OFDM-Sense

2D Localization Leveraging OFDM Signals

ELECOMP Capstone Design Project 2025-2026

Technical Director(s):

Dr. Guoyi Xu
Assistant Professor
guoyi.xu@uri.edu
https://www.linkedin.com/in/xuguoyi/

Project Motivation:

Direction finding and localization of RF markers are critical technologies for next-generation telecommunication systems. In addition to transferring data, the proliferation of IoT devices for environmental sensing require accurate location information at a scale that is orders of magnitude higher than previously anticipated. The integration of radar and communication functions is driven by the growing need to access wider signal bandwidth that is strictly regulated, and the technological requirement for higher power efficiency and smaller form factor after integration. This project aims to provide such technology to existing communication networks, with applications in home, urban, industrial, agricultural, and transportation settings.

Students are anticipated to build a functional communication system using software-defined radio (SDR) platforms working in the millimeter-wave (mmWave) frequencies, integrate sensing into the system, and perform laboratory tests. This will provide students with the basics of both OFDM communication and matched filter radar detection principles. Through laboratory experiments students will be exposed to real-world hardware and algorithm design problems that deepen their understanding of the connection between hardware systems and real-world applications. A working system serves as a prototype for next-generation dual-function communication networks that finds its use for IoT, robotics, and intelligent transportation.

Anticipated Best Outcome:

ABO1: Understanding of the working principles of OFDM communication and building of a functional OFDM system using USRP X310 and Sivers EVK06003 modules.

Students will be provided with materials related to basic mathematical background and motivation of OFDM. At the same time, they will be instructed to work with USRP X310 and Sivers EVK06003 as the baseband and front-end SDR platforms, respectively. They will need to successfully connect them and implement an OFDM transceiver for a full communication system and test its performance in a laboratory environment. The block diagram of the system is shown in Fig. 1.

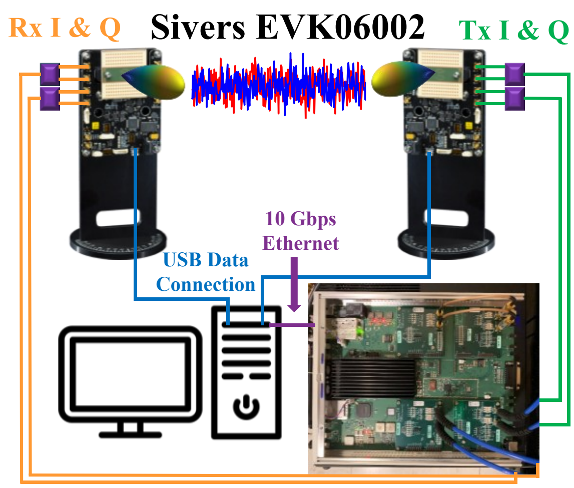

Fig. 1. Communication system established by NI USRP X310 and Sivers SDR platforms.

ABO2: Integration of pilot-based matched filter time delay estimation on a multi-channel communication system.

Based on the working OFDM communication system, students will implement matched-filter-based time delay estimation method using OFDM pilots and test its performance in a laboratory setting. To implement the multi-channel system, students will need to creatively resolve channel synchronization challenges.

ABO3: Simultaneous 2D localization and OFDM communication in a SIMO network.

With the multi-channel time delay estimation system implemented on OFDM communication, the students will design a 2D localization algorithm to find the location of a transmitter/receiver. They will optimize the algorithm to enable fast and accurate localization on top of reliable communication.

Project Details:

The Universal Software Radio Peripheral (USRP) is a software-defined radio (SDR) platform developed by Ettus Research (Austin, TX) and comes with multiple series for respective applications. It provides flexibility in baseband processing and configurability of RF parameters including Tx/Rx gain and carrier frequency. The students will use the X series model 310 (USRP X310) as the baseband processor of the communication system. The motherboard contains a micro-computer, an FPGA, DSP modules and other peripherals, but does not contain RF front-end modules. Typically, X310 can be built into a standalone communication system at sub-6 GHz ranges by adding daughterboards with front-end modules. However, this project is designed for mmWave frequencies, so Sivers EVK modules are used as dedicated mmWave front end modules working at 60 GHz, and correspondingly, basic daughterboards without RF front-end modules are inserted into the USRP X310 motherboard. The Sivers EVK modules is another SDR platform with on-board antenna arrays for beamforming, with configurable front-end parameters including multi-stage transceiver gain, carrier frequency, element-wise antenna control, etc. The USRP and Sivers modules are connected by SMA cables and RF baluns. Their key parameters are shown in Tables I and II below.

Table I. Key parameters of USRP X310.

USRP X310 (12 V input, 45 W power)			
Master Clock Rate	200 MHz	**ADC**	14 bits, 200 MS/s
# Channels	2 Tx & 2 Rx	**DAC**	16 bits, 800 MS/s
FPGA	Kintex 7 -410T	**Internal Reference Accuracy**	2.5 ppm
Logic Cells	406k	**Requires External 1 pps Reference**	Yes
Memory	28630 kb	**Requires External 10 MHz Reference**	Yes

Table II. Key parameters of Sivers EVK06003.

Sivers EVK06003			
# Channels	1 Tx & 1 Rx	**Working Frequency**	57 – 71 GHz
# Antennas	64 for Tx & 64 for Rx	**Beamforming**	2D

The Tx and Rx block diagrams of Sivers EVK06003 are shown in Fig. 2 below.

Phase I (Fall Semester): ABO 1 and 2

The team will focus on building a functional OFDM communication system and implementing the matched filter time delay estimation method using OFDM pilot symbols. Demonstration of the functionality is required, where students will show the successful working of single Tx-to-Rx operation. Multi-channel synchronization is not required.

[Firmware/Software/Computer Tasks:]

1. Program the USRP X310 and Sivers EVK06003 after connecting them with the computer and send sinusoidal test signals to verify the success of the connection.

2. Implement a complete OFDM data packet consisting of synchronization symbols, pilot symbols, and data symbols. Transmit and receive OFDM signals through the system, where the receiver implements Schmidl-Cox synchronization.
3. Show the receiver constellation diagram.
4. Study the matched filter time delay estimation and implement over-sampling-based matched filter time delay estimation to improve the detection accuracy. The algorithm is implemented on OFDM pilot symbols of the aforementioned data packet.

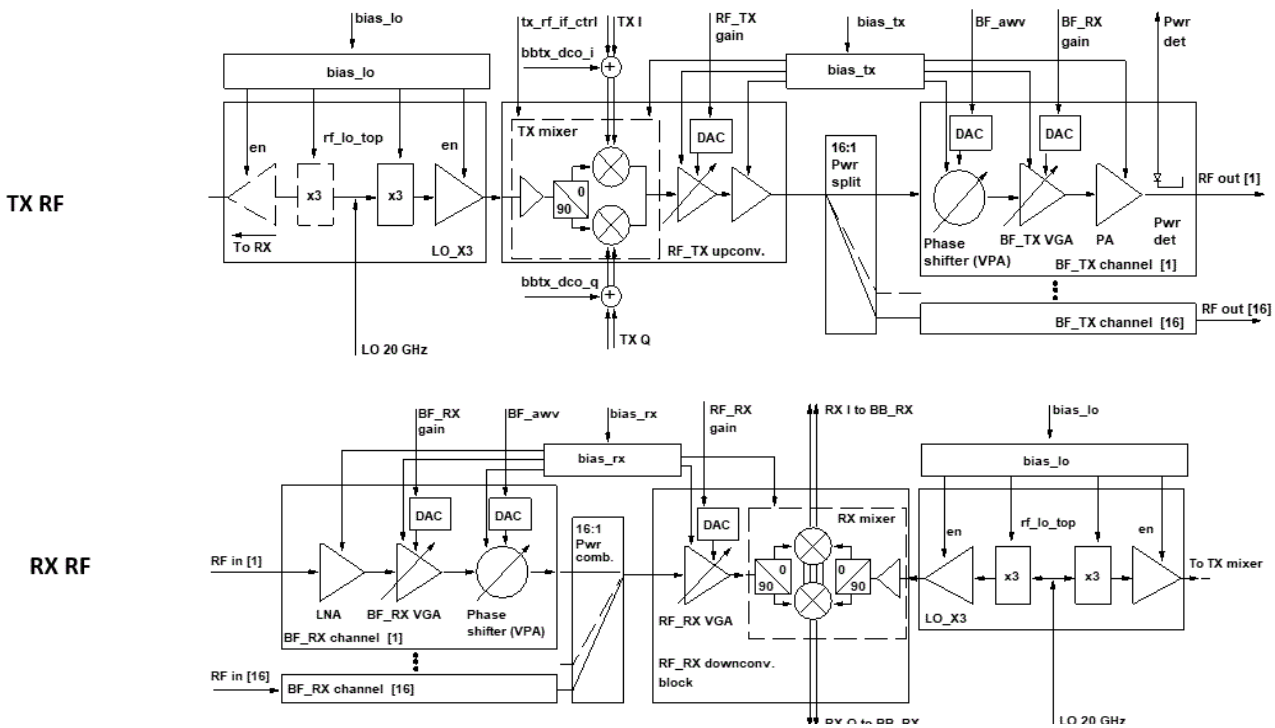

Fig. 2. Block diagrams of Sivers EVK06003 Tx and Rx.

[Hardware/Electrical Tasks:]

1. Connect the USRP X310 and Sivers EVK06003 modules with RF cables and baluns. Properly characterize the baluns using vector network analyzer (VNA) in advance to the connection. In the event any other RF components are required, students will first come up with a plan and properly characterize the components before connection.
2. Debug and test the communication performance throughout the laboratory experiments. Resolve carrier frequency offsets (CFO) and any other issues (such as gain adjusting to avoid nonlinear distortions) that prevent successful execution of OFDM communication.
3. Debug and test the matched filter time delay estimation throughout the laboratory experiments. Demonstrate linearity in delay-distance relationship.

4. (Bonus) Analyze any non-ideal factors from the delay-distance relationship and propose experimental debugging strategies and algorithmic improvements.

Phase II (Spring Semester): ABO 3

The team will first work on wireless multi-channel synchronization, and then on designing and implementing the 2D localization algorithm for the network. Lab experiments are to be conducted, and a final demonstration is required.

[Firmware/Software/Computer Tasks:]

1. Perform channel estimation on all channels by collecting the phase and magnitude information about the channel using OFDM pilot symbols. Analyze the channel estimation results by pointing out the non-ideal factors from both hardware and the channel that affect the results.
2. Using channel estimation results, devise a trilateration-based 2D localization algorithm and implement the algorithm. Test and debug the system and show the localization results.
3. (Bonus) Explore the 2D beamforming capabilities of the Sivers EVK06003 module to extract more information about the localized target.

[Hardware/Electrical Tasks:]

1. Duplicate the OFDM communication and matched filter time delay estimation on multiple channels and enable simultaneous execution on multiple channels.
2. Resolve the multi-channel synchronization in a wireless fashion.
3. Iterate the hardware debugging process with localization algorithm development for performance improvements.
4. (Bonus) Accelerate the algorithm execution by leveraging FPGA programming of the USRP X310.

Composition of Team:

2-3 Electrical Engineers & 1 Computer Engineers

Skills Required:

Electrical Engineering Skills Required:

- Strong digital signal processing background, especially different forms of Fourier transforms and sampling theory.
- Understanding basic circuit theory.

- S parameters and RF module characterization using network analyzer.
- Spectrum measurement using spectrum analyzer.
- Knowledge of free-space propagation equation and radar cross section.
- Optimization theory and algorithms, e.g., gradient descent, convex optimization, linear programming, etc.
- Familiarity with communication systems, e.g., up-conversion/down-conversion, I/Q modulation/demodulation, nonlinearity (harmonics and intermodulation).

Computer Engineering Skills Required:

- Familiarity with Linux OS, basic Linux commands.
- Python and object-oriented programming (OOP), C/C++ preferred.
- (Preferred not required) FPGA development, PCB design.