Development of an Underwater Acoustic Communication System for Sensor Networks or Robotics Applications (WKT1-16)

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Overview
Underwater wireless communication can make it vastly easier to create various underwater systems, such as sensor networks, or autonomous robots. However, wireless communication is highly expensive, with commercial systems costing thousands of US dollars. To solve this, we intended to create a low-cost underwater communication system that can help combat this. We achieved this by utilizing commercially available systems as much as possible, and taking advantage of digital signal processing for maximum cost-effectiveness.

Motivation
Over 70% of the Earth’s surface is covered with water, yet we have only explored less than 10% of it.

This is because it is incredibly difficult to explore underwater, due to the limited abilities of human divers, who can only go beyond 40 meters on occasion, and due to the foreboding cost of underwater technologies. This project aims to combat the costs associated with underwater exploration by creating a low-cost communications system based on acoustic waves that can be used to create a fleet of autonomous robots or a network of sensor apparatus to perform this underwater exploration that is available for use by anybody.

Objectives
- Cost less than US$100.
- Communicate at distances of at least 20 meters.
- Communicate at a speed of at least 200 bits per second.
- Communicate with an error rate of less than 10%.

Implementation
The system uses a shared architecture on both the transmit and receive sides. Both sides use a 40 kHz piezoelectric ultrasonic transducer to both transmit and receive signals, and a STM32F407 micro-controller to digitally process the various signals to generate the transmit waveform or received binary data respectively. An operational amplifier placed between the micro-controller and the transducers to ensure that the correct voltages are generated.

Fully digital signal processing implementation: Commercial off-the-shelf parts Total cost $10

40 kHz Operating Frequency BFSK-based modulation scheme 242 bits per second transmission rate

20+ meters operating range (in fresh water environments)

Performance and Cost
We were able to obtain a signal to noise ratio of 15 dB at 20 meters, which equates to zero frame errors over at least 20 meters in fresh water, which meets the design objectives. This demonstrates that low-cost communications is feasible. However, the performance of this design is not optimized, and can be improved significantly with some hardware and software modifications, resulting in better performance over longer distances with higher bit rates.

By utilizing existing components, especially ultrasonic transducers and a fully digital processing system, we were able to eliminate most of the expensive analog stages of the circuit, thus our communications system could be achieved with a component cost of US$50 which is significantly cheaper than the other systems.