Background

- Underwater communication has numerous applications\textsuperscript{[1]}
- The most common solution is to use acoustics\textsuperscript{[1]}
- The underwater acoustic channel presents several challenges\textsuperscript{[2]}
- Beamforming is one of many viable strategies to combat these issues\textsuperscript{[3]}
Project Goals

- Develop the capability to prototype a Uniform Linear Array (ULA) on a Software Defined Radio (SDR) platform in a lab environment

- Demonstrate the ability to steer transmissions and receptions using multiple hydrophone elements

- Evaluate beamforming capability using SDR hardware and wired connections
Design Considerations

- Beamformer design
  - Time domain vs. frequency domain beamforming
  - Element spacing
  - Number of elements
  - Windowing
  - Steering and Nulling

- SDR Implementation
  - Must run in real time
  - Ettus X310 supports 2 TX channels or 4 RX channels
Hardware

- Provided by MITRE
- Two Ettus X310 USRP software defined radios to send and receive real signals
  - Two wide-bandwidth daughterboards slots
  - C++/Python driver support
- Two UDOO x86 boards to operate as Host Computers
  - Windows, Linux, and Android compatible
Technical Solution Phase 1

MATLAB development of beamforming capability in simulated channels

- AWGN and Stojanovic channels adapted for use with arrays
- Custom time domain and frequency domain beamformers
- Testing beamformers for transmission and reception of QPSK signals over AWGN and Stojanovic acoustic channels
Technical Solution Phase 2

Creation of a beamforming application for Ettus X310 SDRs

- C++ development
- 2 element transmitter arrays, 4 element receiver arrays
- Adjustable parameters for windowing, number of elements, sampling rate
- Unit testing to verify performance is as expected under a range of operating conditions
- Testing transmitter and receiver beamforming over simulated channels
- Multi-in Multi-out (MIMO) transmission and reception with USRPs
Beamforming Class

- A beamforming class was developed in C++
- A beamformer object is instantiated with the desired geometry
- Methods for transmission and reception in any direction have been developed
  - High sampling rates are assumed allowing use of integer sample delays
  - Transmission takes a single input and generates multiple transmission vectors
  - Reception takes multiple received vectors and outputs a single steered reception vector
- Arbitrary weights can be applied across the array with built-in normalization of the weight vector
Beamforming Results

**Clean Beamformed Waveform**

- Channel 1
- Channel 2
- Channel 3
- Channel 4

**4 Element Beamformer Noise Reduction**

- Received Signal
- Beamformed Signal
Spring 2020 Project Timeline

- **1/21/20:** Test Matlab Beamsteering
- **2/10/20:** Develop Beamforming Class
- **3/1/20:** Develop MIMO Class
- **3/21/20:** Debug Class Code
- **4/10/20:** Implement Prototype into SDR
- **4/10/20:** SDR Troubleshooting/Testing
- **4/30/20:** Collect Performance Data
- **4/30/20:** Prepare Final Deliverables
### RACI Chart

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<th>David</th>
<th>MITRE</th>
<th>Dr. Anwar</th>
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References


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