Towards Wireless Controlled Underwater Vehicles

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***Abstract*—This paper presents adaptation of commercially available Arduino-based LoRa radios for remote wireless command-and-control of a underwater remotely operated vehicle (ROV). The system supports half-duplex communication between the two radios and is capable of remote control of an ROV with a paired down message set. We present our developments to reduce message throughput and the implementation of methods to create a permission-based half-duplex LoRa radio. The system was interfaced with MAVProxy, to support a computer-based ground control station. We present the performance results from our tests in an indoor freshwater tank and the system's capability to wireless control an ROV.**

I. Introduction

Remotely operated vehicles (ROVs) have emerged as an increasingly popular platform for close-up exploration of underwater life in ocean environments. ROVs are typically equipped with cameras, use propellers and are capable of human-operated movement. Smaller ROVs generally require tethers, which can be cumbersome to deploy and hinder their ability to move freely in deep water, and thus impede future applications such as connected multi-vehicle swarms. In this work, we investigate, as a first step toward wireless remote command-and-control of ROVs, the use of LoRa-based radio frequency (RF) technology. In particular, we interface the ROV's on-board computer with a half-duplex LoRa radio transceiver and build a bidirectional communication protocol that supports a fixed amount of re-transmissions between a surface/ground control station and the ROV.

Due to the rapid attenuation of RF signals underwater, acoustic signals are the preferred technique for underwater wireless communications over 100 meters. This work is a first step toward the deployment of low data rate acoustically controlled ROVs. We modify both the on-ROV ArduSub open-source autopilot firmware, and the on-computer MAVProxy ground control station (GCS). ArduSub is a specialized version of ArduPilot, designed specifically for remote-operate submarines. MAVProxy is a Python-based interface with the MAVLink protocol. The ROV and GCS are connected through our modified LoRa radios to support efficient wireless data communication exchange between both nodes. The proposed software and hardware developments are evaluated with a commercially available off-the-shelf ROV, namely Blue Robotics's BlueROV2. The ROV was deployed in an outdoor water tank environment at Engineering West, Boca Raton, FL to evaluate its performance in a typical environment. The ROV was also more formally tested in a large water tank at Florida Atlantic University, where the exact performance of the radio link was logged. Wireless real-time navigation of the ROV was demonstrated when the ROV was hovering near the water surface, with control being maintained when shallowly submerged.

II. Previous Work

One of the most underexplored resources in planet Earth is our ocean. The ocean covers more than 80 percent of the planet's surface, yet it remains largely unmapped and unobserved, mainly due to the complexity and cost of underwater operations [1]. To further explore and even network the ocean to the Internet, technology to overcome the obstacles above must be developed.

Remotely operated vehicles (ROVs), are vehicles that can be controlled from a remote location by a person on the surface. One of the first ROVs was the CUTLET ROV. It was designed to recover torpedoes and was developed by the Royal Navy in 1950; this was followed by the more widely known RP-32 Poodle ROV in 1953 [2]. These early ROVs were created primarily for search-and-rescue missions, and worked using tethers that allowed for their control and navigation from a surface operator. However, the challenge with these types of vehicles is the cumbersome tether. This can be difficult to deploy and also limits the operational range of the vehicle.

Autonomous underwater vehicles (AUVs) are also a prominent technology for monitoring and exploring the ocean. The first AUV was developed at the Applied Physics Laboratory at the University of Washington in 1957 [3]. AUVs are currently used for a wide variety of research, commercial, and military work including oceanic exploration and maritime data collection. AUVs do not require human control via a tether, thus enable data acquisition in otherwise dangerous or inaccessible underwater environments. Instead of remote human control, AUVs follow paths that are pre-planned and navigate underwater using either a combination of depth and inertial sensors or by communication with acoustic beacons that are deployed on the ocean floor [4]. As a result, AUVs lack the ability to live transmit and receive feedback by a human or machine operator, which can be an issue if the vehicle

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