Design of an underwater acoustic modem

Context

Underwater communications are peculiar in that traditional electromagnetic communications are inappropriate beyond a few meters due to high attenuation in water. As a result, all medium and long-range underwater communications are acoustic (i.e., they use pressure waves). Bandwidths are also typically orders of magnitude lower than those of over-the-air wireless communications (in underwater acoustic communications, bandwidth generally does not exceed 20 kHz and the carrier frequency is often between 10 and 40 kHz) [Zia, 2021]. These low bandwidths led to the development of many research and commercial modems based on micro-controller units (MCUs) or microprocessor units (MPUs), with some high-end modems relying on field-programmable gate arrays (FPGAs) instead. Given the low carrier frequency, no analog upconversion and downconversion are needed and signals are generally directly sampled (RX) or converted to analog (TX) in bandpass.

Objectives and steps

The goal of this master's thesis is to develop the digital parts of an underwater acoustic modem. Several analog parts (power amplifier at the TX and low-noise conditioning chain at the RX) shall not be developed given how difficult they are to validate. Steps are i) to develop a MCU-based TX supporting a simple modulation (e.g., BPSK) without error correction features ii) to develop a MCU-based RX that demodulates the chosen simple modulation (including basic channel equalization) and to validate it using the TX (a direct wired connection connects the TX to the RX) iii) (optional) to implement the TX and/or RX on a custom printed circuit board (PCB) iv) (optional) to implement error correction with convolutional codes on the TX and RX. A high-end STM32H7 MCU is expected to be used for implementing both the TX and the RX. Evaluation/Development boards for the STM32H7 MCU will be available to the student. The student is expected to leverage microarchitecture enhancements to optimize performance. The student may rely on existing open-source modems (e.g., that of [Renner, 2020], which is based on the similar but less powerful STM32F4 MCU).

Student profile

Ideally, the student should have followed the courses "Microprocessor architecture" and "Modulation and coding". This master's thesis is geared toward students that have an interest in building real telecommunication devices and are eager to learn how to carry out practical work on modern, advanced MCU architectures.

References

[Renner, 2020] Renner, Bernd-Christian et al. "AHOI: Inexpensive, low-power communication and localization for underwater sensor networks and μAUVs." ACM Transactions on Sensor Networks (TOSN) 16, no. 2 (2020): 1-46.
[Zia, 2021] Zia, Muhammad Yousuf Irfan et al. "State-of-the-art underwater acoustic communication modems: Classifications, analyses and design challenges." Wireless personal communications 116 (2021): 1325-1360.

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