Channel Estimation with Interference in OFDM Modulation using GNU Radio

Mid-Review 1

AY 2021-25

GITAM (Deemed-to-be) University

Major Project
Project ID: Alpha 16

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Objective and Goals

Objective

Brief Description :

- This project focuses on designing and implementing an OFDM communication system in GNU Radio, addressing the challenges posed by interference and noise in the channel.
- The system includes channel estimation techniques (e.g., LS or MMSE) to estimate and mitigate interference effects, ensuring reliable data transmission.
- Key features include simulating multipath fading, introducing interference sources, and evaluating system performance using metrics. The project has applications in wireless communication systems such as Wi-Fi, LTE, and 5G networks.

Goals

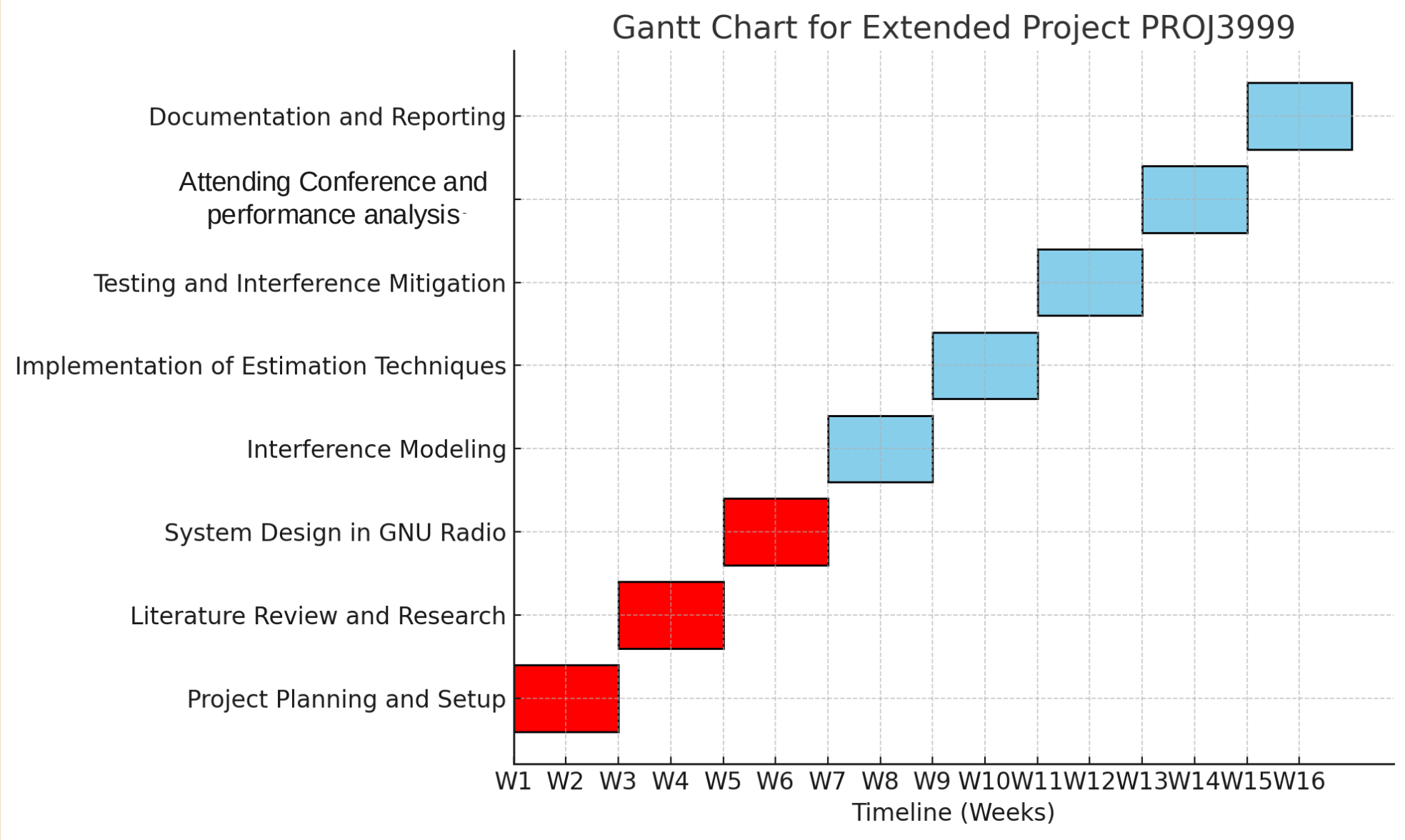
Main Goals

•Implement channel estimation techniques (e.g., LS, MMSE).
•Simulate interference scenarios such as AWGN, narrowband, and adjacent channel interference.
•Evaluate system performance using metrics like BER, MSE, and SNR.
•Mitigate the effects of interference through filtering and adaptive equalization.

Additional Goals

•Simulate real-world channels with multipath fading and Doppler effects.
•Visualize the system's performance using GUI tools like spectrum analyzers and constellation plots.

Project Plan



Project Plan

1. Project Planning and Setup: This phase involves defining the scope, objectives, and deliverables of the project. It includes identifying the tools and resources required, such as GNU Radio and SDR hardware, and establishing a timeline for the tasks.

•**Activities**:

- •Setting up the project environment.
- •Allocating responsibilities within the team.
- •Preparing the initial framework for OFDM system implementation.

2. Literature Review and Research: This phase focuses on gaining a comprehensive understanding of existing techniques and challenges in OFDM channel estimation under interference. It involves studying scholarly articles, books, and other resources to identify gaps in the current methods.

•**Activities**:

- •Reviewing pilot-based channel estimation methods (e.g., LS and MMSE).
- •Analyzing the impact of co-channel and adjacent-channel interference on system performance.
- •Identifying potential mitigation strategies and algorithms.

3. System Design in GNU Radio: This phase translates the theoretical framework into a practical design using the GNU Radio platform. It includes creating the OFDM system model and integrating components for channel estimation and interference analysis.

•**Activities**:

- •Designing the OFDM transmitter and receiver.
- •Configuring pilot signals for channel estimation.
- •Developing initial algorithms to model interference scenarios.

Literature Survey (Improved post minor project)

Key Publications

1. **Intersymbol and Intercarrier Interference in OFDM Systems: Unified Formulation and Analysis**
   Authors: Y. Manasa, D. Dharun, U. Vamshi, M. Gowtham
   Published: IEEE International Conference on Information Technology, Electronics and Intelligent Communication Systems (ICITEICS) 2024
   Literature Survey:
   Objective:
   1. Explore practical Orthogonal Frequency Division Multiplexing (OFDM) implementation using open-source GNU Radio software and software-defined radios (SDR) like HackRF One and RTL-SDR.

   Methods:
   1. Utilized GNU Radio to design OFDM transmitters and receivers, integrating hardware platforms for signal transmission and reception.
   2. Addressed synchronization, channel estimation, and error correction to enhance performance.

2. **OFDM Simulation Using GNU Radio on Dynamic Channels**
   Author: Duc Toan Nguyen
   Published: Master's Thesis, University of Wollongong, 2013
   Literature Survey:
   Objective:
   1. Develop and evaluate the practical performance of OFDM systems under various propagation conditions using GNU Radio and USRP

   Methods:
   1. Constructed a testbed integrating GNU Radio with USRP hardware to validate the error performance of OFDM.
   2. Simulated and experimentally evaluated channel estimation, synchronization, and signal-to-noise ratio (SNR) techniques.

Literature Survey (Improved post minor project)

Key Publications

3. OFDM Simulation Using GNU Radio on Dynamic Channels

Authors: Nyaris Pambudiyatno, B. B. Harianto, A. Mauludiyanto
Published: ICATEAS 2022, 2023
Literature Survey:
Objective:

1. To evaluate OFDM system performance using GNU Radio for real-time data transmission across dynamic channel models..

Methods:

1. Implemented OFDM transceiver simulation with BPSK modulation using GNU Radio.
2. Simulated transmission over Additive White Gaussian Noise (AWGN), Rayleigh fading (NLOS), and Rician fading (LOS) channels.
3. Analyzed performance variations under different noise levels (25mV to 200mV).

4. Implementation of OFDM Using GNU Radio with HackRF One and RTL-SDR

Authors :Y. Manasa, D. Dharun, U. Vamshi, M. Gowtham
Published :IEEE International Conference on Information Technology, Electronics and Intelligent Communication Systems (ICITEICS) 2024
Literature Survey:
Objective:

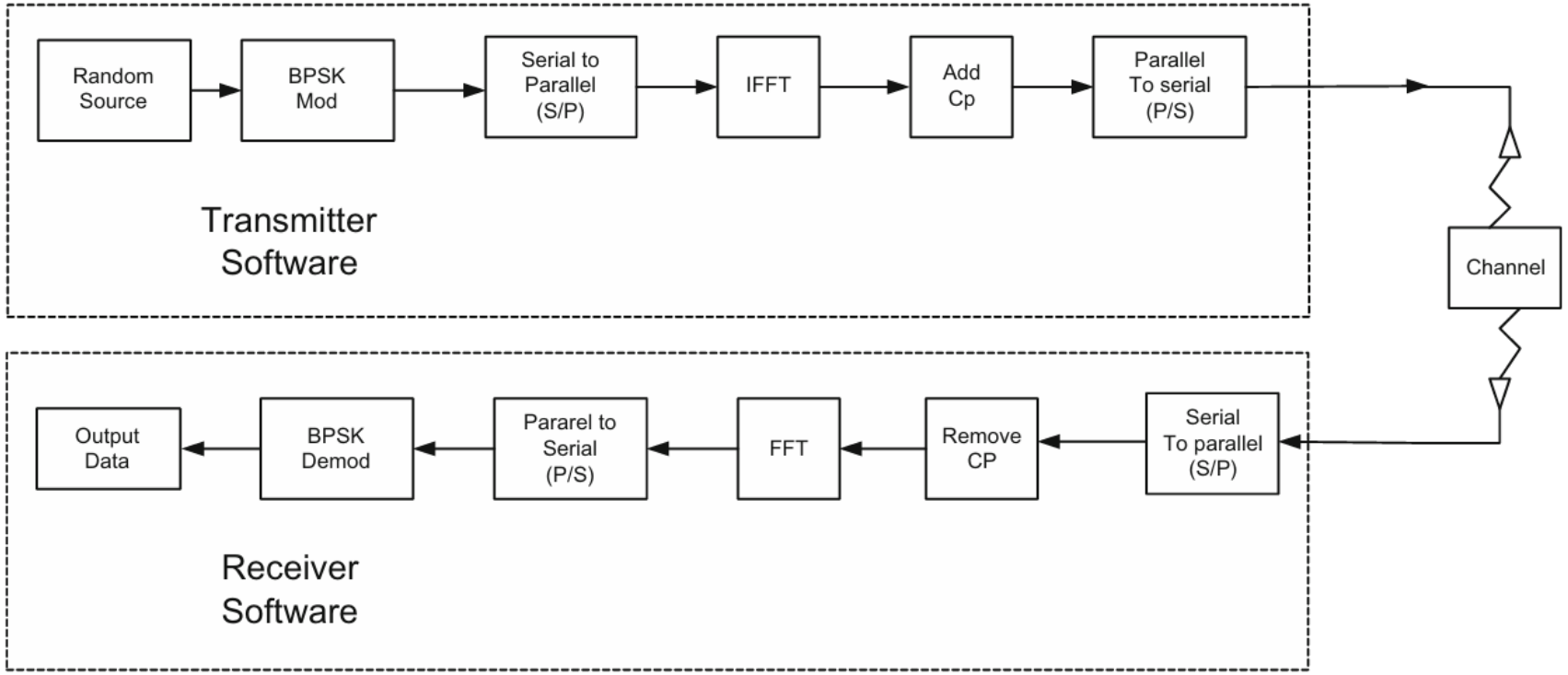
1. Explore practical implementation of Orthogonal Frequency Division Multiplexing (OFDM) using open-source GNU Radio software and software-defined radios (SDR) like HackRF One and RTL-SDR.

Methods:

1. Constructed a testbed integrating GNU Radio with USRP hardware to validate the error performance of OFDM.
2. Simulated and experimentally evaluated channel estimation, synchronization, and signal-to-noise ratio (SNR) techniques.

Architecture

Structural Diagram



Use Cases & Testing

Use Cases

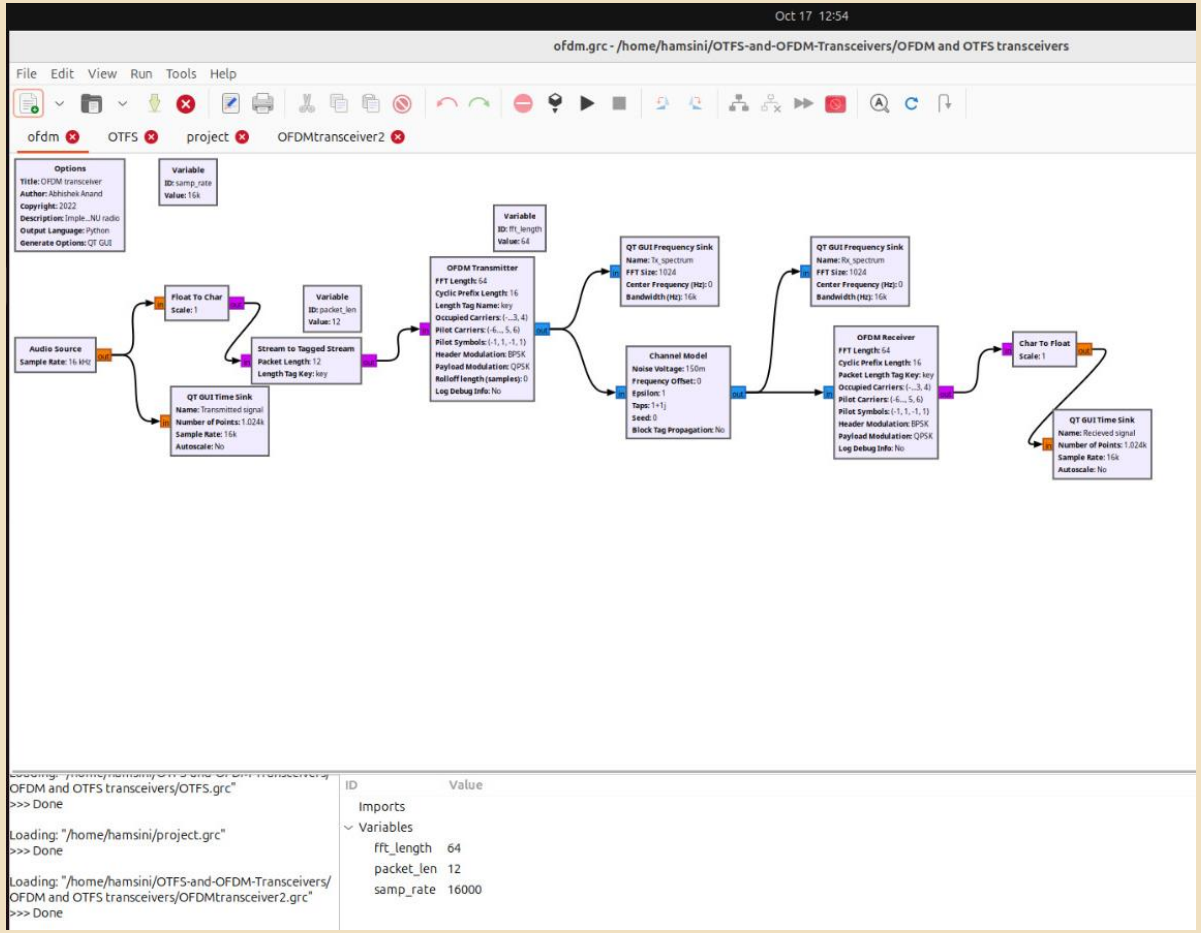
- **5G and Future Wireless Communication Systems**: Use in high-speed wireless networks to improve spectral efficiency and robustness against multipath fading and interference.
- **IoT Networks**: Implementation in IoT devices where power and bandwidth are constrained.
- **Military and Secure Communications**: Application in communication systems that require robust performance in environments with deliberate interference (jamming).
- **Vehicular Communication Systems (V2X)**: Utilized in Vehicle-to-Everything (V2X) communication to maintain connectivity despite interference from surrounding vehicles
- **Research and Development**: Serve as a testbed for experimenting with novel algorithms and interference mitigation strategies.

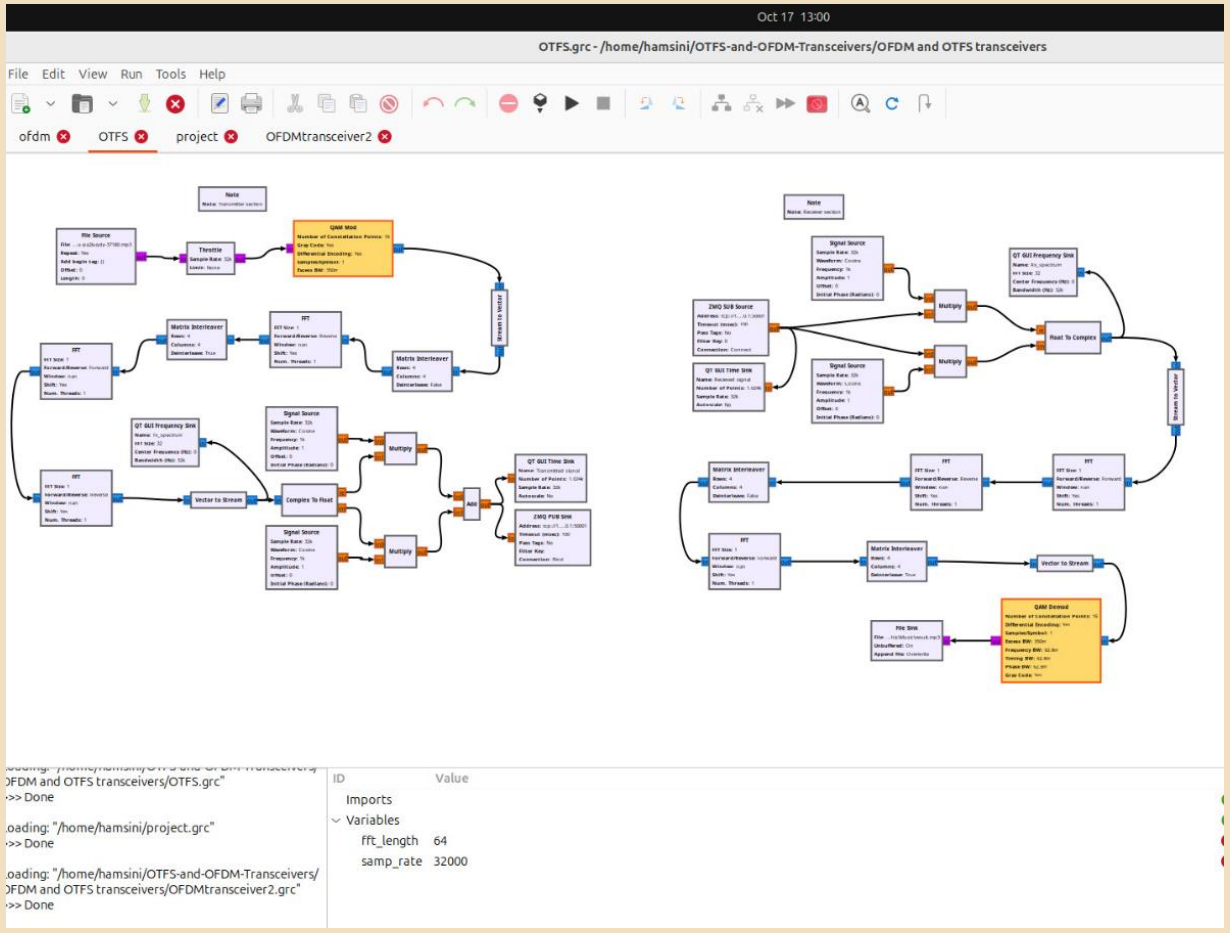
Test Cases

- **Functional Testing**: Verify that each module of the OFDM system (e.g., transmitter, receiver, channel estimator) operates as intended.
- **Interference Analysis**: Evaluate system behavior under different interference scenarios
- **Performance Testing**: Assess the system's ability to handle low-SNR conditions and high-interference environments.
- **Robustness Testing**: Ensure the system remains operational under extreme conditions.
- **Comparative Testing**: Compare the developed methods with existing techniques.
- **Real-Time Testing**: Use SDR hardware to transmit and receive signals in real time and measure system performance in real-world interference scenarios.

Implementation and Results – Iteration 1

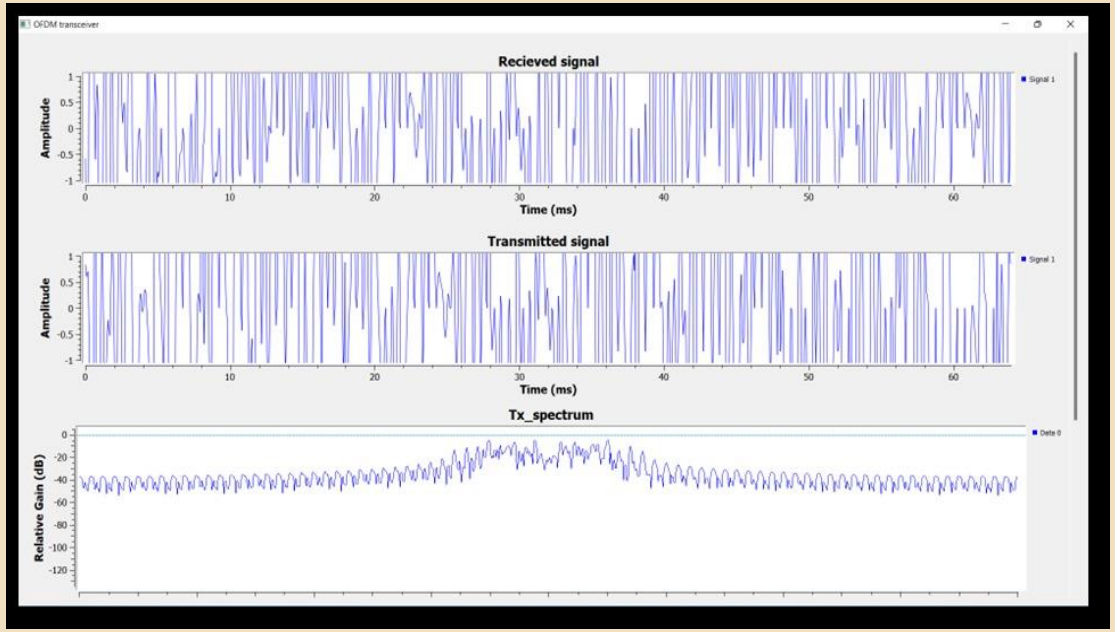
Iteration 1 : Results

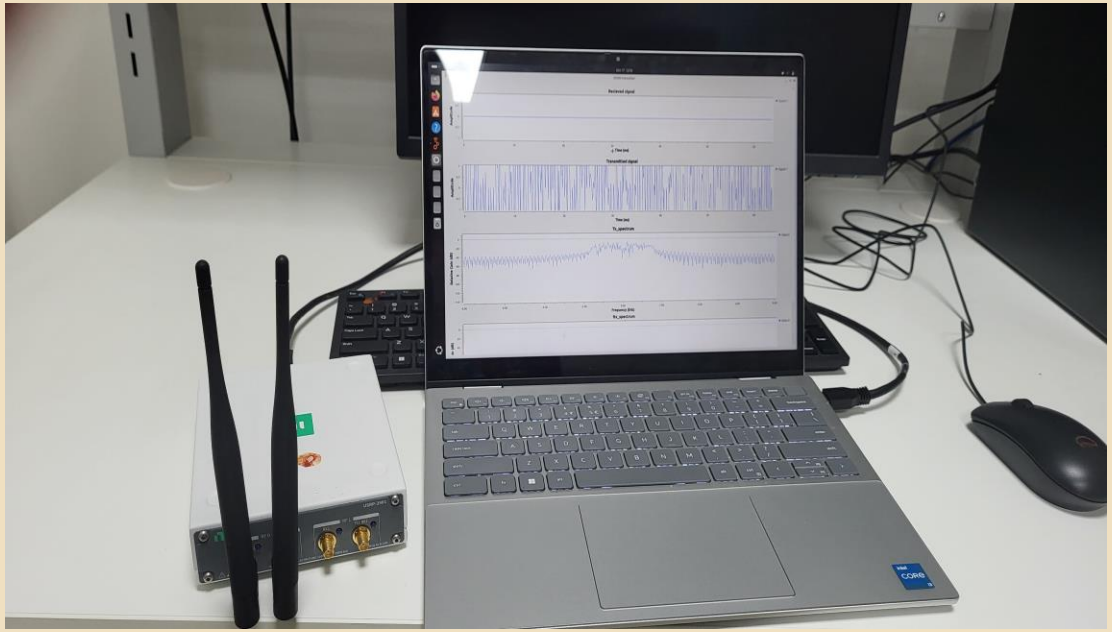




Implementation and Results – Iteration 1

Iteration 1 : Results





Contribution

Team Progress and Movement

- **Phase 1: Project Planning**
  - Defined objectives and allocated roles.
  - Successfully set up the environment for GNU Radio and SDR hardware.
- **Phase 2: Literature Review**
  - Team collaboratively researched OFDM channel estimation techniques.
  - Identified gaps and proposed methods for interference mitigation.
- **Phase 3: System Design(Ongoing)**
  - Built a modular OFDM transceiver using GNU Radio.
  - Incorporated pilot signal integration and prepared for interference modeling.

Individual Contribution

- **Key Contributions: Kiran P S**:
  - Conducted an extensive literature review on OFDM channel estimation techniques.
  - Designed and implemented pilot signal patterns for LS and MMSE estimators.
  - Assisted in developing interference modeling strategies.
- **Key Contributions: Haripriya Rao M**:
  - Developed and tested GNU Radio blocks for OFDM transceiver design.
  - Focused on implementing real-time testing using SDR hardware.
  - Led the analysis of BER and MSE under various interference conditions.
- **Key Contributions: Hamsini Reddy K S**:
  - Proposed and implemented filtering algorithms for interference mitigation.
  - Conducted detailed performance analysis using SNR and MSE metrics.
  - Documented the results and prepared reports for future enhancements.

THANK YOU

Have a Great Day !