Adapting the USRP as an Underwater Acoustic Modem

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We describe how the Universal Software Radio Peripheral (USRP) coupled with GNU Radio can be adapted for use as a configurable underwater acoustic (UWA) modem. The USRP contains an Altera Cyclone EP1C12 FPGA and typically acts as the baseband and IF section of a radio communication system.

Our work is the first time that the USRP/GNU Radio is applied to an UWA channel and represents an exciting branch into a field that has a need for cost-effective and configurable modems. The USRP facilitates such needs through its low cost, ability to be used to rapidly prototype, and synergistic open platform. We outline how to set up a USRP for receiving acoustic signals and passing the received information to a host PC so that the reception and processing are done in a mix of hardware and software.

UWA communication research will benefit greatly from the adaption of the USRP as an underwater acoustic modem. First and foremost, the development of a modem using the USRP has applications in oceanographic monitoring and communication. Quantitative information such as pollution and military surveillance data can be monitored in a more cost-effective way and relayed in underwater networks. Also, improved acoustic networking would allow more efficient transfer of information between oceanographic equipment such as autonomous vehicles, piloted vehicles, and underwater profilers [1].

Introduction

Acoustics is the the best technique for underwater communication. Compared to radio-based terrestrial communication, relatively little is known in the field of underwater acoustic networks. UWA communications face unique physical challenges that are not associated with radio communication [2]. The first is low propagation speed, which is five orders of magnitude lower than radio wave propagation. Second, the medium causes significant reverberation due to multipath propagation. Last, there is a relatively small bandwidth available for acoustic signals. Considering these physical challenges, UWA communication equipment needs to be well adapted to the physical properties of the channel.

Though commercial acoustic modems are available, there are not many to choose from and their proprietary nature makes customization of these products expensive or simply infeasible [3]. Researchers need a better option to prototype their algorithms and further develop the field of UWA communication. In particular, the ability to add functionality to a proprietary system is difficult. For example, as researchers we wish to investigate designs with different parameters such as carrier frequency, bit rate, and packet size [4]. Commercial modems do not provide the flexibility to parameterize and experiment available in an open, reconfigurable platform [5].

The USRP as an UWA Modem

The USRP is an open platform that is an excellent solution for research in implementing UWA modems and related signal processing. Both the hardware and software that make up the package are open source, and thus highly customizable (See Figure 1). For instance, one can make efficient use of the FPGA by only implementing those features required of underwater communication. This enables more investigation of hardware/software trade-offs, where more processing could be done in hardware if appropriate.

The GNU Radio Python front-end provides the ability to easily choose from a library of pre-designed processing blocks to create implementations that resemble signal flow diagrams. The Python interface also inherently provides the device with the benefits of built-in debugging, interactive execution, and basic self-documentation. Also, researchers can define their own custom signal processing blocks in software using GNU Radio [6].

We propose to obtain a Universal Software Acoustic Peripheral (USAP) by maintaining the software from the USRP, but changing the radio peripheral (RF antenna) to an acoustic transducer/hydrophone (see **Figure 1**).

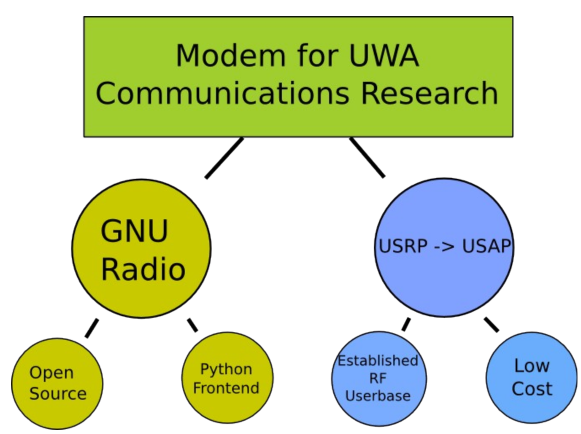

Figure 1: Overview of UWA Modem Using USRP/GNU Radio

The main problem encountered when considering the USRP as an underwater acoustic modem is that the peripheral is designed for electromagnetic communication. The initial focus of our work is to adapt the USRP for audio communication applications. We are implementing the receive pipeline, shown in **Figure 2**, to convert signals from an UWA transducer and send that information to a PC running GNU Radio. The receive pipeline is the first step in applying the USRP and GNU Radio platform to a full protocol stack.

ADC Pipeline

The receive path sets up the main signal flow in hardware, using parameters controlled using the GNU Radio Python front-end. Parameters include setting the pre-ADC gain and the frequency of the baseband multiplier, as shown in **Figure 2**.

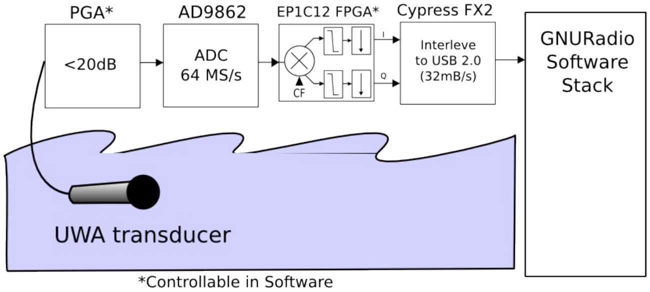

Figure 2: Simplified Receive Channel

The programmable gain amplifier's (PGA) gain and FPGA digital down converter (DDC) decimation and frequency shift are configurable using the USRP package included in GNU Radio. Since UWA signals have much lower frequency than what is typical in radio communication, there is no need for an analog front-end and all the processing is performed digitally.

Most of the hardware's processing occurs in the FPGA DDC. The DDC accepts inputs from four on-board ADC's. To utilize more bandwidth and provide more flexibility in our software processing, we use I/Q sampling. Using two ADC's per channel reduces our number of possible receive channels to two per USAP. Each channel has its own DDC, which is detailed in **Figure 3**. The complex multiplier shifts the input signal to baseband. The cascaded integer comb filter acts as a lowpass filter and decimator with programmable factor N. The outputs of each DDC are sent through the same USB connection, and therefore must be interleaved by the Cypress FX2 USB 2.0 interface chip.

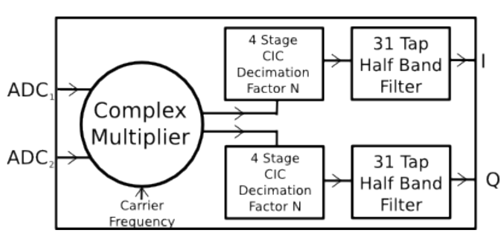

Figure 3: DDC in Detail

After the outputs from the DDC's are interleaved in the Cypress FX chip, the datarate is acceptable for a USB 2.0 connection to a host PC running GNU Radio. From this point, the processing is done in software [7].

Applications

The USAP's open platform allows the acoustic communication community to take advantage of the technical knowledge and advances of the USRP radio community, which is relatively large and well established. In addition to making use of developed library modules, developers of acoustic modems can learn from custom blocks that have been developed for the radio platform.

As we become more familiar with using the USRP for receiving acoustic signals, we will apply this knowledge to the transmit side of the device, thus completing the foundation for the physical layer. Future efforts can also be based on investigating the hardware/software interface to utilize more processing on the FPGA if appropriate.

The goal of the USAP is to facilitate and help to expand oceanographic research. Networking equipment that is critical in effective marine science and monitoring can be easier to implement using the USAP, helping researchers to investigate new directions. Such a device can catalyze development in the underwater acoustic sector by promoting shared knowledge through its open platform. Open collaboration can tremendously help development in a field where so little is currently known.

Acknowledgments

This work was supported in part by the following grants: NA06OAR4170019 and NSF 0708420.

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