6.S965
Digital Systems Laboratory II

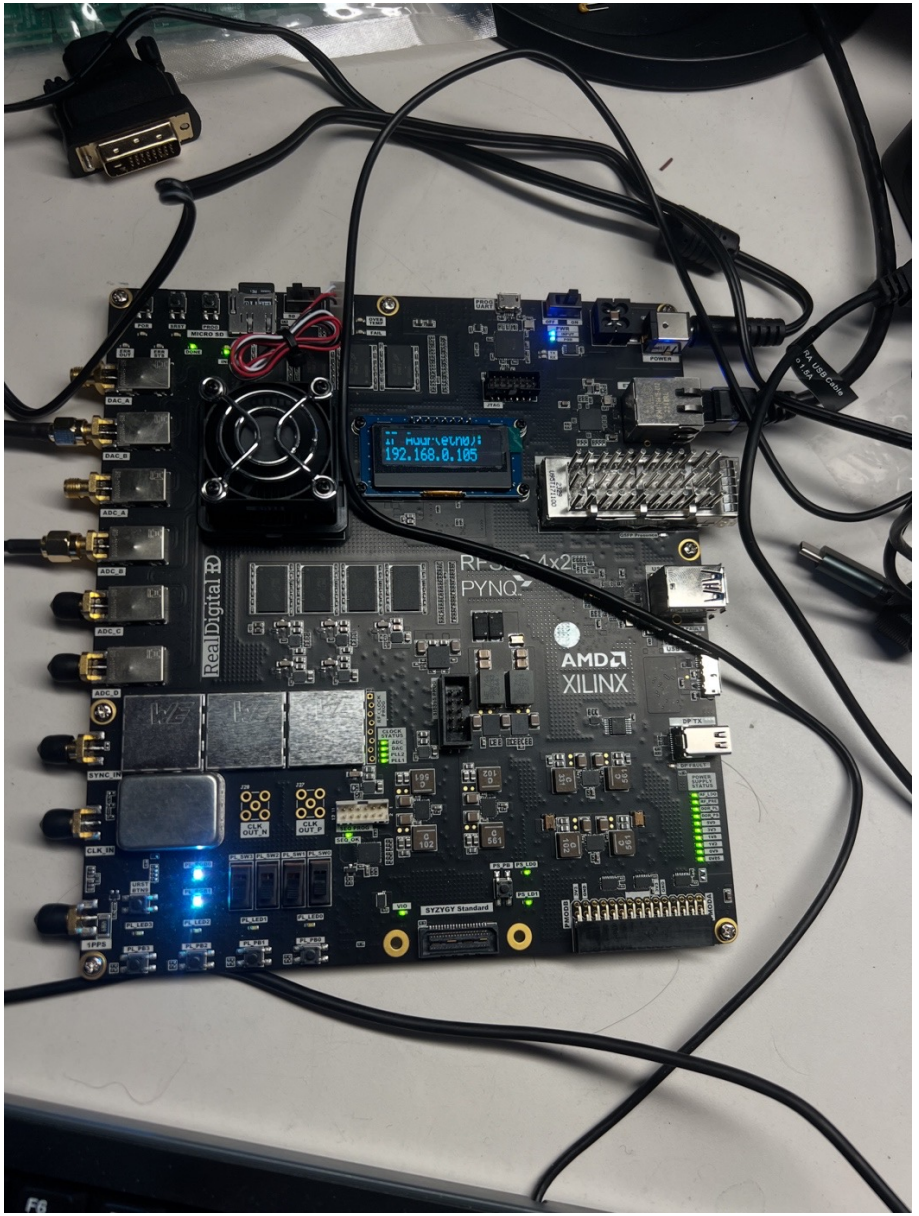
Lecture 10

Administrative Stuff

- I need us to figure out final projects and teams in the next day.
- In the next day or so, I'll put on the site a RFSoC lab. I'll set up (for starters) six RFSoC boards in the lab and we'll need to try to time-share them if possible (I have more)
- Next week I'd like to cover the idea of coverage with Cocotb and our verification framework
- Then we'll just roll into final projects

Lab This Week:

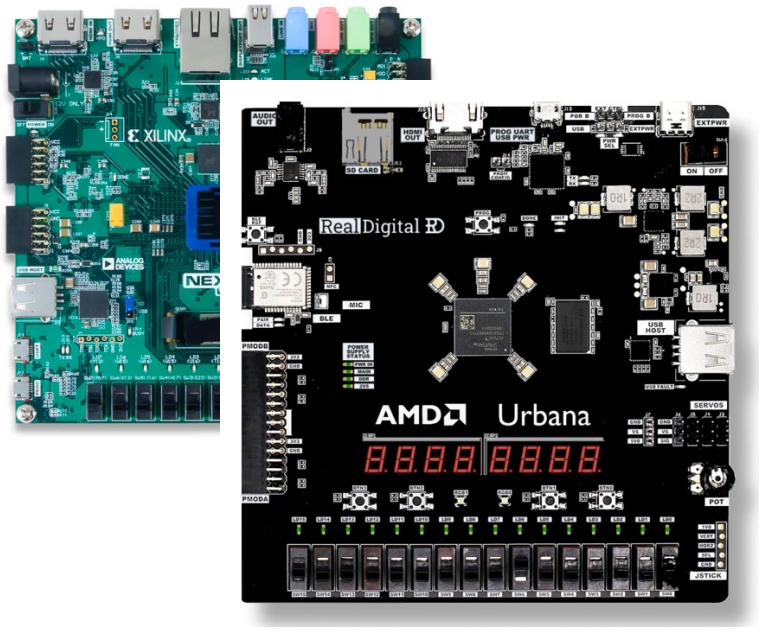
- We'll work with the RFSoC Board
- For starters we'll just configure and run the ADC and LO and dump some data into memory to analyze



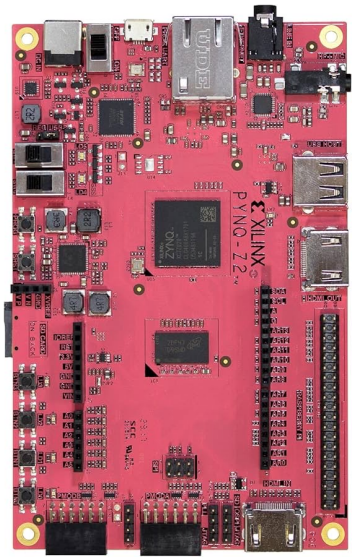
Final Project Environment

- Board Choice…don't really care, specifically…just pick one

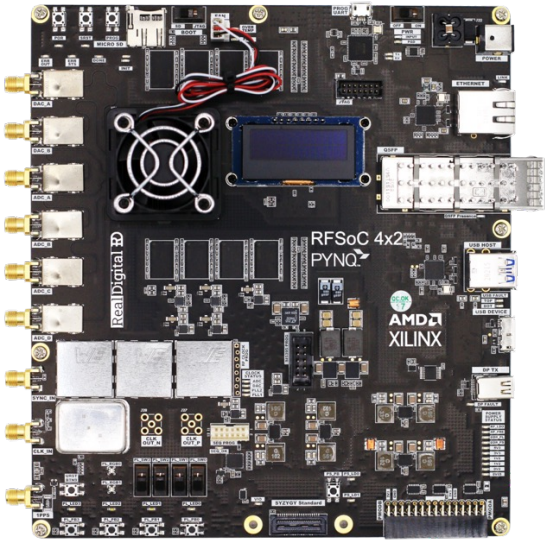
Regular FPGAs



Standard SoCs



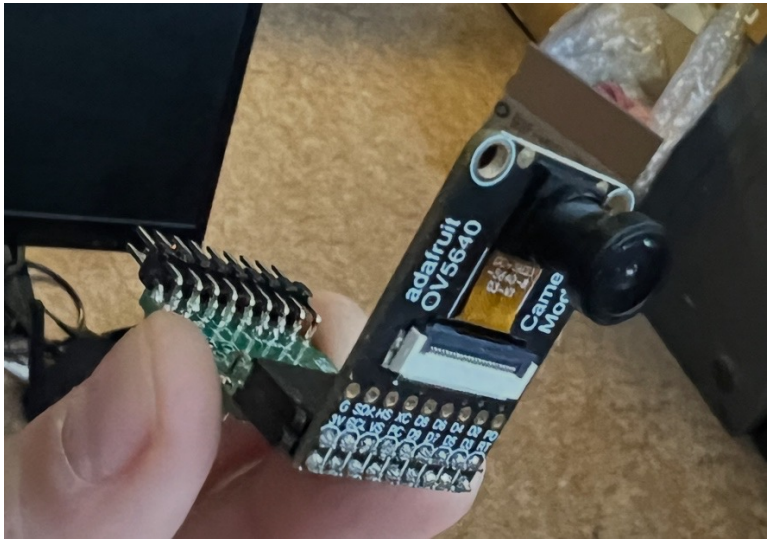
RFSoC



Regular FPGAs

- We have extra Urbana boards (and we have pretty well-functioning DDR interface logic this year!)
- Also a bunch of Nexys 4 DDR boards (about 2X resources of Urbana)
- Also have several Nexys Video boards (about 8X resources of Urbana)

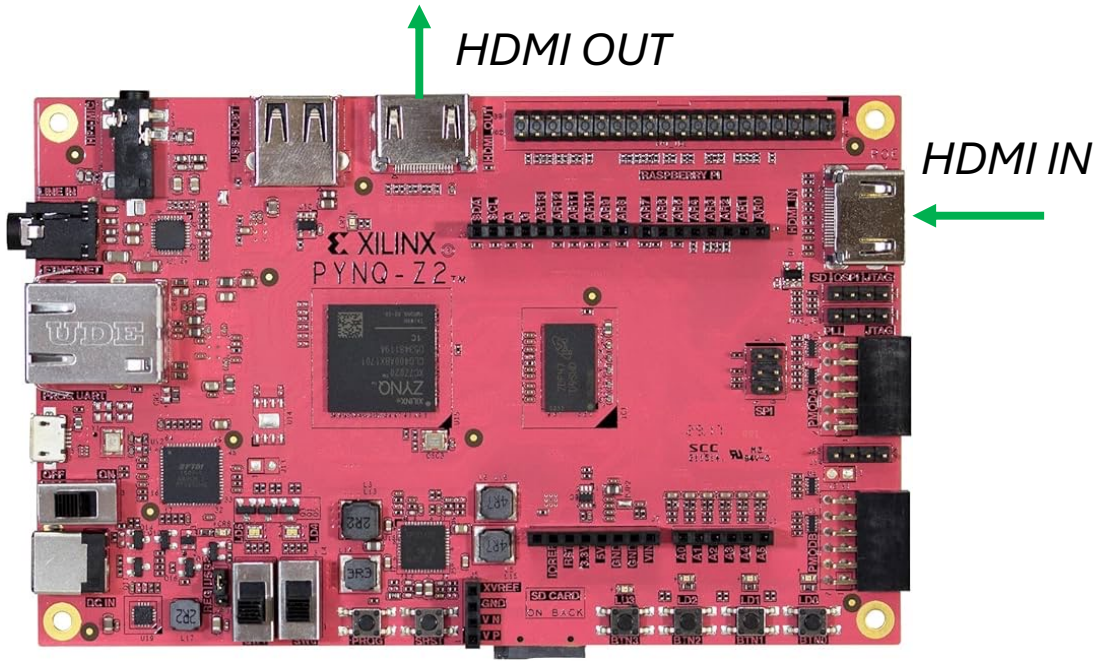
Additional Equipment



- 6.205 has a *much* better camera this year (720p 30fps) so if you want to do something with image-processing/anything, we have some you can use.
- Need a slightly different adapter for Pynq but just need to make more of those

The Pynq Z2 Board

- Does have HDMI in and out, so it is possible to incorporate this into some interesting video-processing pipelines.



Anything with Computer Vision, this could be a good environment

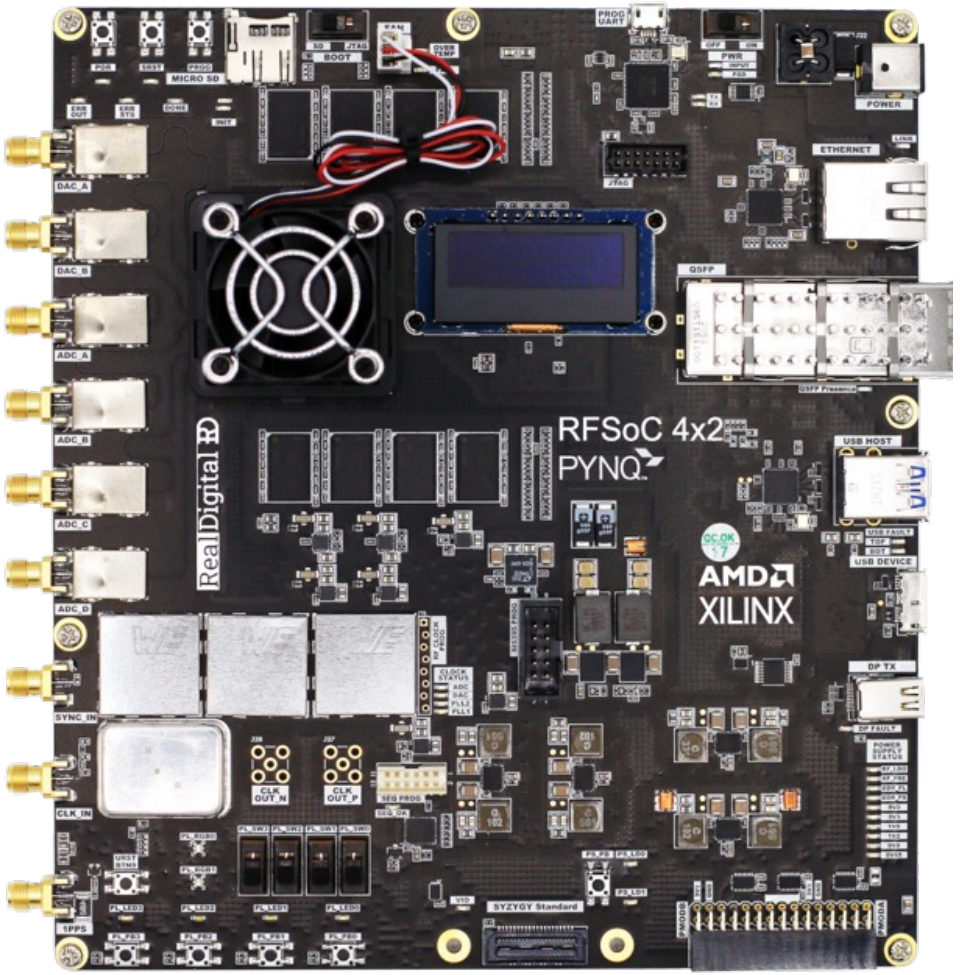
- https://www.youtube.com/watch?v=QPshQ9PsuFs

- Sources of data could be computer feed (passthrough to monitor using HDMI in and out)

- Or camera input (@ 30 fps)

RFSoC

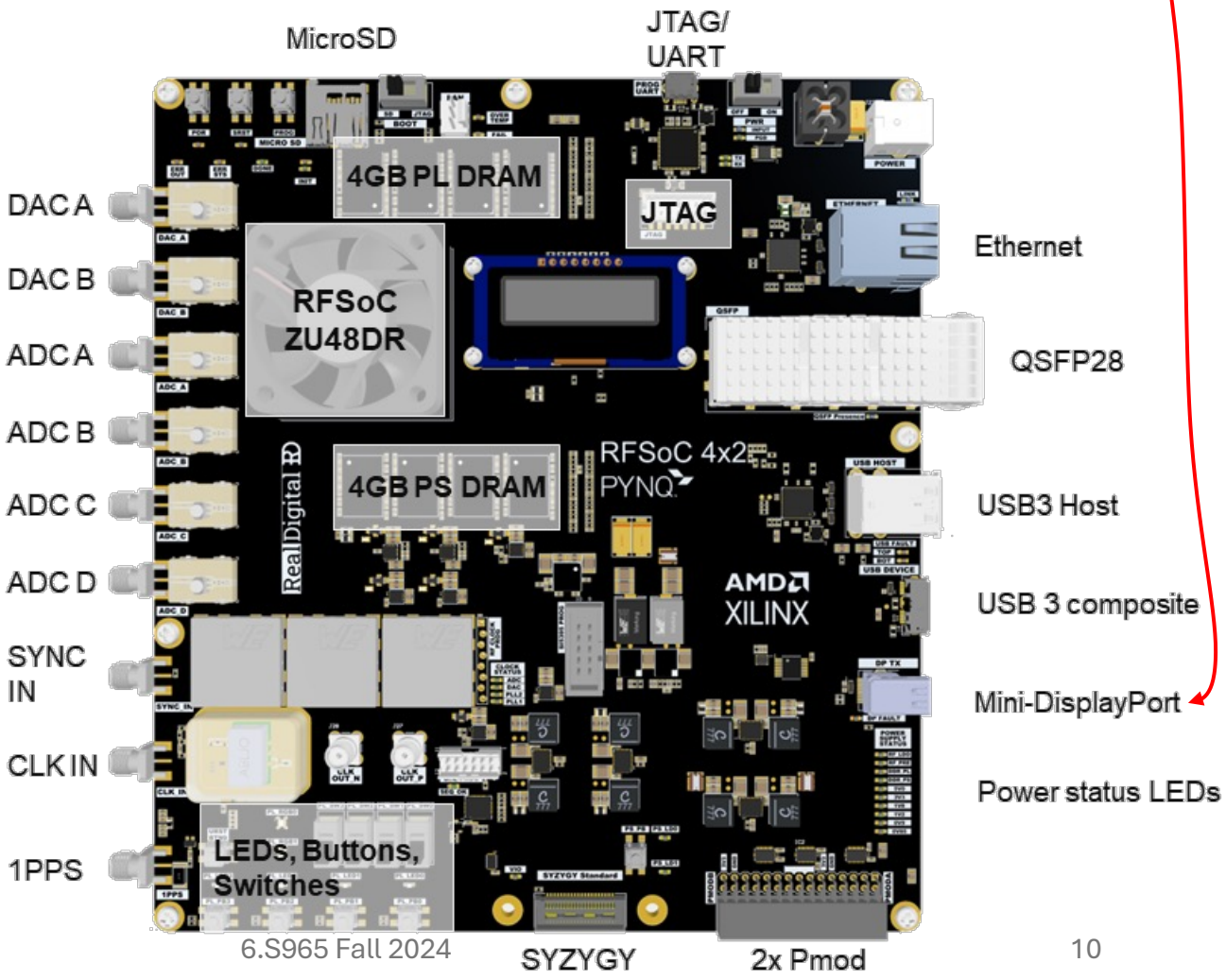
- It is basically the Pynq Z2 but with a lot more resources, the ADC, DAC and a lot less “fun” breakout parts like HDMI
- Chances are, outside of the ADC and DAC, most other peripherals have minimal codebase support



I've tested the...

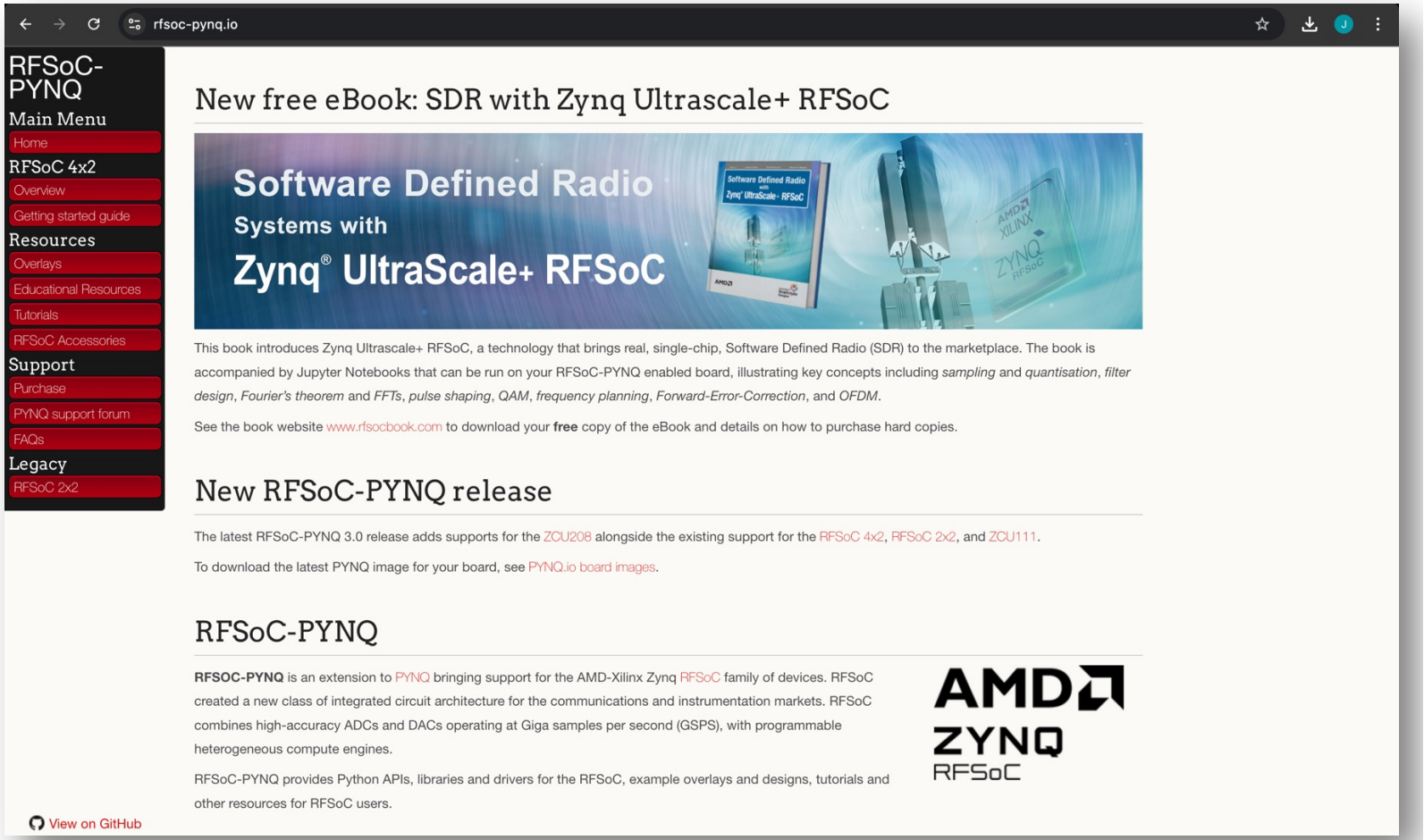
- ADC
- DAC
- LEDs
- Switches
- Buttons
- Pmod pins
- DMA

Oh there's a display port



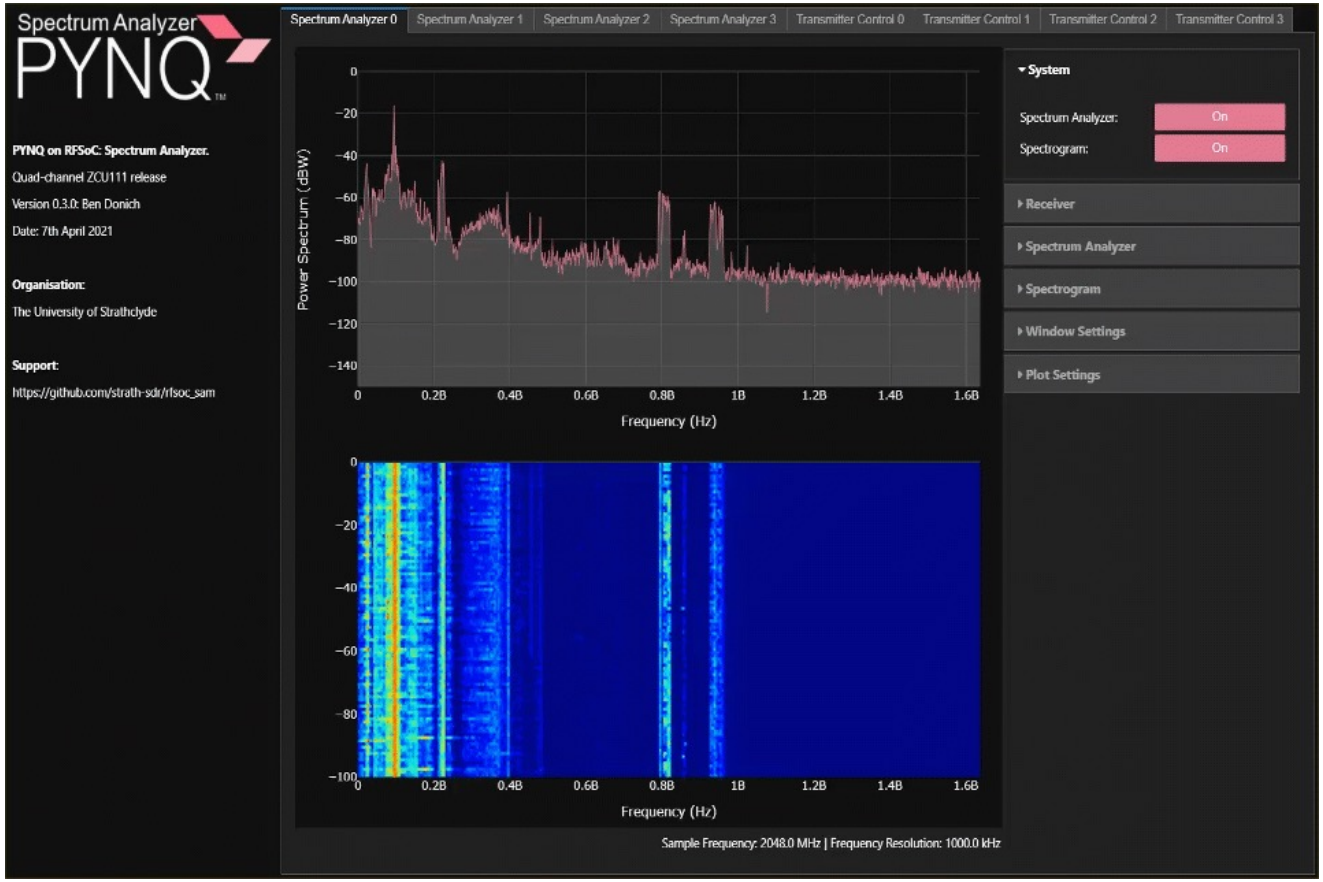
rfsoc.pynq.io

- Reference one:



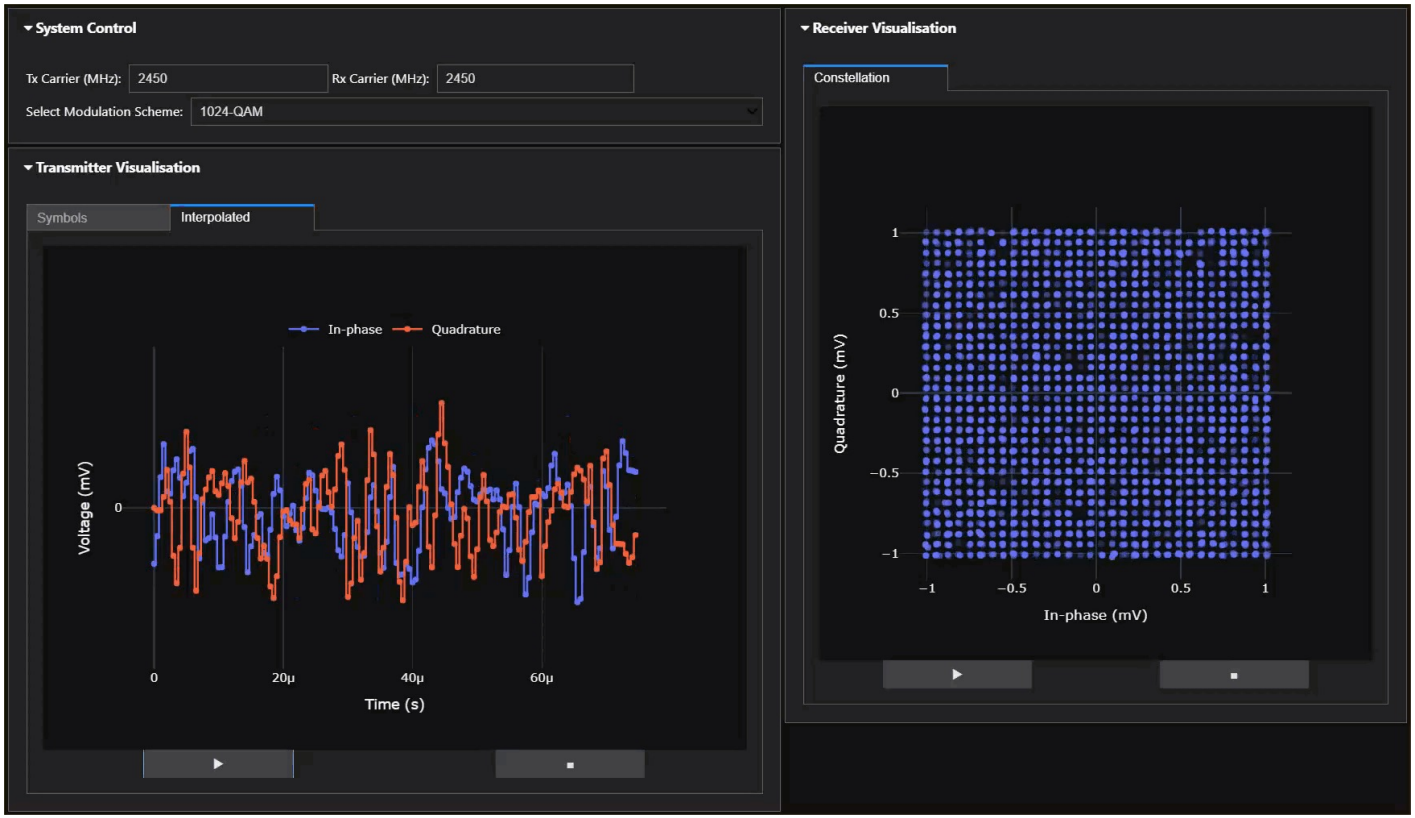
Has some interesting overlays

- Regular Old Spectrum Analysis



Has some interesting overlays

- 1024-QAM demo



Downsides

- All the code and widgets are found here:
  - https://github.com/strath-sdr/rfsoc_studio/tree/master
- All of their stuff was built with old Vivado (2022 or before). It does not build on 2023 or 2024, and they don't seem in any hurry to do anything about that.

You can run their notebooks and there's some interesting demos

- Most of which are built off of this "base.bit" overlay they wrote which has a lot of functionality in it.
- But you can't open it or rebuild it in vivado 23 or 24 (and even when I tried early on with vivado 22.2 it broke)

Good News

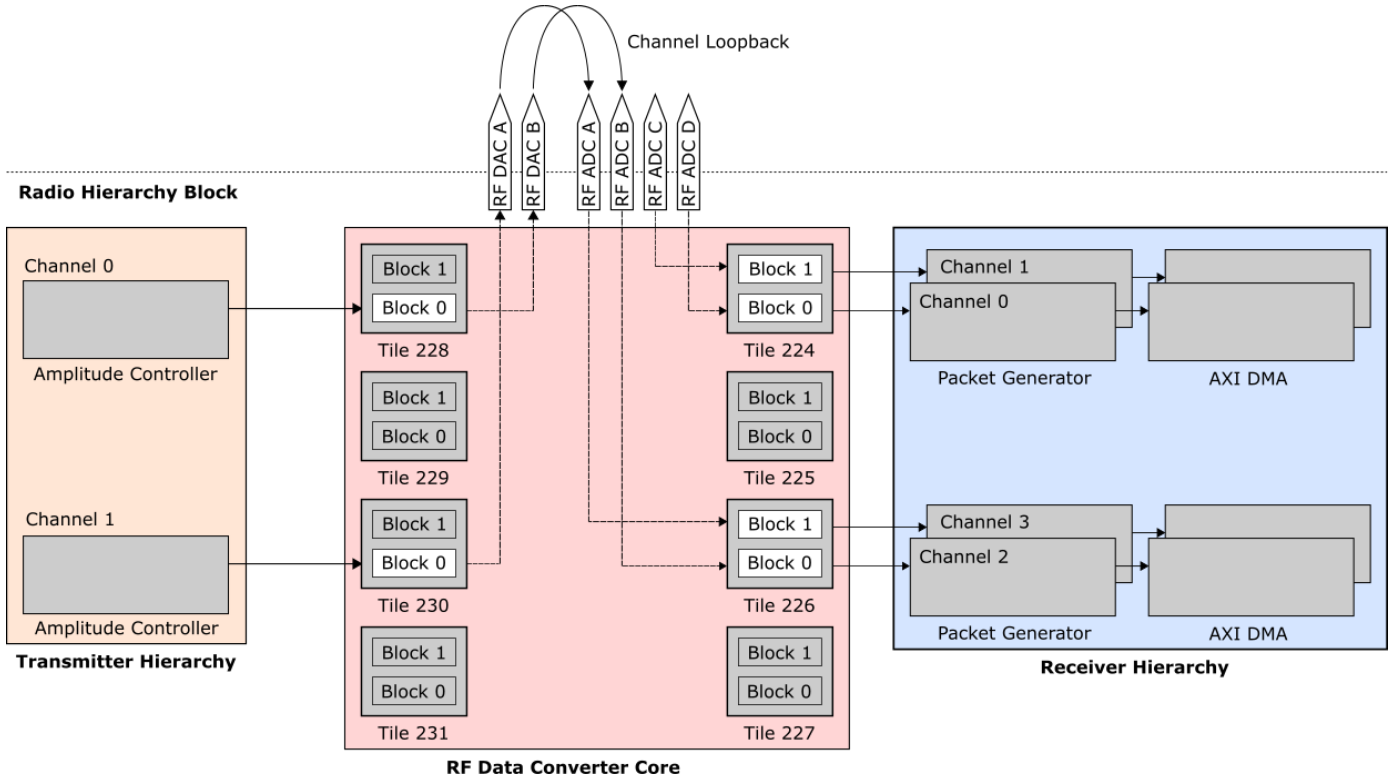
- Everything we've done on the cheaper Pynq board, including DMA ports right over in my experience.
- Things do seem to work with the Pynq…it isn't that it is unsupported in my experience, it is just there is nothing out there to show you how for specific things.
- There just aren't many walkthroughs about how to actually build something on the RFSoC out there.

There's two "new" devices

- The ADC and the DAC

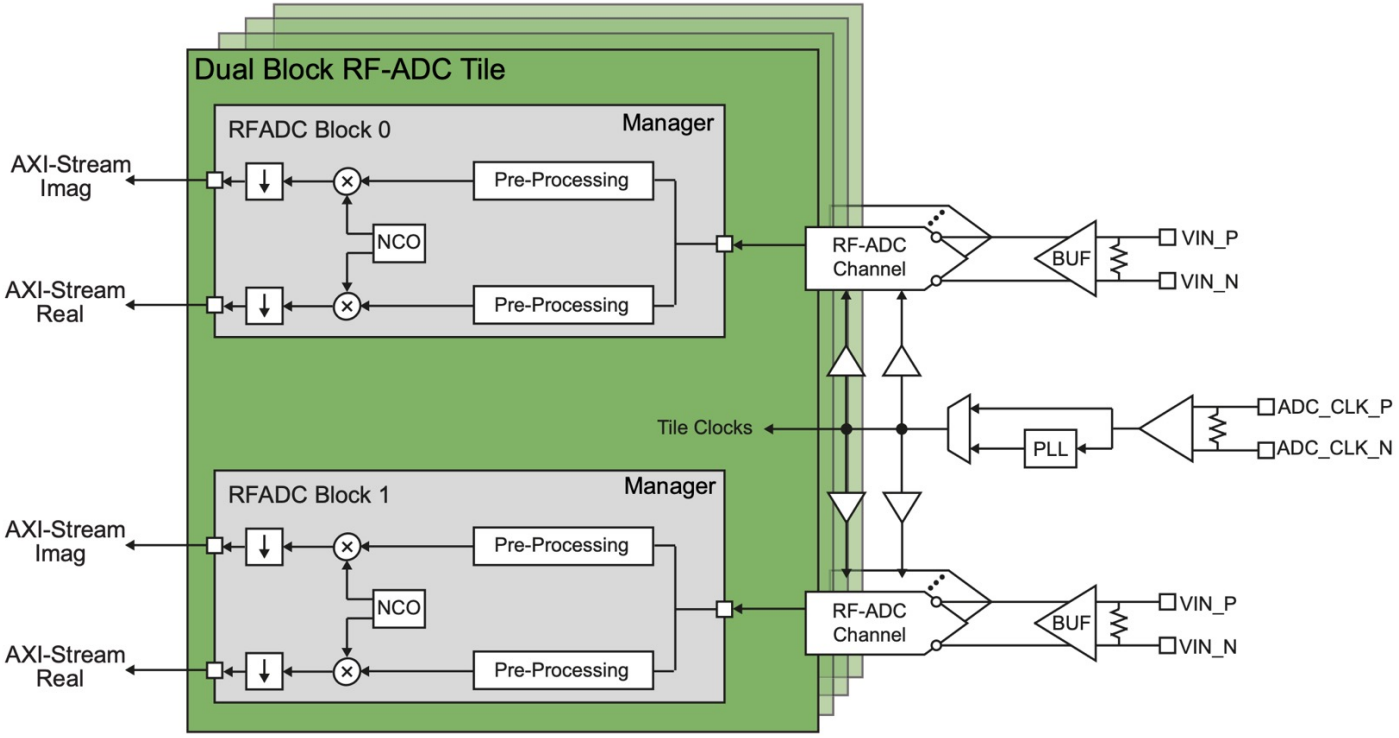
- Week 6/Lab 6 will focus on the ADC since I think most of you will be using that (if you do use the RFSoC)

The RFSoC Board has DACs and ADCs in two blocks



ADCs

- You pretty much need to use these in I/Q format to get most functionality



DACs

- Basically work the opposite

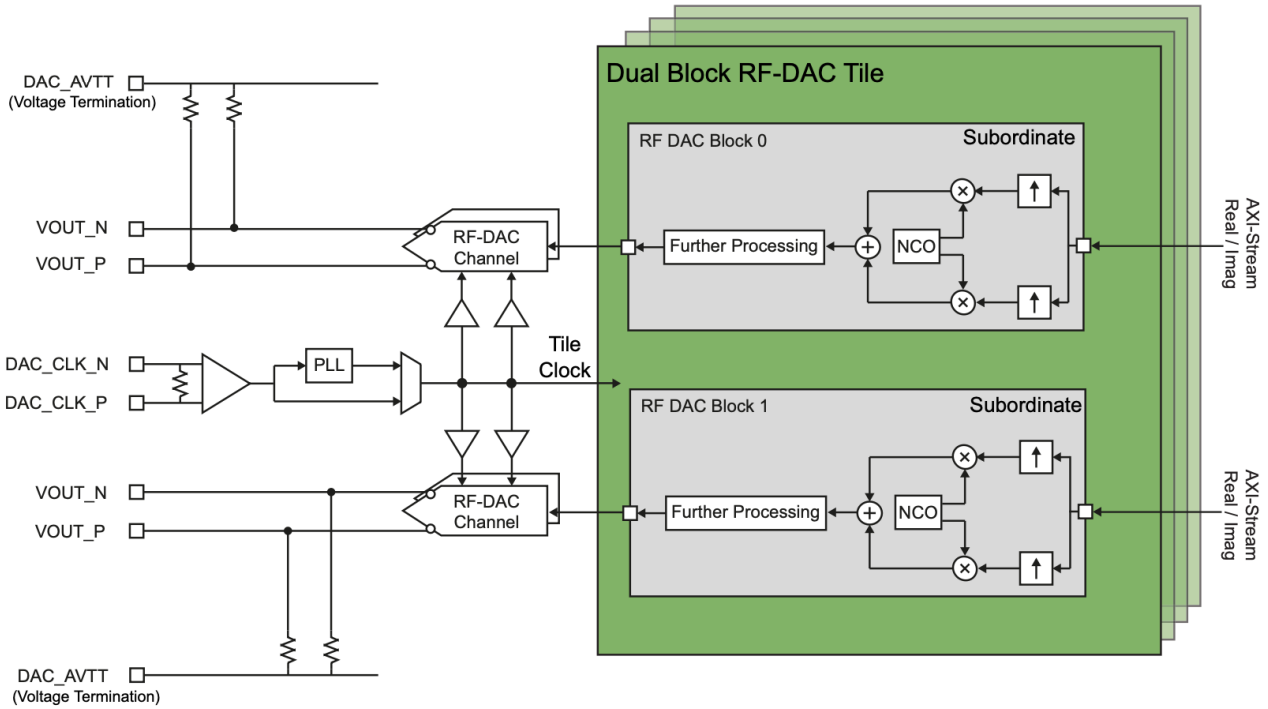
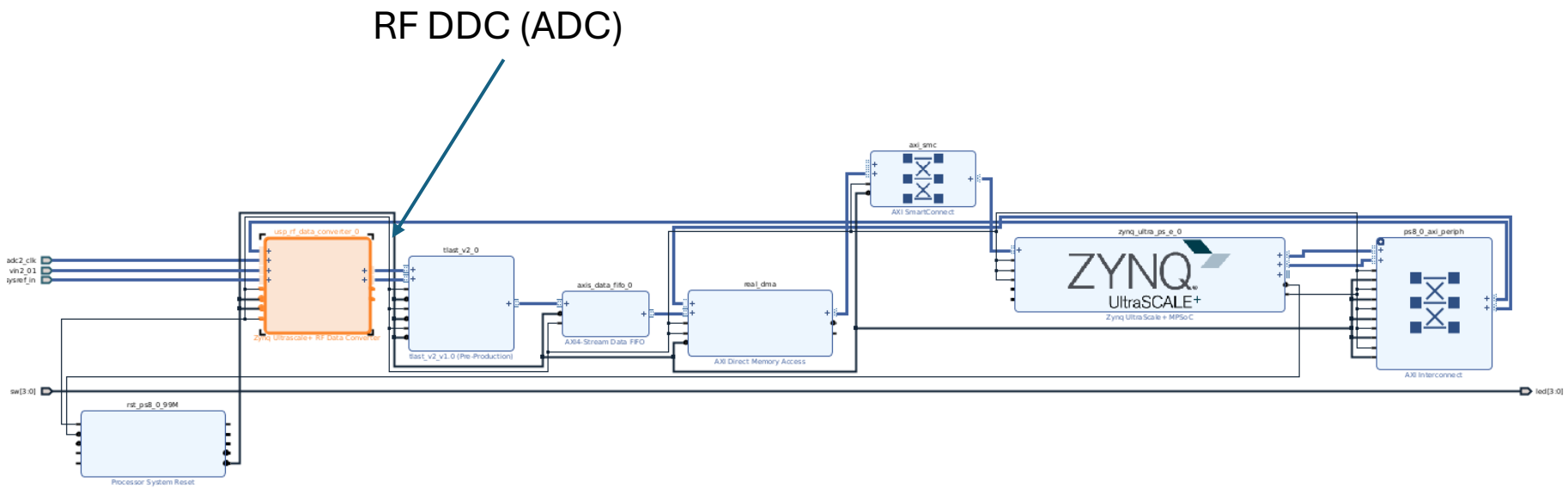


Figure 3.11: RF-DAC hierarchy for the ZU48DR RFSoC device [90].

Week 6

- Build an ADC pipeline and look at some signals in python



Project Ideas for RFSoC

- I wanted to list out some things that we could use the RFSoC for for ideas

Project Idea: QICK

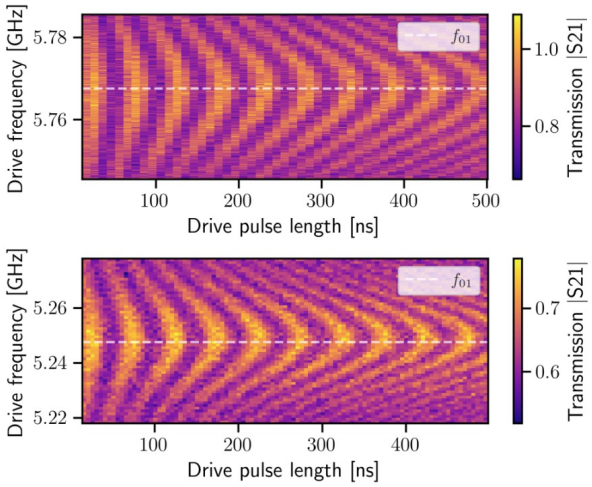
- I think quantum stuff is made up, but the RFSoCs are getting a lot of use in qubit analysis.
- Slides here:
  - https://docs.google.com/presentation/d/1rrgFXOn-ZROhKadeiPFlLhmJAO-Ze_ezWnpo-j1usnw/edit#slide=id.g30110b82c28_0_31
- I think there might be some interesting projects here involved in measuring these fake phenomena

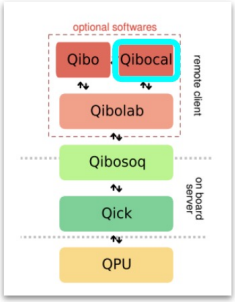
QICK on a RFSoC

- Look at those Rabi oscillations (?)! Very cool

Multi-qubit control with the Qibo/QICK stack

Simultaneous Rabi oscillations in neighboring qubits





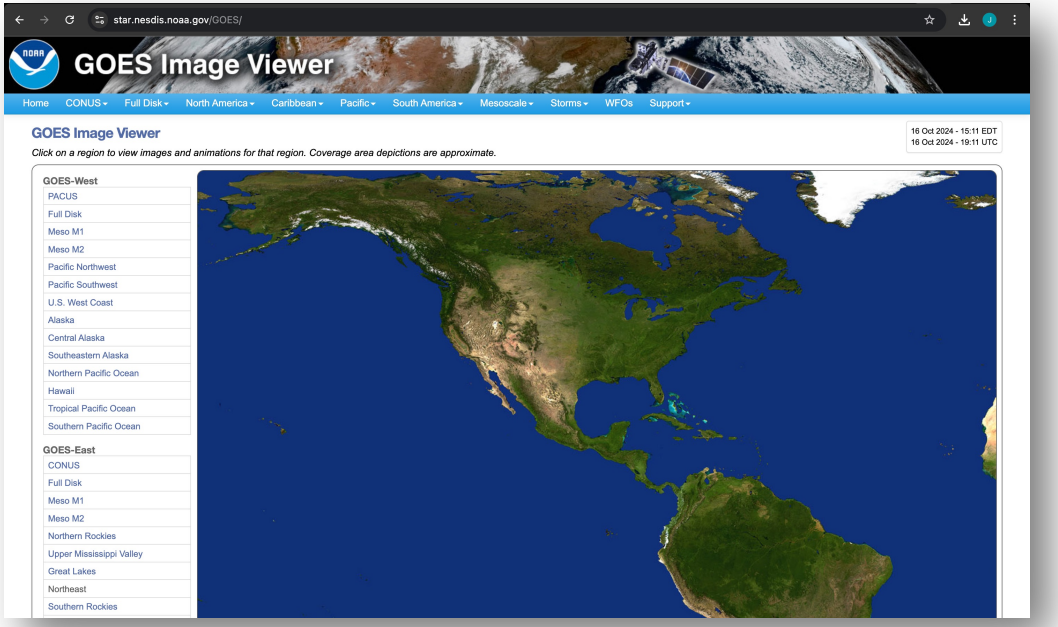
More by Qibo team:

- ❖ Characterization of 2 pairs of CZ interactions between 3 qubits
- ❖ Work-in-progress to use two synchronized ZCU216 QICK boards to control 8 qubits

Moretti, R. et al. Transmon qubit modeling and characterization for dark matter search (arXiv September 2024)

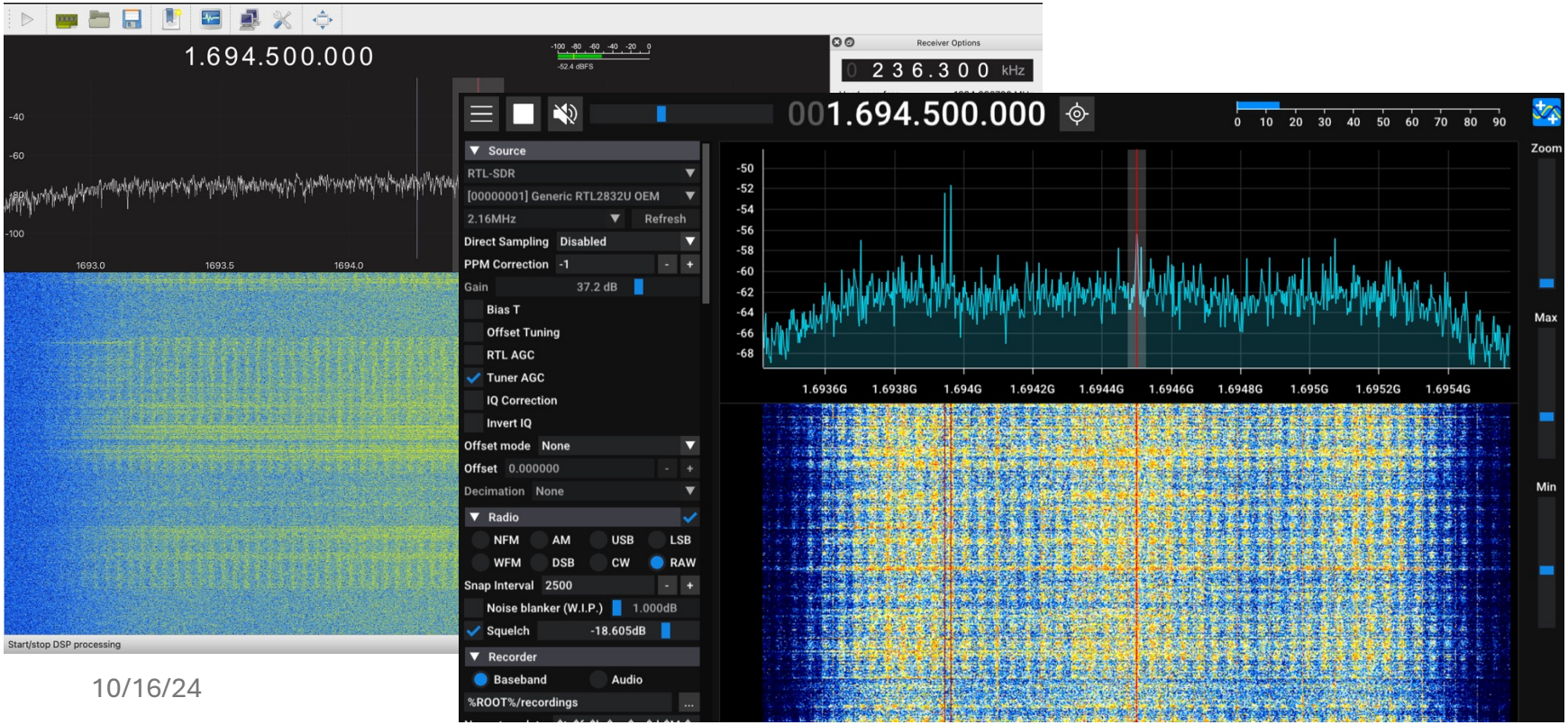
Satellites

- GOES (Geostationary Operational Environmental Satellites) send down really cool images with a complicated protocol
- Signals around 1.7 GHz



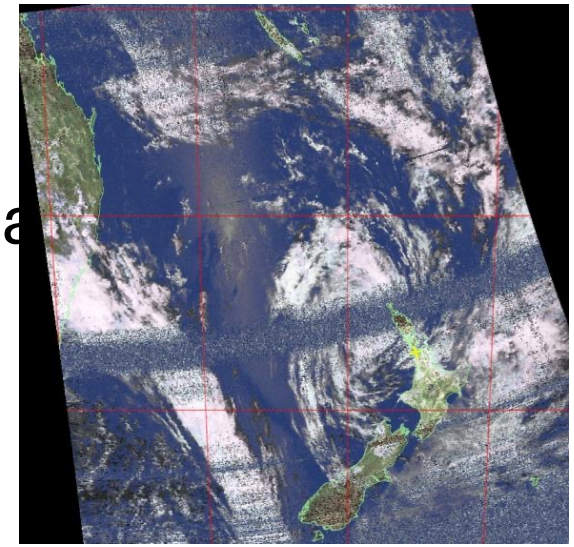
Satellites

- That dish I have on the 6th floor is meant for GOES…pointed it and with a front-end filter and LNA we were able to see some signal



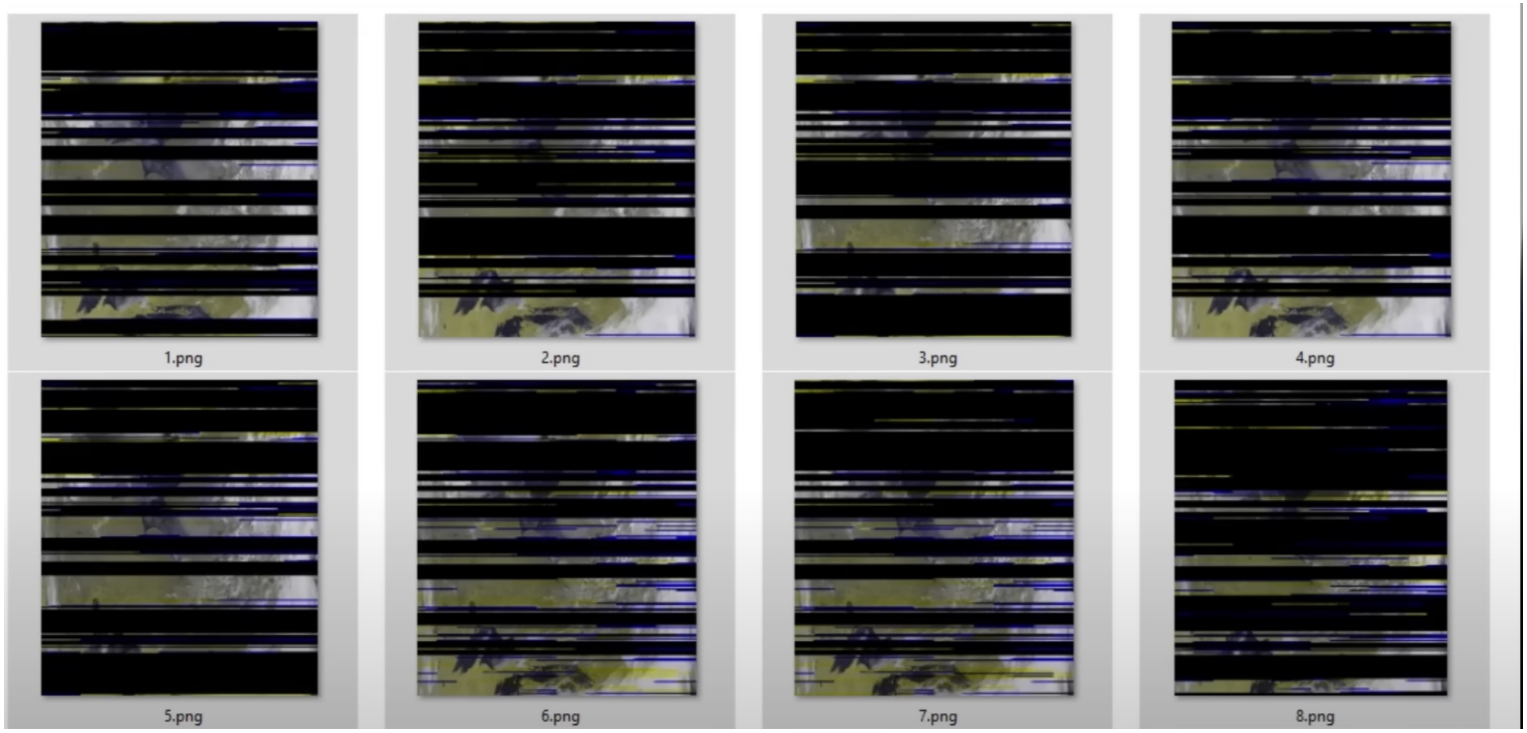
NOAA APT Satellites

- APT= Automatic Picture Transmission Satellites
- Not geostationary so will have to track…but should be possible…
- Send down
- Signals on/around 137 MHz
- Use circularly polarized antenna



Meteor Satellites (Russian)

- Russian weather satellites are also not geostationary but can give good images



International Space Station

- Periodically sends down SST (Slow-Scan Television) as well as other signals
- https://www.youtube.com/watch?v=HaAprfh9ZtM

Use some of these…parts

- Antennas
- Low Noise Amplifiers
- Some Front-end filters

Commercial FM radio

On that topic…Budget

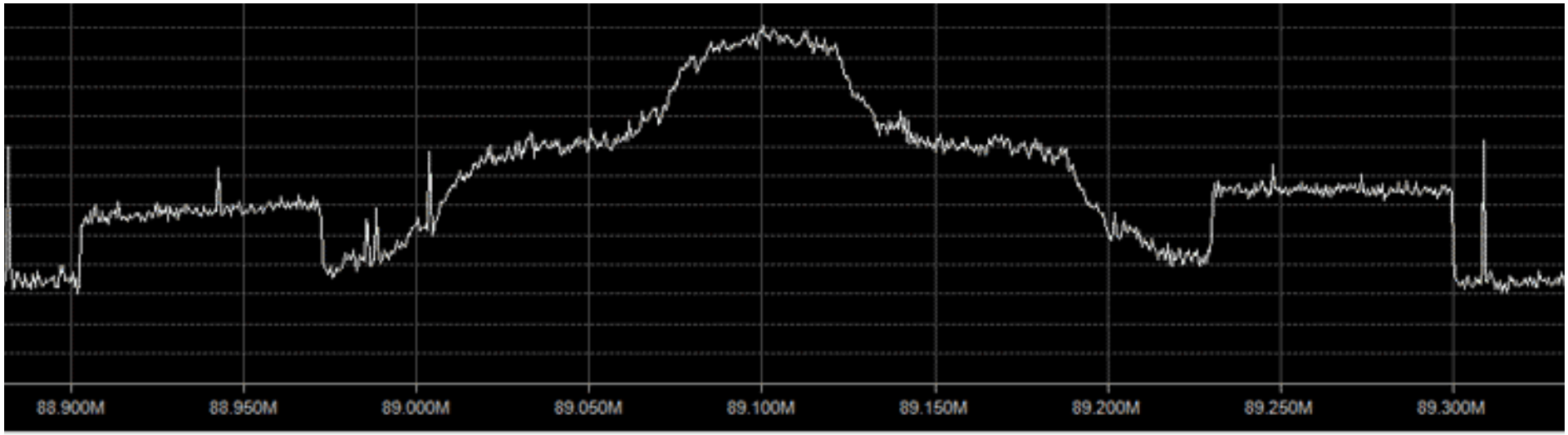
- I have ~3K cash dollars or so to spend if we need to (for full class) so any antennas, amps, filters, we can get.

Traditional FM radio

- Just do regular FM demodulation (which you can do using IQ data). It isn’t that easy.
- Make it tunable to listen to all the stations

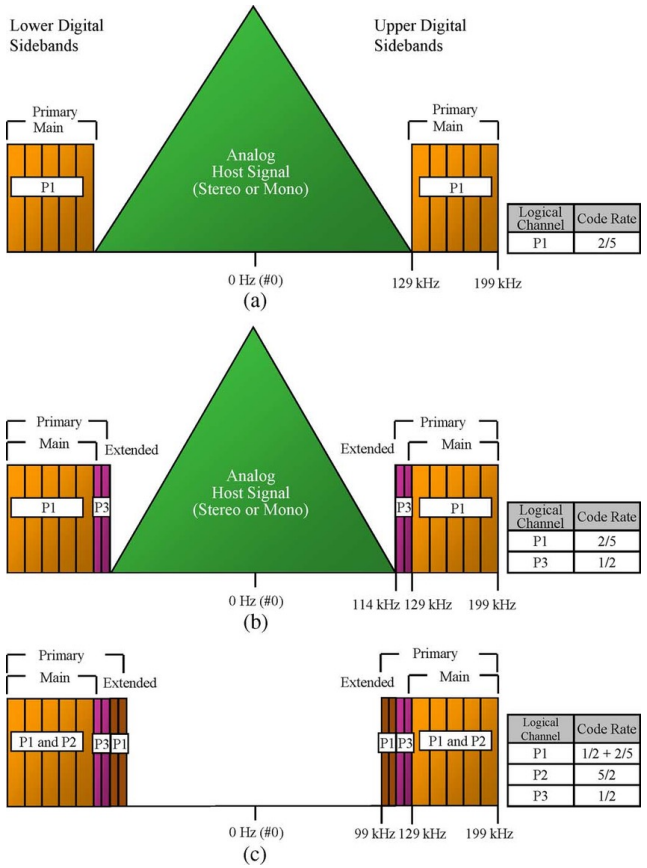
Digital Terrestrial Radio

- https://www.rtl-sdr.com/decoding-and-listening-to-hd-radio
- https://github.com/theori-io/nrsc5-nrsc-5-with-an-rtl-sdr/



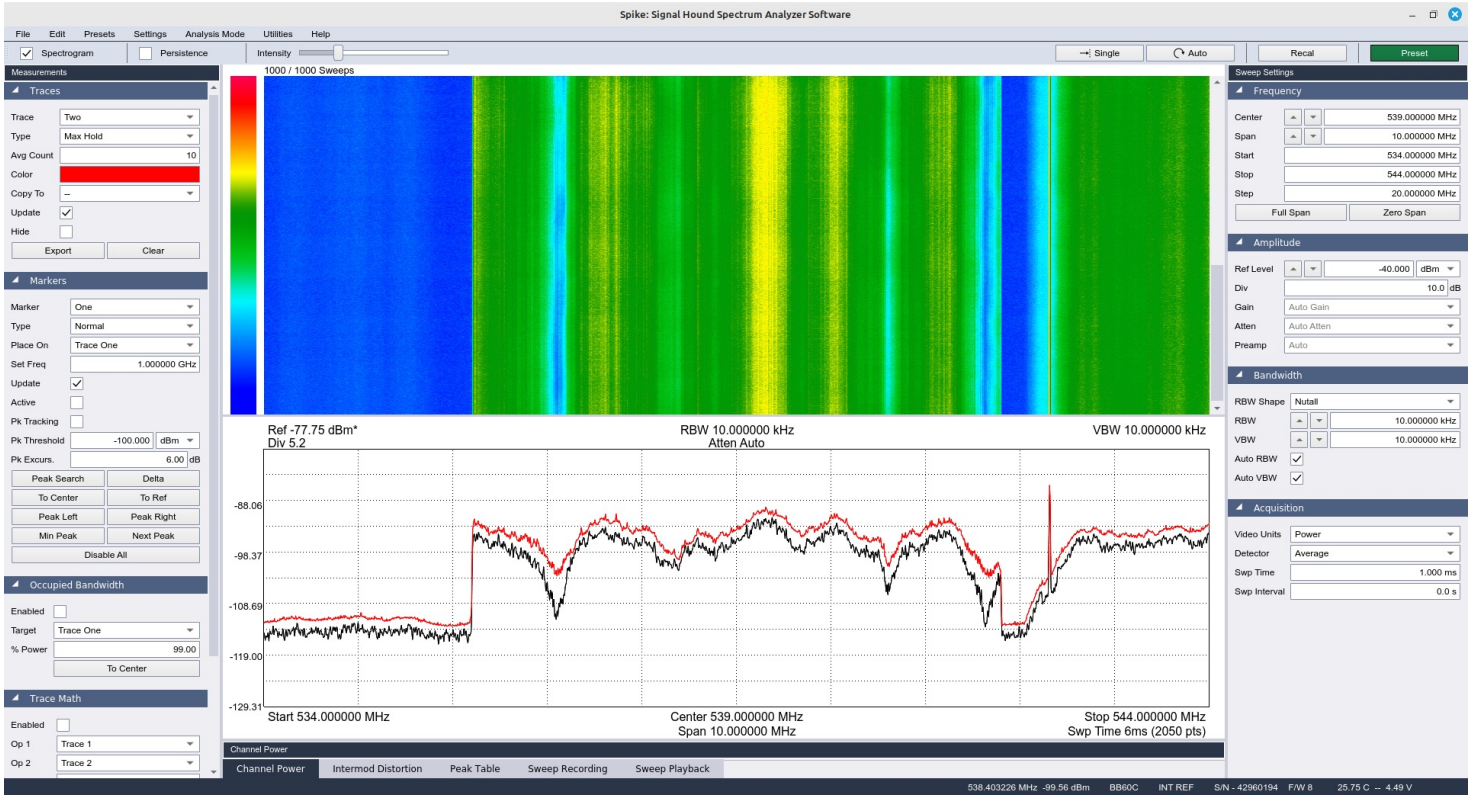
Digital Terrestrial Radio

- https://www.rtl-sdr.com/decoding-and-listening-to-hd-radio
- https://github.com/theori-io/nrsc5-nrsc-5-with-an-rtl-sdr/



Digital Television

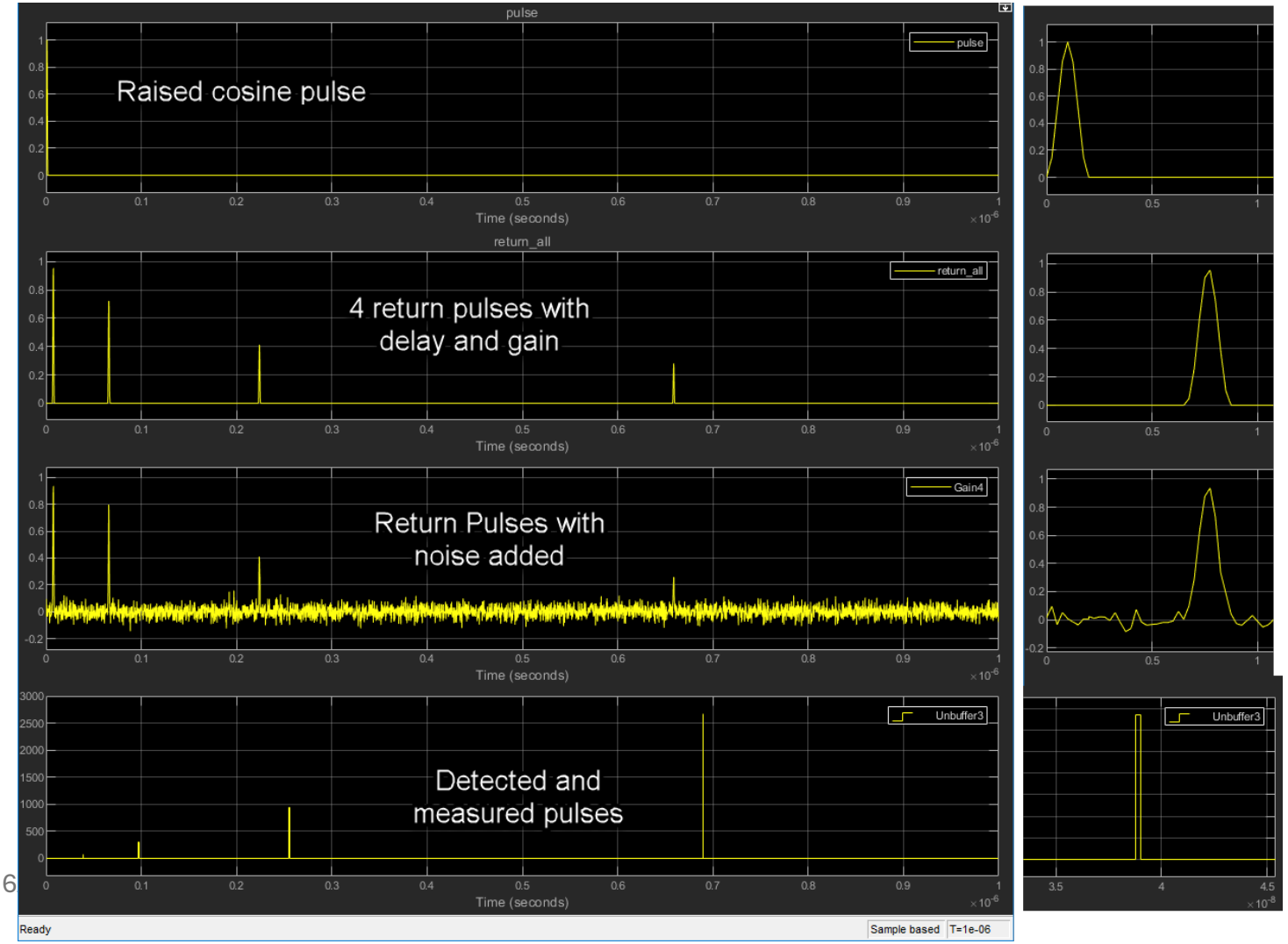
- Modern over-the air TV is digital. USA uses ATSC (Advanced Television Systems Committee)



LIDAR (use DAC)

- Some sort of continuous wave LIDAR:
  - https://www.bridgerphotonics.com/blog/frequency-modulated-continuous-wave-fmcw-lidar
- AMD/Xilinx have this projct here:
  - https://www.xilinx.com/developer/articles/lidar-pulse-detection-accelerator-model-based-design-targeting-vitis-and-rfsoc.html

Pulse-based LIDAR?



So…

- I will post a teaming form and a project idea submission thing tonight.
- I'll talk about final project ideas in any depth you want.
- I'm not doing Wed evening office hours tonight since I need to finish the final 6.205 lab. I'll do a bit tomorrow and then Friday afternoon like usual