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ON BIOTELEMETRY'S BIDIRECTIONAL ACOUSTIC TAG

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ABSTRACT

Acoustic tagging is one of the primary resources for tracking marine species and understanding their behaviors within these protected zones. However, traditional acoustic tags have several limitations, resulting in data loss or inaccuracies, complicating ecological studies. In this work, we describe the deployment of BTAGs in high-density and elongated array configurations, alongside USBL-based direction and range measurements, providing a versatile toolset for ecological studies, improving the ability to monitor marine species, assess Marine Protected Areas (MPAs), and contribute to the sustainable management of marine ecosystems.

Keywords: *acoustic biotelemetry, bidirectional acoustic tag, usbl*

1. INTRODUCTION

Marine and oceanic ecosystems face significant threats from climate change and overfishing, necessitating continuous monitoring to assess and mitigate their impact [1]. Marine Protected Areas (MPAs) have been introduced to counteract these challenges, but their effectiveness depends on robust data collection methods [2]. Acoustic tagging is one of the primary resources for tracking marine species and understanding their behaviors within these protected zones [3].

The use of acoustic tagging in marine research dates back to the mid-20th century. Early acoustic tags were relatively simple, relying on ultrasonic pulses that could be detected by hydrophones placed in strategic locations. [4]. By the 1970s and 1980s, advancements in electronics and miniaturization enabled the tagging of smaller fish, broadening the scope of research beyond large commercial species. Acoustic telemetry soon became a widely used tool for studying fish behavior, habitat use, and population dynamics, contributing to the development of Marine Protected Areas (MPAs) as a key conservation strategy [5].

Despite its success, traditional acoustic tagging technology has had several limitations. The most significant drawback is the unidirectional nature of data transmission, where tags send signals to receivers but cannot receive information or be reprogrammed remotely [6]. This constraint limits real-time data retrieval, which can be time-consuming and resource-intensive to process.

To solve those unidirectional constraints, a bidirectional acoustic tag has been developed, enabling the acoustic transceivers to send commands to the tags, compute the time of flight (ToF) and receive real-time feedback, thereby improving data accuracy and monitoring efficiency [7].

In this work, the bidirectional acoustic tag (BTAG) system and its deployment options are presented alongside its main specifications.

2. SYSTEM IMPLEMENTATION

The BTAG system is a miniaturisation of a common modem system with tailored solutions to system specifications; these specifications are i. full encapsulation to withstand depths of 500 m, ii. miniaturised design to be able to be carried by a *Nephrops Norvigecus* (i.e., Norway Lobster) following the 2% tag mass to body mass rule [8] and iii. an ultra-low power design to maintain the operativity for a minimum of 3 months up to a 1-year life.

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The system has been designed to comply with these requirements, as seen in Fig.1, with three main blocks in mind, i. the power electronics, which comprises a high energy density lithium thionyl-chloride, a hall effect sensor working with a power switch, enabling the tag's activation and deactivation via an external magnet, ii. the microcontroller from ST Microelectronics, which has the ability to access an ultra-low power sleep mode and a low-power dynamic run mode and iii. the transmission and reception circuitry composed by the input and output amplifier and the piezoelectric transducer.

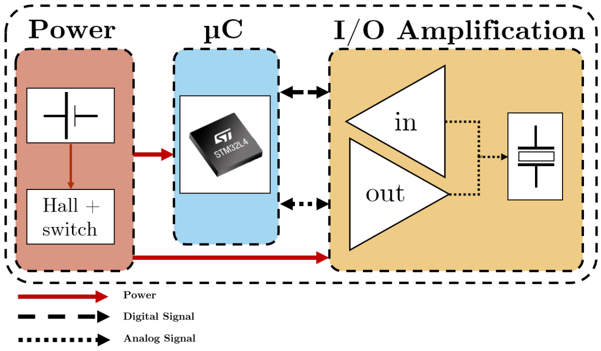

Figure 1. Basic electronic building blocks graphical representation being i. power with the battery and a magnet activated hall sensor with the power switch, ii. ST Microelectronics's ultra-low power microcontroller, and iii. electronic instrumentation with output and input amplification to the piezoelectric element

The output amplifier is a common type D audio amplifier to reduce the power consumption, the input amplifier has been tailored to bandpass 69 kHz which is the most used in the acoustic tagging, being the carrier of the pulse position modulation (PPM) used to transmit the ID of the tag, the polling message from the transceiver station and the response of the BTAG.

The BTAG is encapsulated in a hard resin to ensure the mechanical and water ingress protection (See Fig. 2), and for this size, the battery life in days can be estimated using battery tests resulting in the Table 1.

3. DEPLOYMENT TOPOLOGY

Receivers are typically deployed using two primary configurations: i. a high-density array designed to precisely monitor a specific area and ii. an elongated array or straight-line arrangement used for tracking movements along coastlines, migration routes, or changes in marine habitats. The BTAG system is compatible with these deployment strategies, complementing traditional methods while incorporating transceivers to obtain range measurements.

Table 1. Battery life in days depending on the cycle time and the reception window on the cycle

Cycle time	**60 s**	**120 s**	**180 s**
No Rx	3650	3650	3650
Rx 7.45 s	121	230	326
Rx 12.45 s	75	145	210

Additionally, recent tests utilizing Ultra-Short Baseline (USBL) technology from Evologics have demonstrated the capability to determine both the direction of arrival (bearing) and the range through time-of-flight measurements, enhancing the accuracy and efficiency of tracking efforts.

To ensure full compatibility with the other systems, the BTAG employs the Open protocol developed by the European tracking network (ETN) (https://europeantrackingnetwork.org/en) [9] [10].

Figure 2. Bidirectional acoustic tag transparent test encapsulation showing i. the piezoelectric element (white cylinder), ii. the electronics (blue board), and iii. the battery (purple cylinder)

4. CONCLUSIONS

The introduction of the BTAG technology represents a significant advancement in marine species monitoring. The BTAG system addresses key limitations of traditional acoustic tags by enabling real-time data retrieval and range measurements, thus enhancing tracking accuracy and efficiency.

The miniaturized design, coupled with ultra-low power consumption, ensures extended operational life, up to 10 years when unidirectional mode and 1 year when bidirectional.

Additionally, the integration of an open communication protocol allows for seamless compatibility with existing tracking networks, facilitating broader adoption in marine research.

The deployment of BTAGs in high-density and elongated array configurations, alongside USBL-based direction and range measurements, provides a versatile toolset for ecological studies. These innovations improve the ability to monitor marine species, assess MPA effectiveness, and contribute to the sustainable management of marine ecosystems.

Future developments may focus on further miniaturization, enhanced battery performance, and the incorporation of additional environmental sensors to expand the system's capabilities.

5. ACKNOWLEDGMENTS

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