Development and Exploration of Existing 5G and 6G Standards

Dr. Chih-Chun Wang[1], Dr. Husheng Li[2], Andrew Fewell[2], Raghav Aggarwal[3], Justin Lin[4], Rohan Iyer[5], Aaron Slamovich[6]
Electrical and Computer Engineering[1,2,5,6,2], College of Sciences[3], Purdue Polytechnic Institute[4]

Digital Communications

Digital Communication

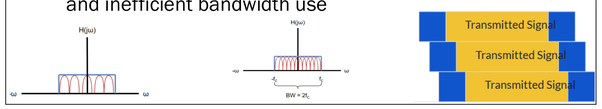
- Use radio waves to transmit and receive data
- Common frequencies for transmitting data are 2.4/5 GHz

Research Goal

- Research how it works and new developments, we explored OFDM, USRP, ISAC, and Carrier Synchronization

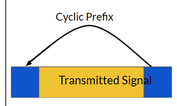
What is OFDM?

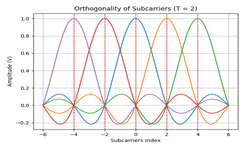
- Orthogonal frequency division multiplexing (OFDM) is a modulation technique used in the 5G cellular system and Digital Communications
- OFDM solves the issue of intersymbol interference (ISI) and inefficient bandwidth use



How Does OFDM Solve ISI and Inefficient Bandwidth Use?

- OFDM solves ISI using cyclic prefix
- OFDM solves inefficient bandwidth use through the originality of its subcarriers

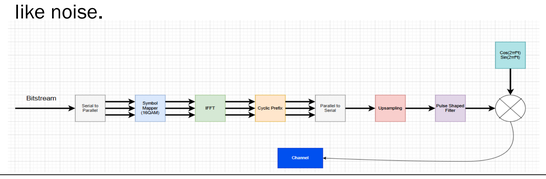




What is OFDM?

OFDM Block Diagram

- Simulated the block diagram in Python/MATLAB to explore OFDM
- Simulation is limited, since it lacks real world conditions, like noise.



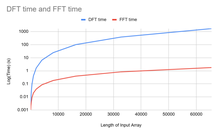
OFDM Results and Future Work

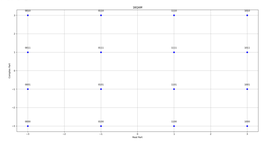
Results

- QAM Symbol Mapper
- FFT Vs. DFT

Future Work

- Finish the OFDM transmitter
- Build a basic channel simulator



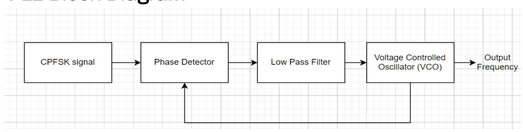


What is Carrier Synchronization?

- Process by which a receiver adapts the frequency and phase of its local carrier oscillator with those of the received signal [1]
- All digital communication need to use some carrier synchronization
- Need to synchronize phase and frequency to demodulate data

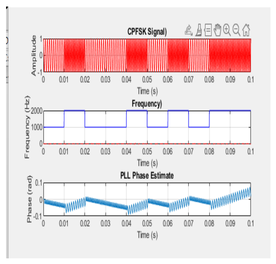
Carrier Sync Methods

PLL Block Diagram



Carrier Sync Results

- Created MATLAB simulations of signal phase synchronization .



Carrier Sync Future Work

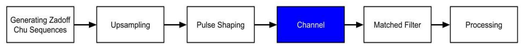
- Synchronizing the phase of imaginary signals
- Synchronizing the timing of the transmitted and received signal

ISAC Background

- Goal: Integrating sensing into existing communication architecture
- ISAC combines the goals of transmitting information with sensing environment.

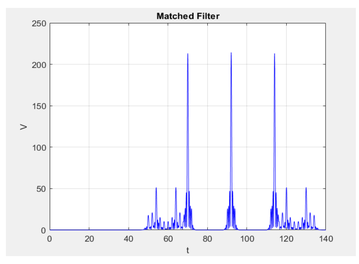
ISAC Methods

ISAC Block Diagram



ISAC Results and Future Work

- Method: Used Zadoff-Chu sequences to simulate using pilot signals to sense simulated objects
- Results: Created a MATLAB simulation of Zadoff-Chu sequences and simulated their transmission and filtering
- Future Work: Simulating object detection and processing the filter result to detect simulated objects.



USRP Background

- Chirp signals are widely used in Universal Software Radio Peripheral (USRP)
- **What is a Chirp Signal?**
  A chirp signal is a waveform where the frequency increases or decreases over time. It is commonly represented as: $s(t)=A\cos(2\pi f(t)t+\phi)$
  where f(t) is a time-dependent frequency function.

USRP Methods

RF filter: Radio Frequency filter, PA: Power amplifier, LNA: Low noise amplifier, DAC: Digital to analog converter, ADC: analog to digital converter

- The received signal comes in from an antenna, is converted to the digital domain via the analog to digital converter (ADC)
- The transmitter performs all the signal processing in software and sends the signal out of the antenna via the digital to analog converter(DAC).

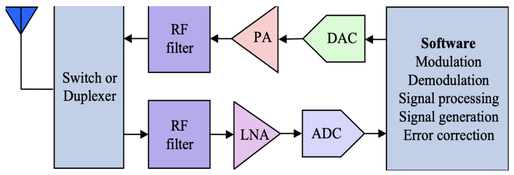
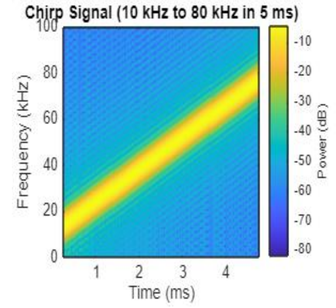


Fig. Basic structure of SDR[1]

USRP Results Goals and Future Work



[1] Nasir, A.A., Durrani, S., Mehrpouyan, H. *et al.* Timing and carrier synchronization in wireless communication systems: a survey and classification of research in the last 5 years. *J Wireless Com Network* **2016**, 180 (2016). https://doi.org/10.1186/s13638-016-0670-9
[2]