, along with a hydrophone, 3-axis accelerometers whose output can be integrated to give local fluid particle velocity information. In principle, a single AVS can give unambiguous bearing information, and multiple vector sensors used in arrays of moderate size can improve spatial resolution. The use of AVS on small autonomous vehicles holds great promise for battlespace as well as oceanographic information gathering, but there are fundamental difficulties and compromises involved in the integration with a moving vehicle of an instrument responsive to particle accelerations in the surrounding medium.

The overall goal of this project is to develop a practical compact AVS mount on the basis of passive materials technology, which will be robust and durable in the ocean environment, inexpensive to produce and reduce demands on the vehicle's signal processing capacity.

OBJECTIVES

Design of an AVS mount must address the following engineering challenges:

(1) **Mitigation of the effect of vehicle accelerations within the medium**. Ideally, for an AVS to respond with fidelity, it should be adrift in the medium and it will always be preferable for the platform vehicle to be stopped for listening. However, the more general case is the vehicle in motion. Hence, the sensor mount should decouple it from accelerations to the greatest extent possible.

(2) **Isolation from own-vehicle vibration and noise**, whether structureborne or waterborne. Any type of physical connection will be prone to transmitting some own-vehicle noise into the sensor. One approach has been to mount sensors on towed arrays, which effectively isolates the sensors from structureborne noise but has the drawbacks of generally increasing mass and volume, requiring neutral buoyancy in the array, necessitating additional orientation references, and complicating vehicle storage and launch.

(3) **Coupling to the medium while protecting from hydrodynamic drag**. The requirement for exposure to the free field is at odds with that for hydrodynamic fairing in a vehicle. A common solution to this problem is to interpose a faired window, but this limits the view angle and entails a compromise between acoustic transparency and sufficient structure to hold its shape under hydrodynamic loads.

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The objective for this Phase I SBIR was to demonstrate the feasibility of a mount designed around material properties available in advanced nonmetallic materials.

APPROACH

KaZaK's approach to the problem is a classic passive suspension embodied in an innovative compact design. The central feature of the mount is a series of resilient elements with sufficient stiffness (modulus) to maintain the sensor position under hydrodynamic loads. The AVS proper is to be surrounded with an impedance-matched material which can be shaped for low drag and flow-induced noise.

All of the desired characteristics are available in developmental materials. At the proposal stage KaZaK highlighted several possible candidates, some of which have been gaining applications in deep submergence, such as base polymers for low-observables treatments. However, in the course of this Phase I we identified other materials with superior properties.

KaZaK's approach breaks down into the following areas:

Mount Design

The concept put forth in the original proposal gives the mount a very low natural frequency, tailored to be outside the frequency range of interest, and enables it to act as an effective filter for own-vehicle noise.

KaZaK's design packages maximum decoupling and damping performance into a small volume, so as to work with the limited space available and not significantly affect UUV hydrostatics. The constructional materials have specific gravity near unity and therefore will produce little bias force on the mount. An important feature of the mount concept is that it minimizes added mass effects in the direction of signal arrival.

The simple shape of the isolating elements lends itself to rapid prototyping with inexpensive tooling.

Acoustic Coupling of Surround

The Navy has noted that coupling or impedance matching is relatively well understood, with suitable compounds available for the surround such as Conathane EN-1556 Rho-C rubber and the Naval Undersea Warfare Center's XP-1 polyurethane-urea. KaZaK was therefore directed to concentrate on the resilient mount materials.

Vehicle and Hydrodynamic Integration

The concept includes a comprehensive approach to vehicle integration. KaZaK's design adapts to both of the basic vehicle mounting situations, on center axis or on the parallel body side, including a linear array. The design permits the mount proper to be contained in a quiescent volume of surrounding seawater, while the AVS surround is configured to be fair to the external profile. The intent is to eliminate any separate fairing or window, with its associated tradeoff of structural and acoustical properties and consequent degradation of the signal, and give maximum exposure to the free field.

Key Personnel

Mr. Robert Karnes – KaZaK Senior Composites Engineer and Principal Investigator
Mr. Karnes has an M.S. in Mechanical Engineering from the University of Connecticut and more than 20 years experience in an unusually broad range of composites-related fields, including high performance elastomers, reinforced thermoplastics, polyurethane composites, syntactics, and low observables materials. He also has wide experience in submarine hydrostatics, hydrodynamics and materials for deep ocean submergence, gained in various positions over 11 years at General Dynamics Electric Boat.

Dr. Jerry Fanucci – KaZaK President
Dr. Fanucci is a MIT Aeronautics and Astronautics Ph.D. with over 25 years experience in composite design, material selection and development of unusual, automated composite processing systems. Dr. Fanucci has considerable background in military application of composites, as well as underwater acoustics. His Master's thesis, funded by NUSC, was a study of near-body acoustic signal behavior entitled "Some Characteristics of Stagnating Turbulence in Two and Three-Dimensional Flows".

Mr. Roger Faulkner – President, Rethink Technologies Inc.
Mr. Faulkner has spent most of his career working on elastomeric materials, adhesives, and coatings, mainly from a chemical and formulation perspective. He has a strong interest in non-polymer based composites, including cermets. He has formulated a very wide range of materials for an equally wide range of applications, and has knowledge and experience in several areas, including: formulation, manufacturing process design, and materials science.

Dr. Raymond Nagem - Associate Professor of Aerospace & Mechanical Engineering - Boston University
Dr. Nagem is a world-recognized expert in underwater acoustics. He is currently working with KaZaK as a partner on our active Phase II ONR STTR related to the development of a composite towed acoustic noisemaker for mine hunting.

WORK COMPLETED

Phase I work concentrated on materials research. Families of advanced engineering nonmetallics were investigated and several candidates were downselected for initial testing.

A simple coupon-level resonant damping test was arranged for at Boston University and samples were molded.

Testing of shear moduli and damping factors was completed, with excellent damping measured in several of the candidate materials.

RESULTS

Several materials suitable for seawater immersion were shown to have predictable moduli and very high damping at resonance. Certain candidate materials also promise for higher performance by loading with various fillers.

KaZaK considers that the results obtained in the tests demonstrate the basic feasibility of the passive isolation approach. Phase I Option work will continue to develop materials.

IMPACT/APPLICATIONS

For the near term, KaZaK sees an important opportunity with the compact AVS mount to support the development of battlespace information gathering with small autonomous vehicles. In 2004, ONR Code 321 set forth the Vector Acoustic Research Initiative (Reference 1). The stated goal of this initiative is "to advance and disseminate the understanding of ocean acoustic vector properties (velocity and intensity) and how they can best be sensed and exploited. This effort supports the broader goal of developing multiple low-cost unmanned assets to remotely detect, classify and identify targets of interest to the U.S. Navy". Development of a compact, high performance AVS mount can also complement efforts such as the ONR-sponsored slow-speed synthetic aperture sonar being developed for the Mission Reconfigurable UUV, or expendable UUVs such as the Mk39.

For future, there are commercial applications for a sensitively mounted AVS that range across the oceanographic field, such as monitoring seismic signals from undersea volcanic activity or charges set off to delineate geological features in oil exploration. More broadly, there is a virtually limitless range of application for highly dissipating materials in compact acoustic isolation and antivibration mounts for machinery or land and marine vehicles.

RELATED PROJECTS

"Penetrator Fuze Shock Mitigation Concepts", Robert Karnes (PI). Phase I SBIR sponsored by the Air Force Research Lab under topic AF071-153, Innovative Fuze Technology Research. AFRL contract FA8651-07-M-0185. Concerned with using highly engineered nonmetallic materials to protect fuzes from impact shock in penetrating weapons.

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