Retractable UUV Antenna Buoy with Smart Tether GPS

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PROBLEM STATEMENT

Unmanned Underwater Vehicles (UUVs) are used in applications where long-term underwater operation is required. Among these are mine countermeasures (MCM), surveillance, and swimmer detection and targeting. UUVs typically navigate via inertial navigation units that are fixed to GPS prior to diving; while submerged communication is normally via acoustic communications only, which has significant bandwidth limitations. The vehicles are typically equipped with fixed antennas for high-speed Radio Frequency (RF), Iridium, or cellular communications when surfaced. The ability to communicate rapidly while still submerged would be very beneficial to UUVs, particularly those developed for the Terminal Swimmer Detection and Targeting (TSDT) Future Naval Capability (FNC) and the developing Large-Displacement UUV (LDUUV). A tethered antenna that supports two-way RF communication and Global Positioning System (GPS) reception will conserve power normally required for surfacing and diving to refresh the UUVs position fix or engage in high-bandwidth communication. A tethered antenna buoy will also enhance performance of the system by enabling real-time transmission of high-bandwidth data while the UUV remains submerged and continues to operate, increasing the stealth and mission efficiency of the UUV while allowing the operator expanded control and monitoring capabilities.

WHO ELSE CAN BENEFIT?

The retractable communications antenna system can be of benefit to any underwater platform that requires continuous or periodic GPS positioning or real-time communication. Possible applications include oceanographic sensor platforms, surveillance equipment or marker beacons, and undersea supply storage facilities. Within the domain of UUVs, the benefits are confined not just to defense applications, but could prove beneficial for other UUV users, such as the oil and gas industry and the academic community.
Naval Sea Systems Command (NAVSEA) PMS 406 which is an advanced development program office for Underwater Maritime Systems (UMS) and PMS 408 Joint (CREW) Program Management Office are also potential users of this technology. Prime contractors that develop UUVs for the military could also benefit from this technology. Examples of these commercial organizations include: Bluefin Robotics, Northrop Grumman, Boeing, L-3 Marine & Power Systems, and Alumifuel Power.

**BASELINE TECHNOLOGY**

There are three types of baseline technologies to which the retractable UUV antenna buoy should be compared.

1) **Acoustic communications systems.** While a UUV is submerged, this is typically the only communications link between the vehicle and the operator. Acoustic communication is limited in bandwidth, meaning that only basic commands can be sent and received by the vehicle. It is not possible to stream real-time sensor data or make mission decisions on-the-fly with this technology, since the baud rate is typically less than 200 baud, whereas KCF’s RF link can be as high as 115,200 baud (source: Bluefin Robotics).

2) **Inertial navigation systems.** Inertial navigation systems can be extremely accurate, allowing a UUV to navigate accurately for long duration while submerged. However, they can be cumbersome to initialize, and they are subject to drift over time, meaning a GPS fix is periodically required to re-locate the vehicle and correct for the accumulated drift. Because GPS satellite signals cannot penetrate the water column, this means that whenever a GPS correction is required, the UUV must surface. Additionally, inertial navigation systems are roughly double the cost of KCF’s UUV antenna.

3) **Surface GPS and communication.** Currently UUVs are capable of direct GPS navigation and RF communication only when the vehicle is on the surface. Surfacing and diving a vehicle has significant energy costs, which increase exponentially with the size of the vehicle. For a large-diameter UUV the cost of surfacing and diving can be over 500 Watt-hours, vs. less than 5 Watt-hours for a surface and dive of the retractable buoy. It is also extremely inefficient to operate the vehicle on the surface because of wave action and incomplete submersion of the propulsor, which can lead propulsor efficiency to drop by as much as 50 percent (source: PSU-ARL). Surfacing also obviously reduces the stealth capabilities of the vehicle.

**TECHNOLOGY DESCRIPTION**

The retractable UUV antenna buoy allows increased operational capabilities for UUVs by allowing GPS navigation and real-time high-speed communication while the vehicle remains submerged. The system consists of a buoy containing the necessary antennas and modems for communication and GPS navigation, an instrumented shape-measuring KCF Smart Tether, a winch mechanism, and a control system for actuating and monitoring the
system and communicating with the host UUV. The modular communications buoy is capable of housing a variety of devices including GPS, RF, Iridium and cellular.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Benefit</th>
</tr>
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<tbody>
<tr>
<td>Deployable RF/GPS Antenna</td>
<td>Allows RF communication while UUV is submerged</td>
<td>• Continuous communication with and tracking of asset</td>
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<td></td>
<td></td>
<td>• On-the-fly mission data collection and decision-making</td>
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<td></td>
<td></td>
<td>• Increased mission time via reduced time and energy wasted surfacing</td>
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<td></td>
<td></td>
<td>and diving to use fixed antenna</td>
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<tr>
<td>Smart Tether Navigation</td>
<td>Tether-based navigation system to correct watch</td>
<td>• Corrects difference between buoy GPS position and actual UUV position.</td>
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<td></td>
<td>circle error</td>
<td>• Significantly less expensive than inertial navigation system</td>
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To exemplify the potential energy savings of the retractable UUV antenna, the following table illustrates the possible energy savings of the retractable UUV antenna for a 48 inch diameter UUV operating for 60 days at sea.

<table>
<thead>
<tr>
<th>Mission Type</th>
<th>Surface/Dive Frequency</th>
<th>Time on Surface</th>
<th>Operational Depth</th>
<th>Traditional Energy Needed</th>
<th>Smart Buoy Energy Needed</th>
<th>Energy Saved</th>
<th>Battery Volume Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>Every 12 hours</td>
<td>~0 minutes</td>
<td>100 m</td>
<td>64 kilowatt-hour (kWh)</td>
<td>1.1 kWh</td>
<td>62.9 kWh</td>
<td>0.439 m³</td>
</tr>
<tr>
<td>Precision Navigation</td>
<td>Every 6 hours</td>
<td>2 minutes</td>
<td>100 m</td>
<td>140 kWh</td>
<td>2.2 kWh</td>
<td>138 kWh</td>
<td>0.962 m³</td>
</tr>
<tr>
<td>Active Searching &amp; Reporting</td>
<td>Every hour</td>
<td>5 minutes</td>
<td>30 m</td>
<td>948 kWh</td>
<td>4 kWh</td>
<td>944 kWh</td>
<td>6.59 m³</td>
</tr>
<tr>
<td>Critical Searching &amp; Reporting</td>
<td>Twice per hour</td>
<td>5 minutes</td>
<td>30 m</td>
<td>1716 kWh</td>
<td>8 kWh</td>
<td>1708 kWh</td>
<td>11.9 m³</td>
</tr>
</tbody>
</table>
CURRENT STATE OF DEVELOPMENT

The retractable antenna buoy has undergone integration and at-sea testing on a 12 inch Bluefin UUV, putting the system at Technology Readiness Level (TRL) 7. The prototype system is constructed as a modular payload section for the Bluefin vehicle. The current generation of the antenna contains GPS and RF antennas and transceivers. Going forward KCF plans to perform integration into other underwater platforms, such as large-diameter UUVs and underwater supply platforms, both of which are interested in purchasing systems from KCF. With additional funding or orders for production systems, KCF will refine the prototype design into a product line to suit various applications.
REFERENCES

The Applied Research Laboratory at The Pennsylvania State University
Mike Pierzga
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Bluefin Robotics Corporation
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WHEN THE TECHNOLOGY WILL BE READY FOR USE

KCF’s retractable UUV antenna is quite ready for transition to production. KCF needs for the system to be adopted by programs that will benefit from the features and advantages offered by the system. KCF sees particular significance for this system in the upcoming push for more development on larger-diameter UUVs, and hopes to be involved in the development of that and other future Naval platforms.

ABOUT THE COMPANY

KCF is a 10-year-old technology company (structured as a sub-chapter S corporation) focused on the development and commercialization of electromechanical devices and systems. The company was founded in November 2000 by three researchers from Penn State University and specializes in energy harvesting wireless sensors, underwater navigation and smart material devices. Our vision is to be a leader in the development of federally-funded technologies and bridge the gap to successful commercial products by establishing strategic partnerships. We perform SBIR and other federal contracts, primarily for the Navy and Army to solve technical challenges for DoD applications, in addition to several Department of Energy (DoE) and National Science Foundation (NSF) projects. We distinguish ourselves with rapid technology development, which we achieve by focusing on rapid prototype development and practical solutions. Every KCF Phase 1 SBIR project since 2004 has gone into Phase 2 and/or Phase 3 stage, and all of KCF’s completed Phase 2 projects have achieved Phase 3 funding or commercial product sales. KCF is not just an SBIR-funded company. As of 2011, more than half of KCF’s revenues come from non-SBIR sources. Our primary business model is to secure company and/or federal funding, perform technology development, and then execute strategic partnerships to bring the product or subcomponent into commercial form, usually in the form of a Joint Development agreement and royalty/license. What makes KCF unique is that we form the strategic partnerships early and focus on technology transition (commercialization) from the onset in all projects, and insist on achieving a successful commercial product outcome for every project.