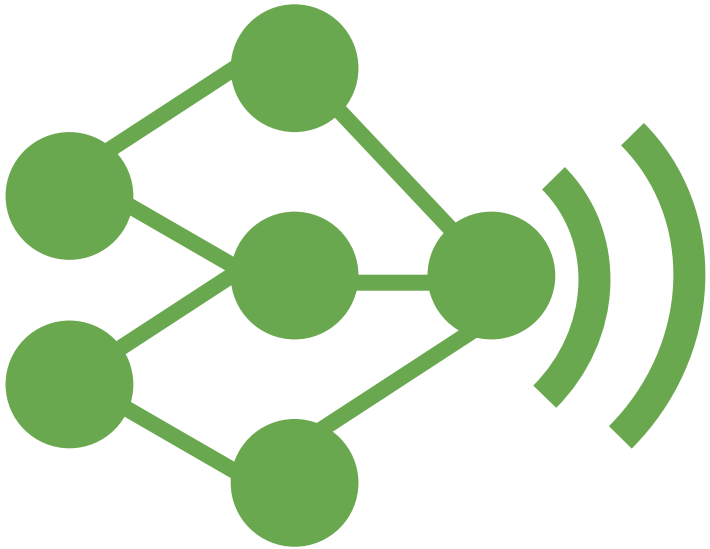


Modulation Classification with FPGA

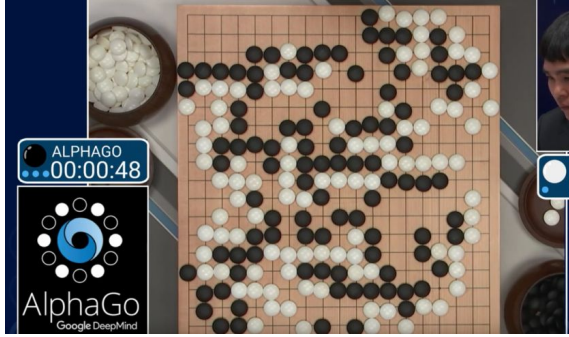
Brenda So, Cory Nezin
Advisor: Professor Toby Cumberbatch

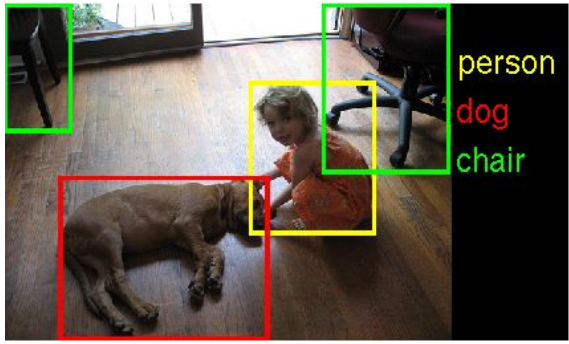
Neural Network Explosion

Advancements in GPUs led to popularity of **convolutional neural networks (CNNs)**

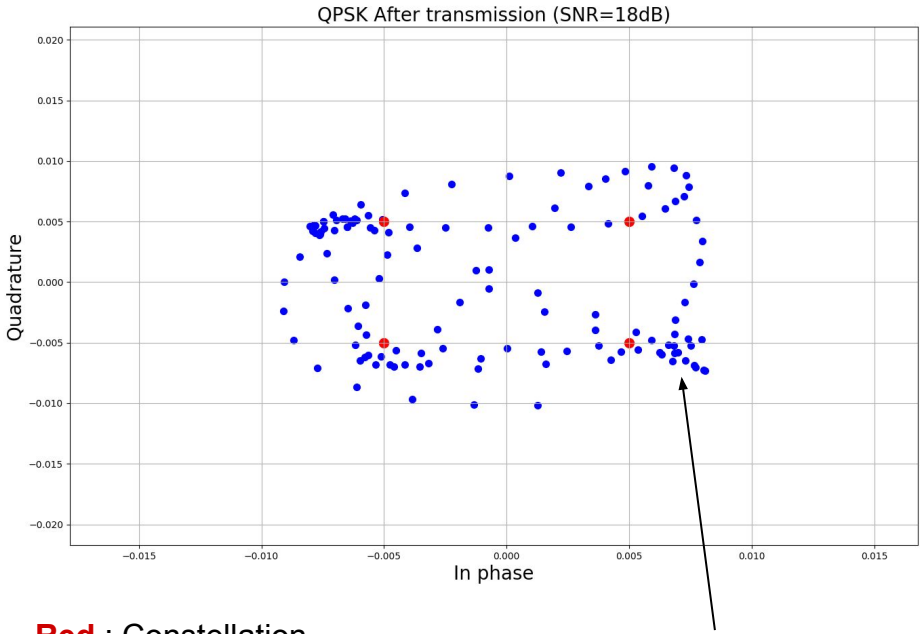
CNNs are found to supercede human and traditional machine learning performance

Recent research expand to areas such as communication networks





Goal : Classify modulation with raw IQ samples on FPGA



Red : Constellation
Blue : Transmitted signal

Signal corrupted by channel effects!

Current modulation classification is done with either **likelihood based methods** or **feature based methods**

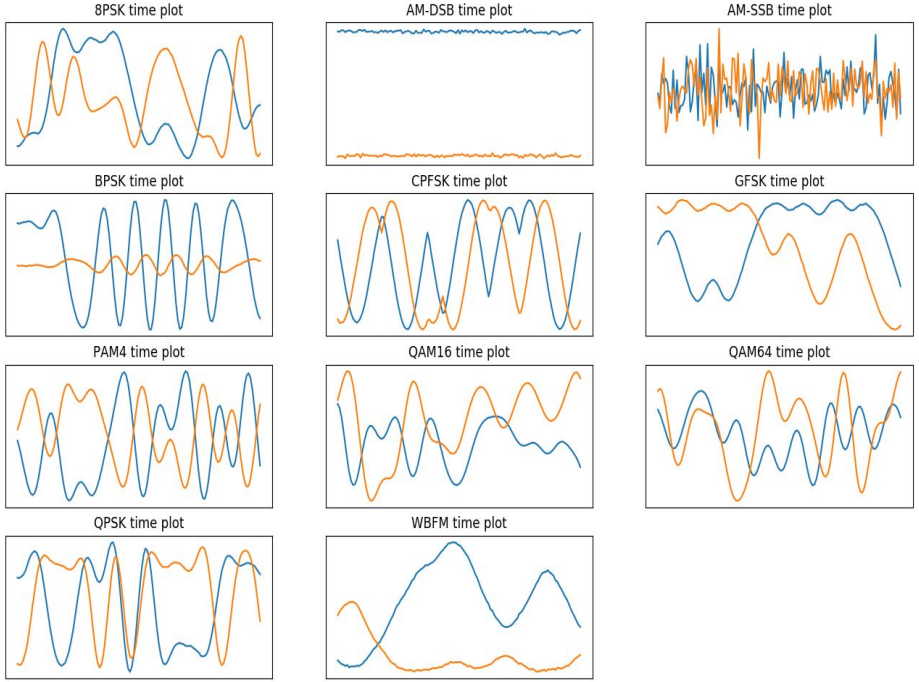
1) High computation complexity
2) Requires a lot of expertise

Current research focus on CNN architecture design

Test CNN physically with FPGA

- Benefits : low latency and power
- Challenge : Limited resources!

Radio Signal Dataset



Time Series Samples from **radioML** dataset

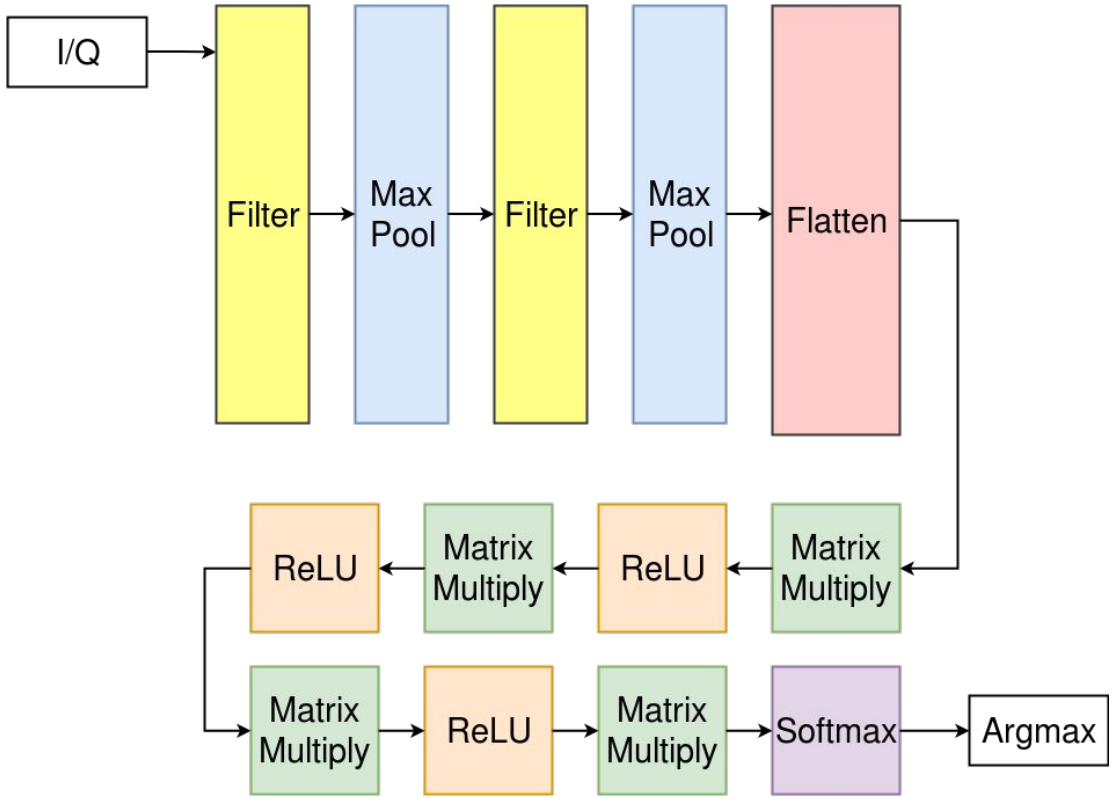
radioML is a simulated radio dataset

Takes into account of channel effects and a range of SNR

Includes 8 digital and 3 analog modulation schemes

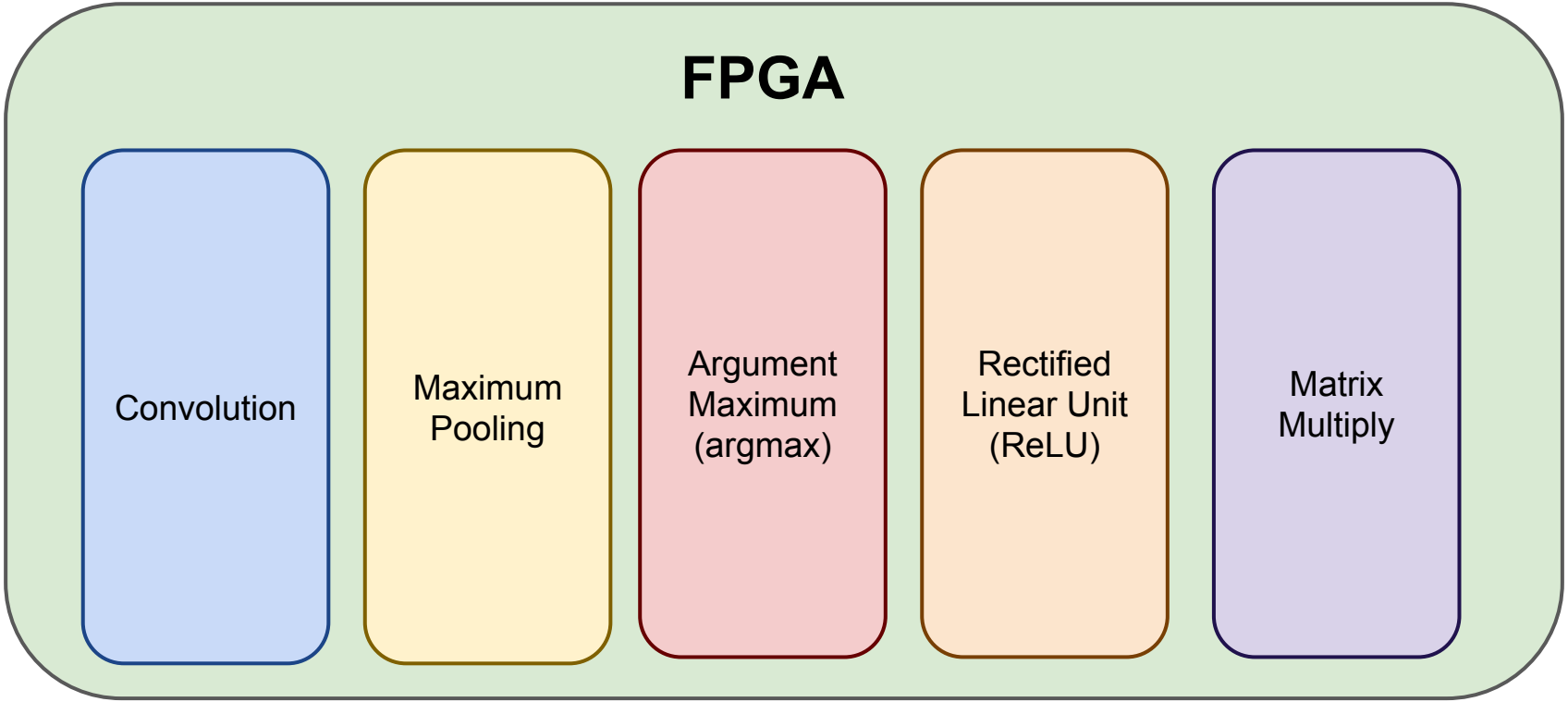
A total of 220k segments of 128 complex-valued baseband IQ samples

CNN Architecture



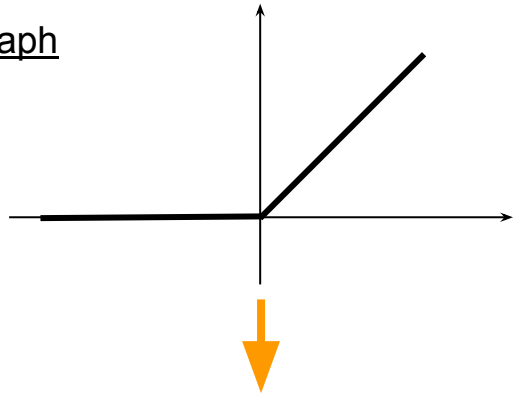
Requires ~0.5M MAC operations per inference.

Building basic blocks for CNN

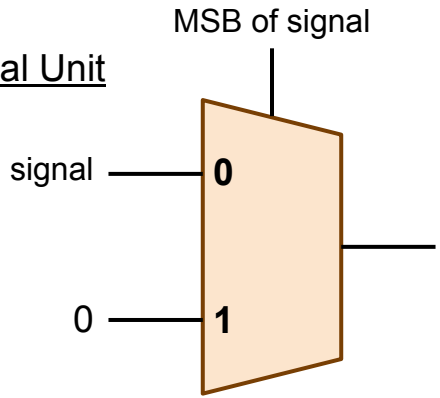


Rectified Linear Unit (ReLU)

ReLU Graph



ReLU Functional Unit



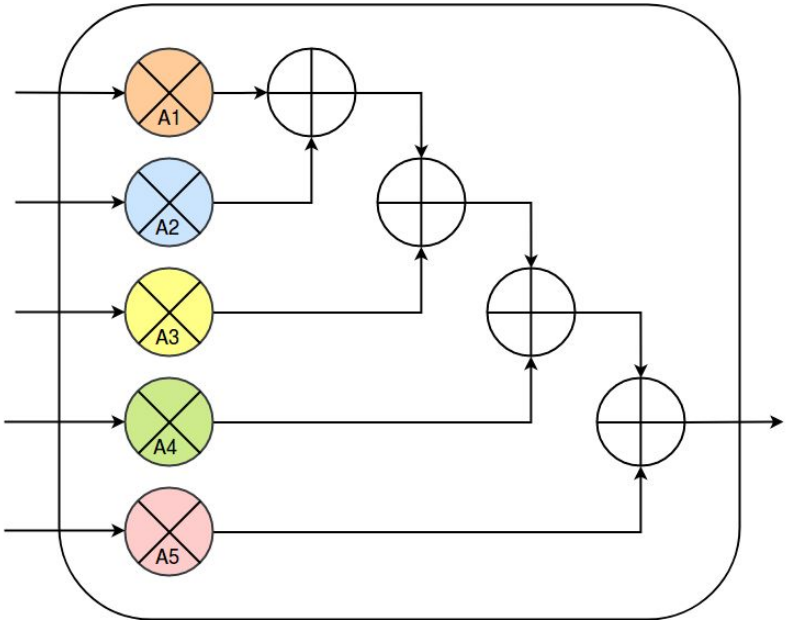
ReLU introduces **non-linearity** to the model

Easily implemented with a Mux

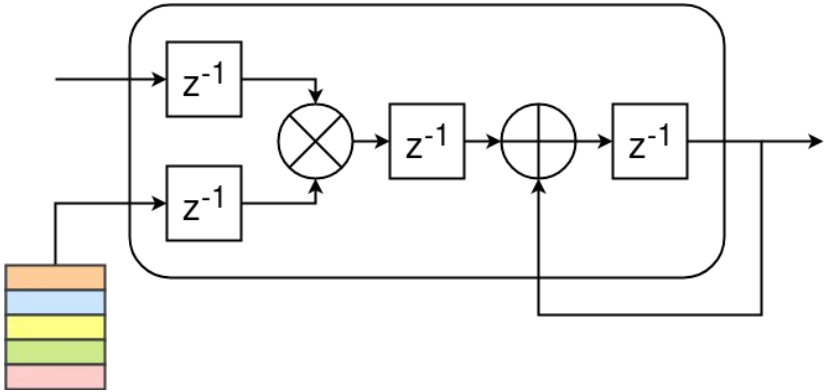
For a 2's complement binary number, the **MSB** indicates whether the number is negative or not!

Matrix Multiplication / Inner Product Architecture

Naive



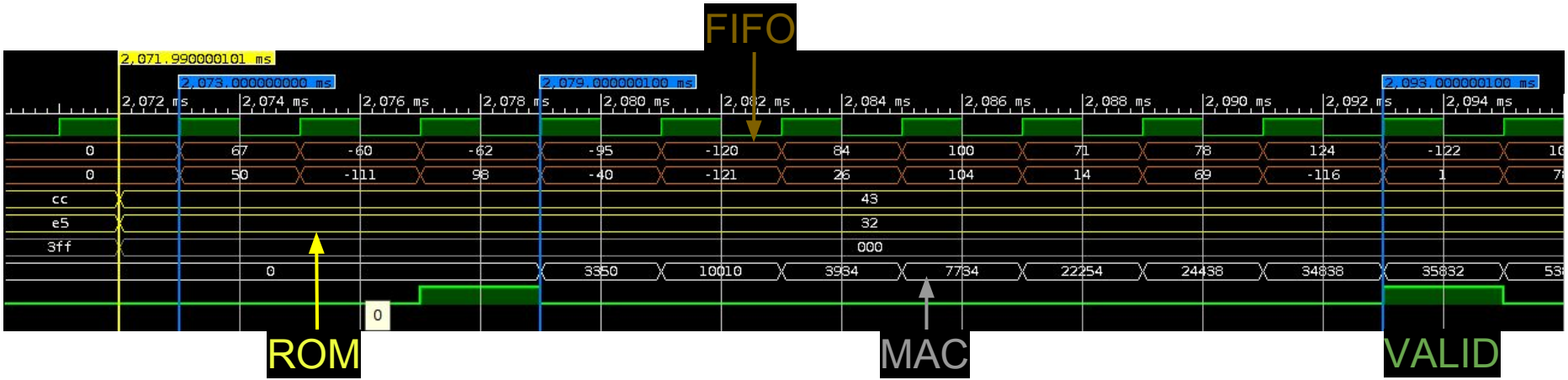
Pipelined



Less resource intensive.
Shorter critical path.

Simulation

Simulated a FIFO reading from ROM to emulate radio module



Designing a Radio Playground

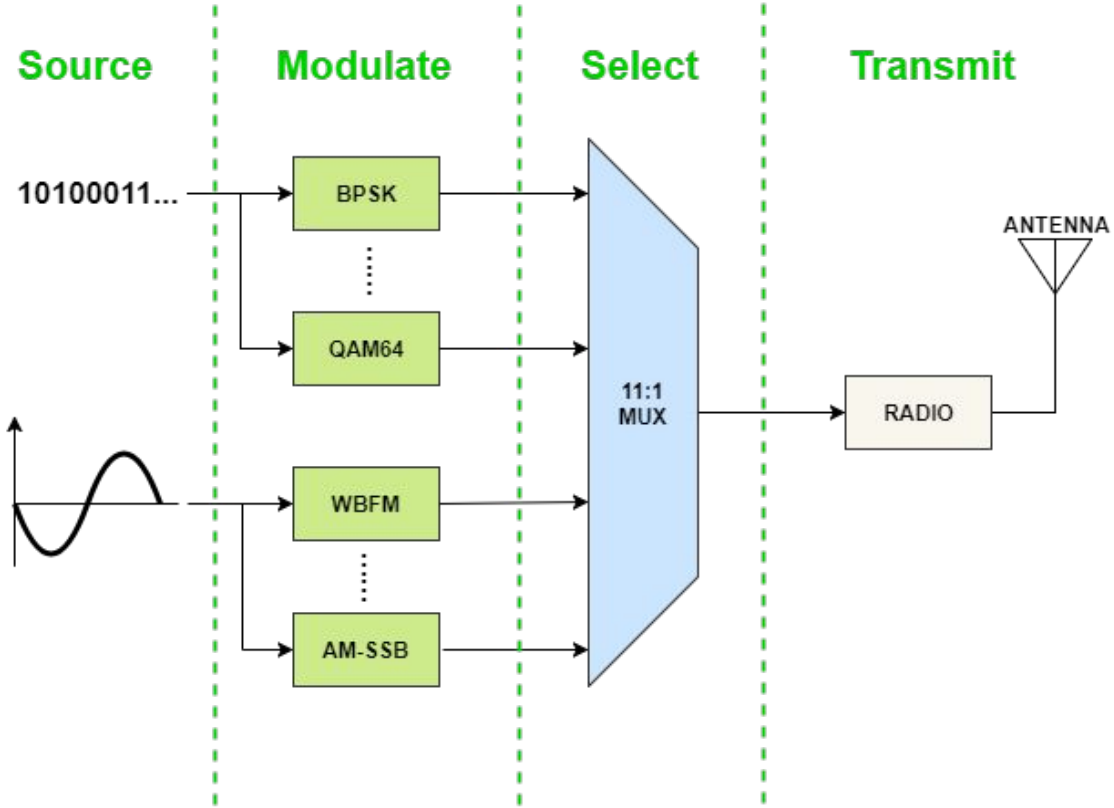
We want to be able to...

1) Send modulated signals
2) Choose modulation
3) Adjust noise level added to signal

Solution : Transmit signals with a software defined radio (SDR)!

GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

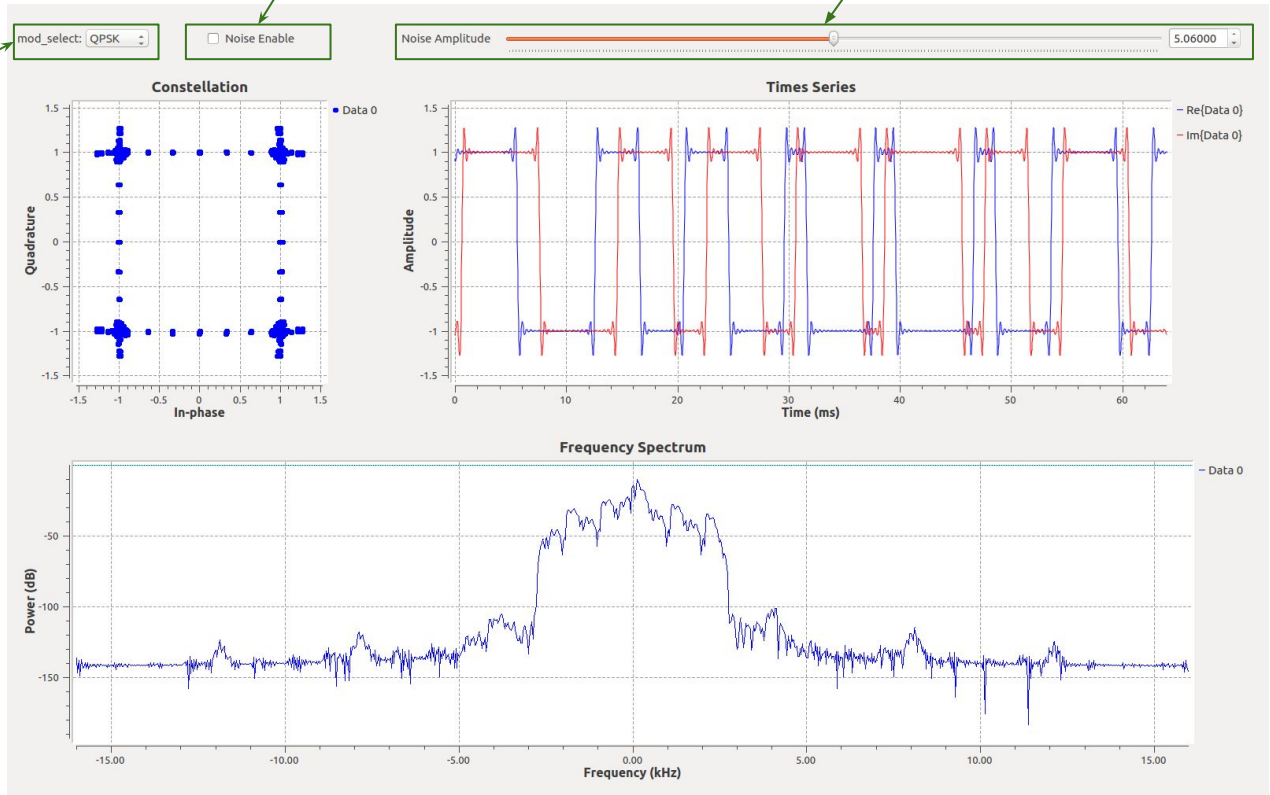
Physical System Block Diagram



Add noise to signal

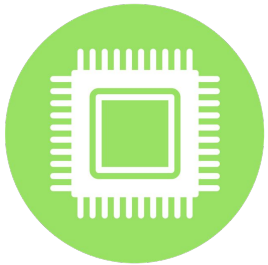
Control Noise

Select Modulation Scheme

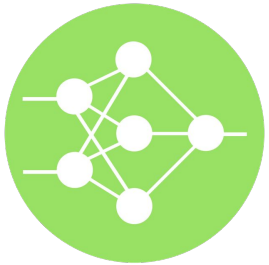


End of Semester Goals

Wireless System Setup



FPGA Implementation



CNN Implementation

Thank You!
Any Questions?