ECE4900/4910 Project Overview

Project Name: Creating an OFDM Modem

Clinic Sponsor: Zeta Associates

Team Members: Greyson Mitra

Faculty Advisor: Dr. Angela Rasmussen

Date: September 16, 2021

I. PROJECT DEFINITION STATEMENT

I will be creating an OFDM modem. First, I will simulate such a modem by creating a Python program that will be able to simulate a digital transmitter and receiver. Then I will adapt that simulation code to work with an actual Software Defined Radio (SDR) where I will be able to simultaneously transmit and receive test data. Finally, I will adapt this code to work wirelessly on the University's POWDER testbed.

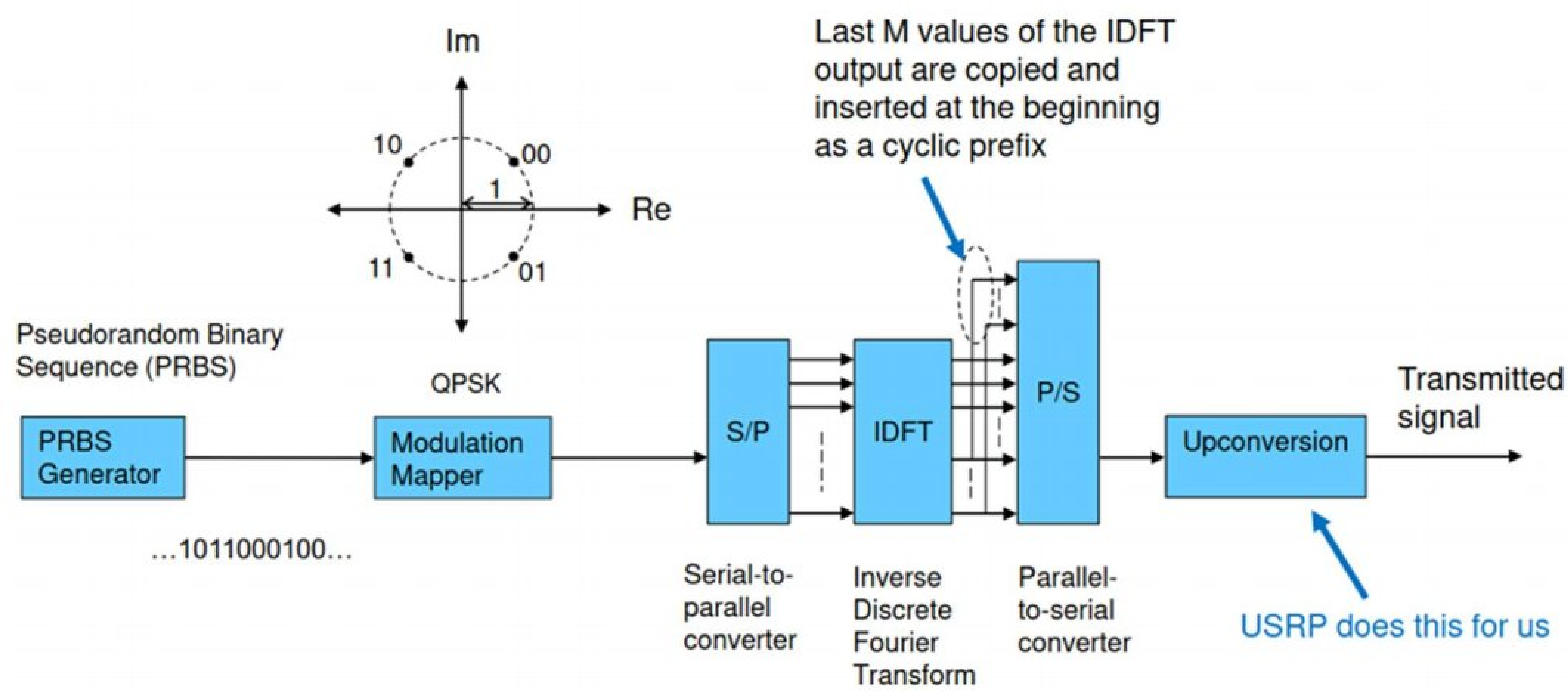
II. BACKGROUND

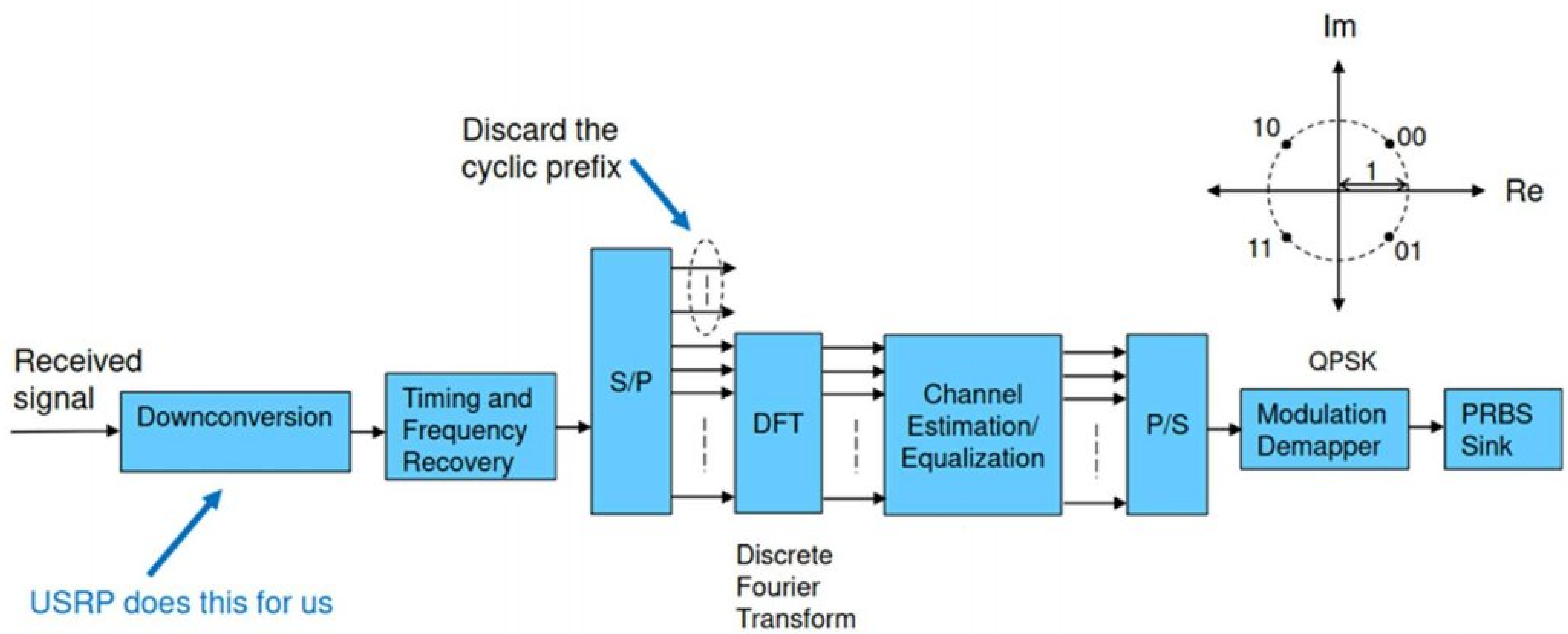
OFDM modem stands for an Orthogonal Frequency-division multiplexing modulator/demodulator and is widely used in many communications systems such as WiFi, television broadcasts in other countries, and in the new 5G standard. It provides many advantages to signals and reduces things like interference as well as efficient use of a given bandwidth [1]. It contrasts with the earlier FDM (frequency division multiplexing which could not achieve as high information rates as OFDM [2]

The use of OFDM transmission helps people receive information faster by improving data rates and providing robust connections. Engineers skilled in digital communications are currently working on implementing OFDM into 5G for a variety of uses, though it is unknown whether or not OFDM will be sufficient for use in future 5G implementations [3]. Due to the complexity of current digital communications protocols and standards, I will be working with OFDM but simplifying some techniques used in standards like 5G. My work is similar to the use of typical OFDM transmission, yet it is much simpler. OFDM is continuing to be used in various standards for communication and will only continue to be used as long as it can be combined with other techniques to achieve efficient and fast transmission of data.

To accomplish my creation of an OFDM modem I will of course be using the technology of OFDM transmission as well as some other techniques to achieve frequency and timing recovery as well as channel estimation/equalization. More specifically, I am doing timing and frequency recovery using a very simple method that is made possible using OFDM. This method is described in [4], and highlights one of the advantages of OFDM, which is its robustness against timing desynchronization. Additionally, I am doing channel estimation and equalization with techniques reviewed in [5]. Combining all of these techniques and technologies will make my OFDM modem work successfully. I will know when I have successfully created such a modem when I am able to send test bits through my system and receive them with a low bit error rate. I will also know I am successful if I can achieve a high data transmission rate which is part of what OFDM is good for.

III. Solution





I will be responsible for each part of the modem. I will create Python modules for almost all of the separate blocks in this block diagram. I will create each block one by one (starting with the PRBS Source/Sink) and create both the Transmitter/Modulator and the Receiver/Demodulator, as well as adapting the code to work with the SDR and the POWDER testbed.

IV. External Constraints

- The most obvious constraints on my project are regulatory. The FCC regulates frequencies in the USA, and it is necessary to send and receive on certain frequencies depending on the application. In many cases, an FCC license is required to transmit and receive certain types of signals. To mitigate this, I will just be using the POWDER testbed which takes care of the FCC licensing.
- Secondarily, there are some health and safety issues in regard to electromagnetic waves. My design will be operating at a frequency of 2.45 GHz which is a higher-frequency electromagnetic (EM) wave that might cause health ailments from prolonged exposure in humans. It has been

shown that the EM wave frequencies used for 5G technology may have carcinogenic effects [4]. To mitigate this constraint, I will make sure that I do not expose myself or others nearby me unnecessarily the EM waves coming from my project testing.

- My design and project may also have unintended environmental impacts. Some sources have said that electromagnetic waves used by humans can affect wildlife and plant life in areas that are frequently exposed to said EM waves. My design and in turn all human wireless communication signals may be causing damage to natural ecosystems and habitats by harming animals or forcing them out of their natural homes. To mitigate this I will only be transmitting signals in controlled environments and will not be expanding my design to transmit in as many places as a cell phone tower might.

V. PROJECT BUDGET

Item	Purchased From	Units Needed	Unit Cost	Total Cost
			$	$
			$	$
			$	$
			TOTAL	$

VI. REFERENCES

[1] Dewangan, Neelam. *A Detailed Study of 4g in Wireless Communication: Looking Insight in Issues in OFDM.* 2014. P. 3. [Online]. Accessed: Sept. 11, 2021.

[2] Narasimhamurthy, Adarsh B., Banavar, Mahesh K, and Tepedelenlioæglu, Cihan. *OFDM Systems for Wireless Communications.* 2010. Synthesis Lectures on Algorithms and Software in Engineering #5, p. 1. [Online]. Available: doi.org/10.2200/S00255ED1V01Y201002ASE005. Accessed: Sept. 11, 2021.

[3] Farhang-Boroujeny, Behrouz, and Hussein Moradi. *OFDM Inspired Waveforms for 5G.* IEEE Communications Surveys and Tutorials, 2016, vol. 18, no. 4, pp. 2474–2492. [Online] Available: doi.org/10.1109/COMST.2016.2565566. Accessed: Sept. 16, 2021.

[4] J. van de Beek, M. Sandell, and P.O. Börjesson. *ML Estimation of Time and Frequency Offset in OFDM Systems.* IEEE Transactions on Signal Processing, 1997, vol. 45, no. 7, pp. 1800-1805. [Online]. Available: doi.org/10.1016/j.comnet.2018.09.005. Accessed: July 22, 2021.

[5] Yinsheng Liu, et al. *Channel Estimation for OFDM.* IEEE Communications Surveys and Tutorials, 2014, vol. 16, no. 4, pp. 1891–1908. [Online]. Available: doi.org/10.1109/COMST.2014.2320074. Accessed: Sept. 12, 2021.

[6] M. Condoluci and T. Mahmoodi, *Softwarization and Virtualization in 5G Mobile Networks: Benefits, trends, and challenges.* Computer Networks, 2018, Vol. 146, pp. 65-84. [Online]. Available: doi.org/10.1016/j.comnet.2018.09.005. Accessed: Apr. 13, 2021.

VII. Milestone Contract for Greyson Mitra

Project Name: Creating an OFDM Modem

Clinic Sponsor: Zeta Associates

Individual Team Members Name: Greyson Mitra

Rest of Team Members: None

Faculty Advisor: Behrouz Farhang-Boroujeny

I agree to complete the three milestones shown below on or before the due dates listed in the class schedule. I understand that I will be awarded points for successful completion of each milestone, and that my performance on milestones will be evaluated by a technical committee that includes my faculty advisor and at least two other faculty members. Further, I understand that I will be required to demonstrate completion of these milestones on video and in person.

If project circumstances change and I feel these milestones require adjustment, I understand that I must contact Dr. Rasmussen and request a Milestone Review. If changes are authorized, I must generate a new Milestone Contract and obtain the necessary approval signatures on it.

Milestone #1 (Fall 2021): Have learned Python and the concepts the govern OFDM transmission. Create the basic simulation for the OFDM modem including all the blocks in the block diagram excluding the timing and frequency recovery and the channel estimation/equalization blocks.

Milestone #2 (Spring 2021): Add the timing and frequency recovery and the channel estimation/equalization blocks to complete the Python simulation. Adapt code to use transmit and receive on the Ettus b205mini SDR and debug until a bit error rate of far less than 1 percent is achieved.

Milestone #3 (Spring 2021): Adapt code from using with the Ettus SDR to use with the POWDER testbed. Ensure code output is achieving a bit error rate of far less than 1 percent. Complete Dr. Farhang's class on Signal Processing Techniques for Software Radios (ECE6590).

Approval Signatures:

Student: Greyson Mitra ______ Date: 9/17/2021

Faculty Advisor: ______ Date: ______

Faculty Committee #1: ______ Date: ______

Faculty Committee #2: ______ Date: ______