# Low Cost GPS Synchronization for Distributed Instrument Arrays

Gavin McCauley

UMass Boston

Mentors: Jim Marchese, Frank Lind

MIT Haystack REU 2012

# Goal

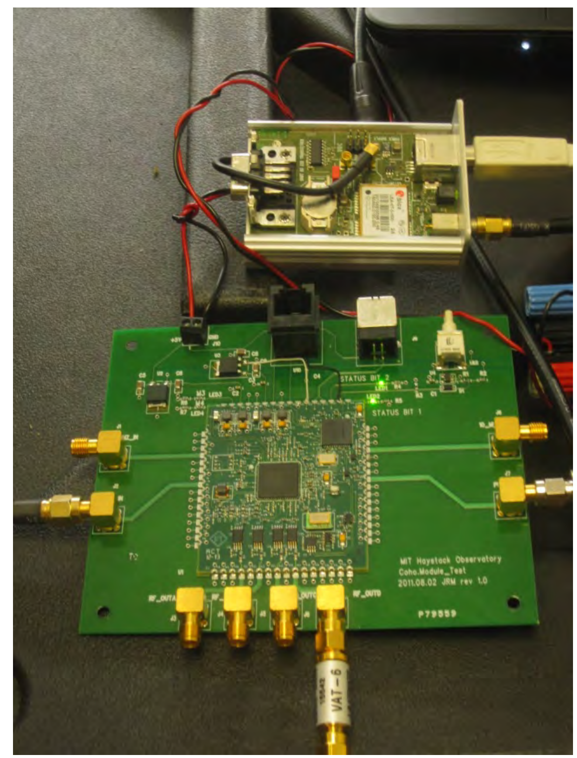
- Implement a low cost coherent oscillator
  - Programmable output frequency
  - Stabilized by a GPS 1-Pulse Per Second reference signal
- Lower cost, smaller size, and higher flexibility than commercial solutions
- Such signals are critical for synchronizing digital receivers in distributed radio arrays

# Project History

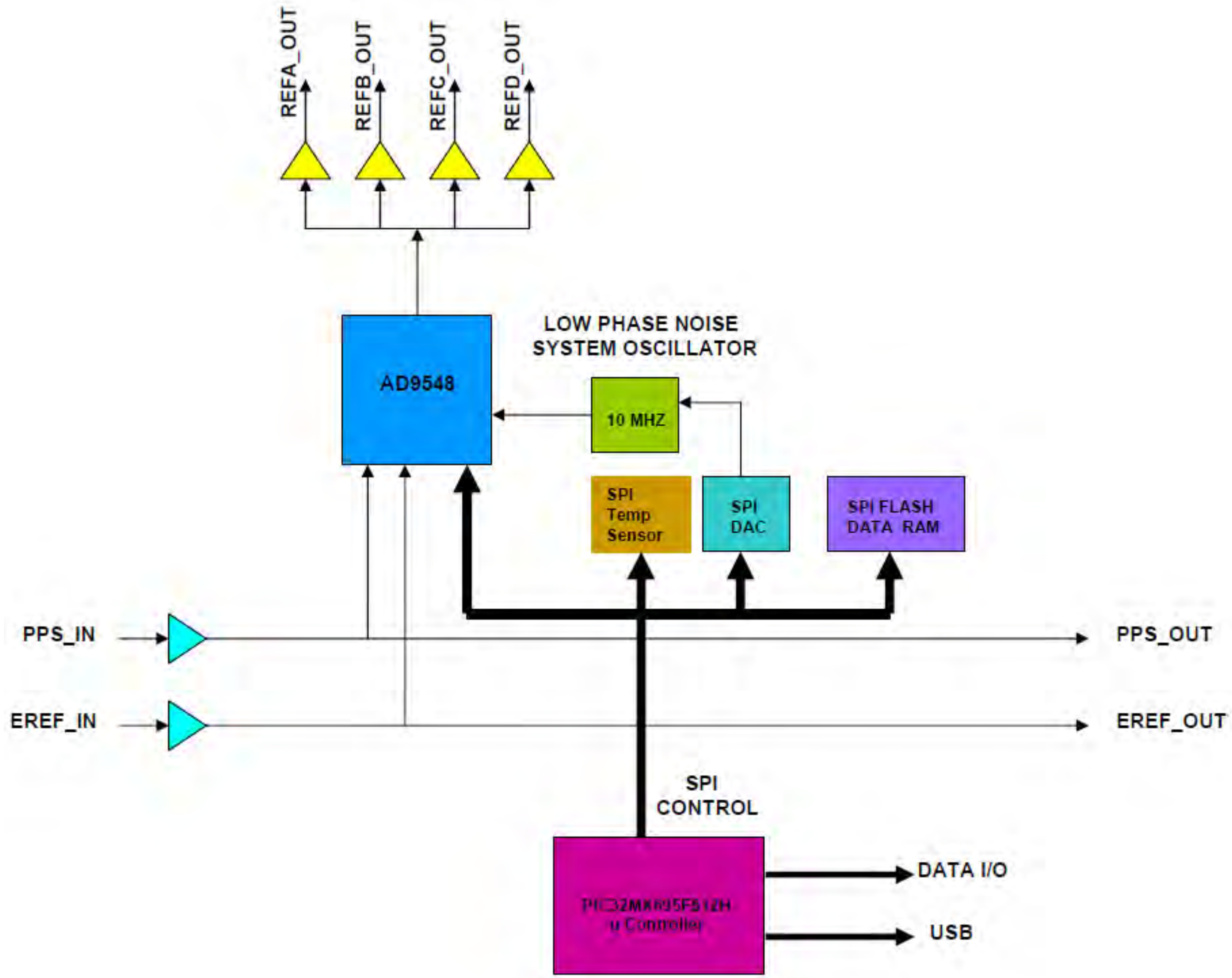
- Started from a REU project last year, continued intermittently afterwards
- Focusing on setting up hardware and beginnings of software for coherence module
- Now focusing on making the PIC and main component functional enough to generate a valid output for testing

# Components of Coherence Module

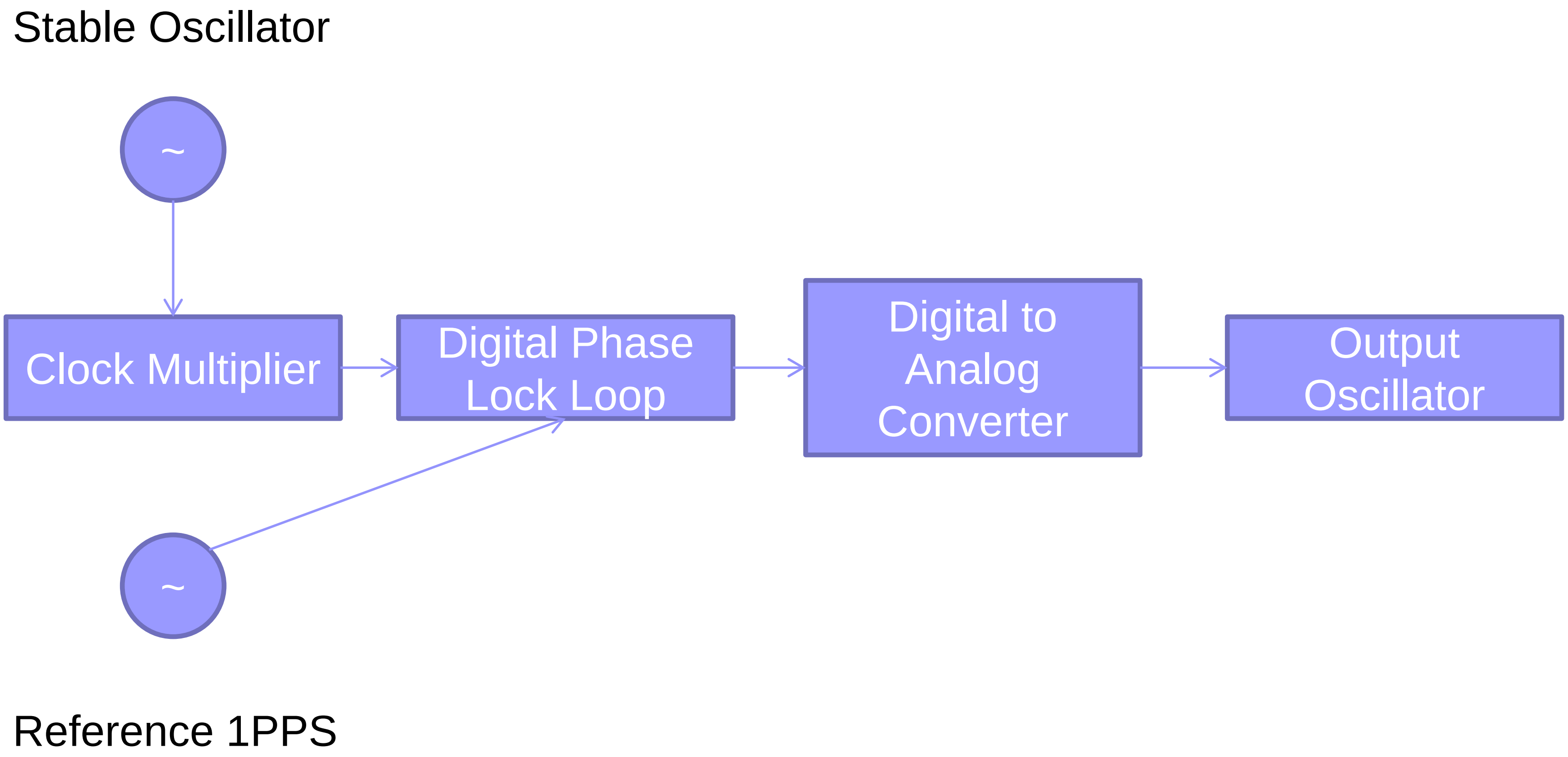
- PIC microcontroller
- AD9548 – clock-generating and clock-synchronizing chip
- Temperature Sensor
- DAC
- SRAM



# Workings of Coherence Module



# AD9548 Synchronization Chip

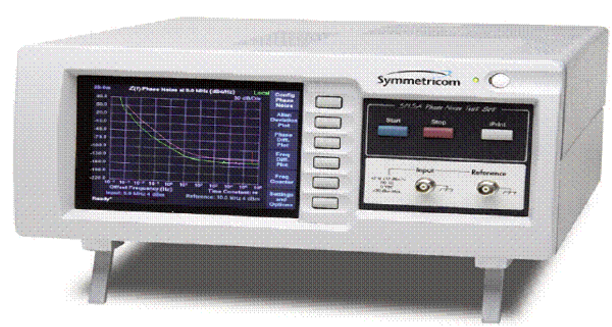


# Development

- Fixed previous test code and established control of all components
- Program the AD9548 chip with register settings known to produce a valid output
- Poll status registers in infinite loop and display lock status using LEDs

# Testing

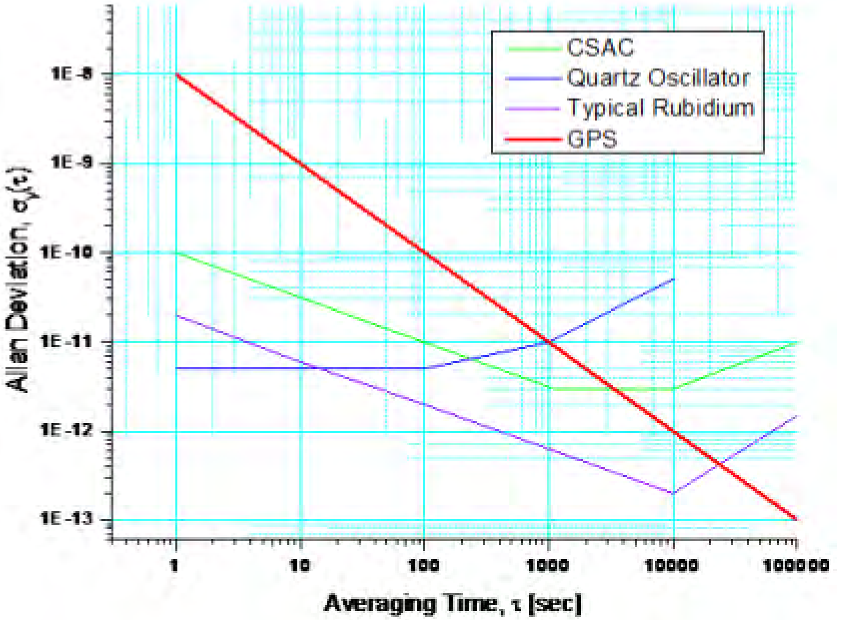
- Symmetricom device used with 5 MHz reference signal from hydrogen maser (very stable)
- Records frequency at a specified time per second and creates stability-related plots, such as Allan deviation (explained on next slide), to be retrieved in a file
- Run several tests with different profile settings to see effects



# Allan Deviation

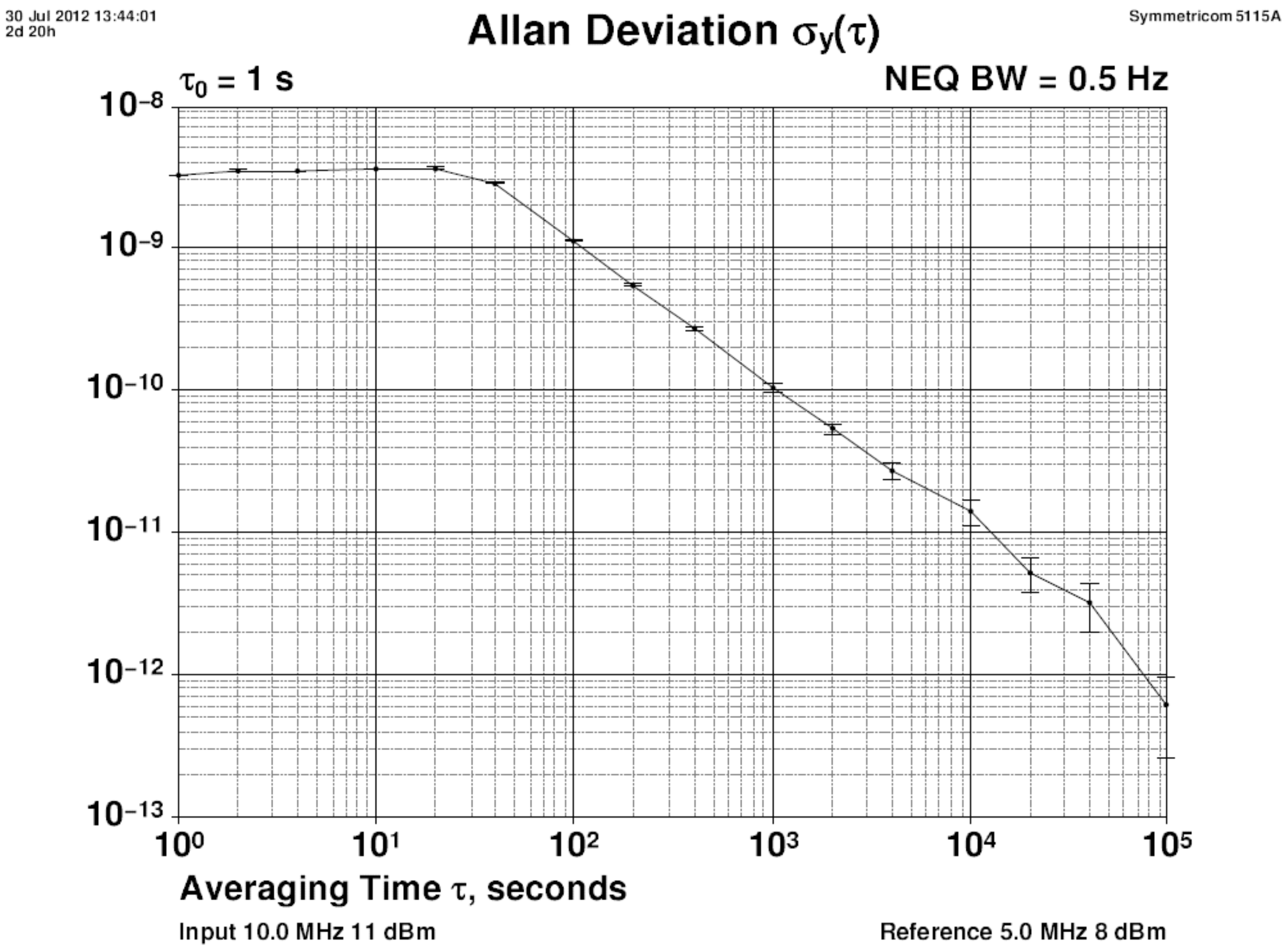
- Measures quality of signal; stability
- Depends on the time period used between samples
- Cannot be represented by one single measurement at any time, a graph is needed over time

$$\sigma_y^2(\tau) = \frac{1}{2}\langle(\Delta y)^2\rangle$$



# Coherence Module Prior to Tuning

Fractional Stability

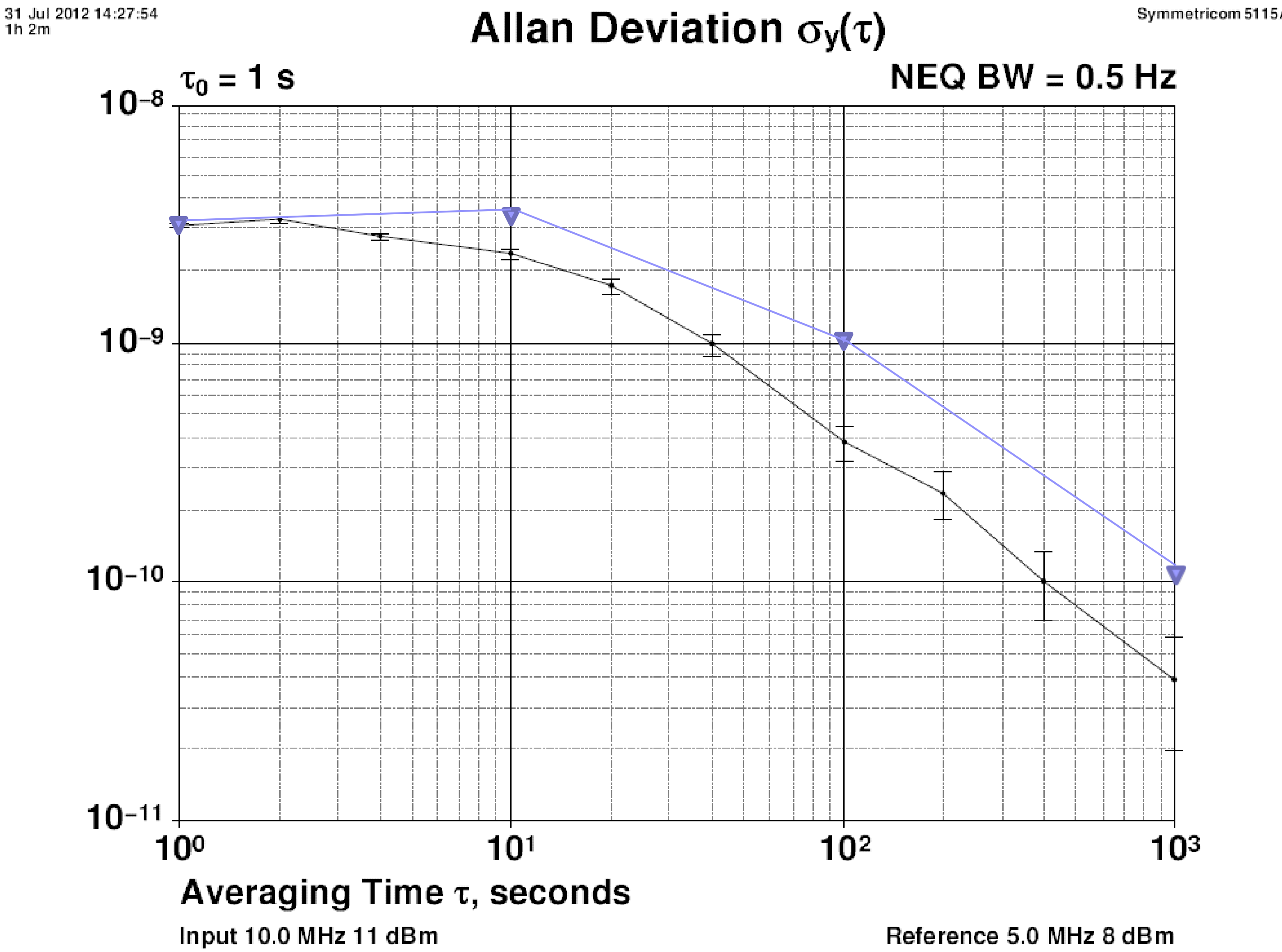


# Tuning Test Cases

- Change one AD9548 loop parameter at a time
- Due to time constraints could only run each test for an hour, giving Allan Deviation data up to $10^3$ seconds instead of $10^5$

# Best Case

Fractional Stability



# Application

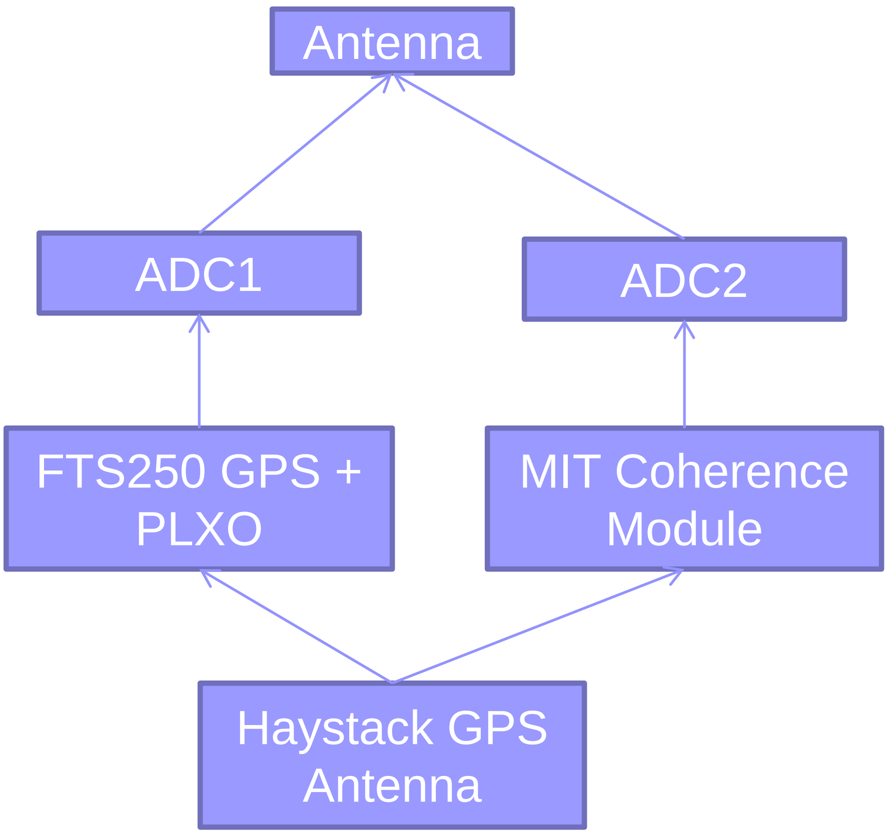
- Once the best case was found, the output frequency was adjusted to 72 MHz and put into Frank Lind’s system for radio signal receiving tests
- Changing from 10 MHz to 72 MHz was a change of two register settings!

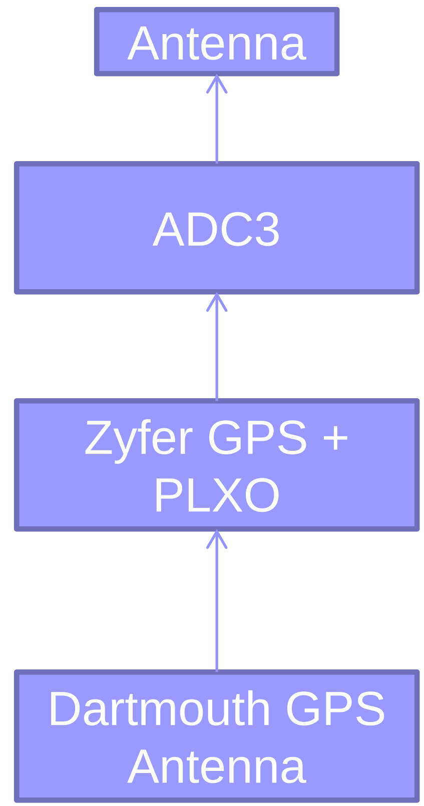
# Intercepted Signals for Ionospheric Science


Haystack

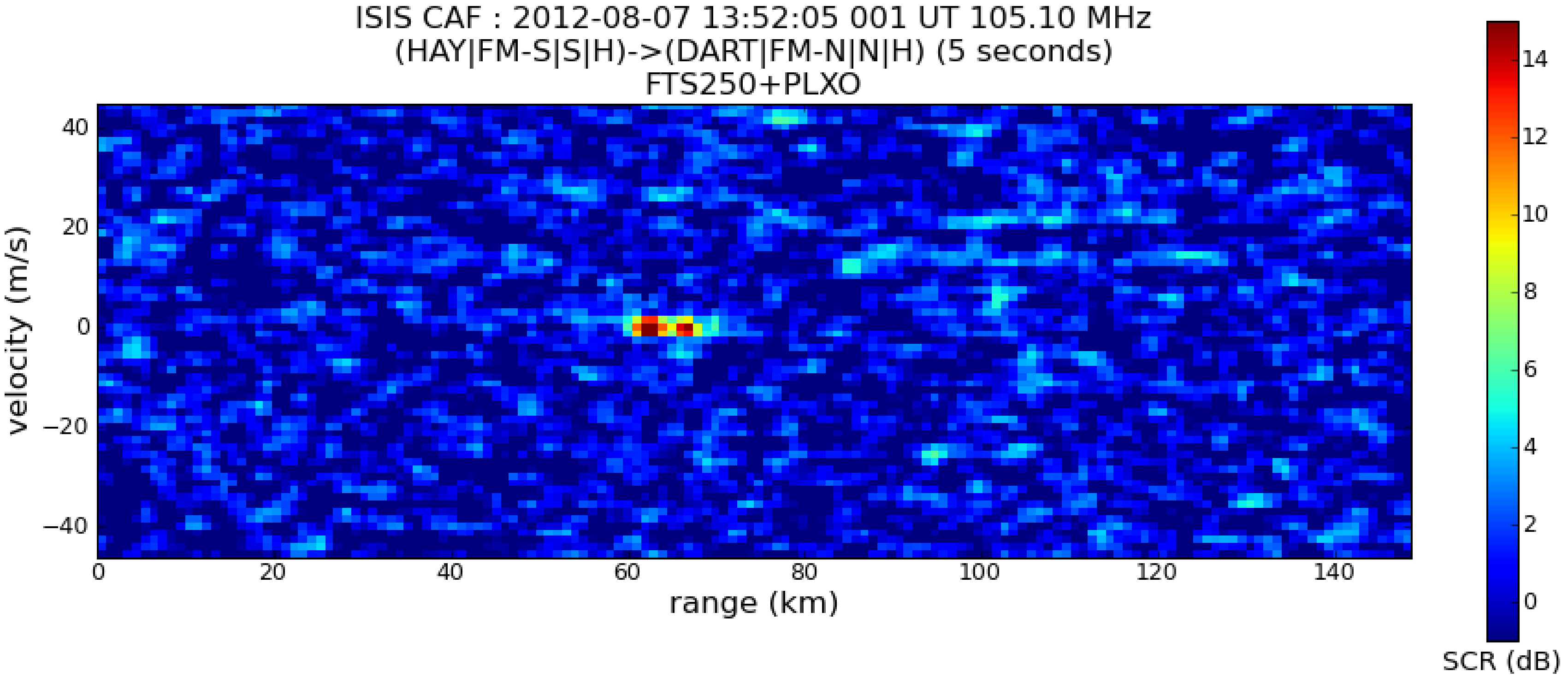
Dartmouth

# ISIS Oscillator Test

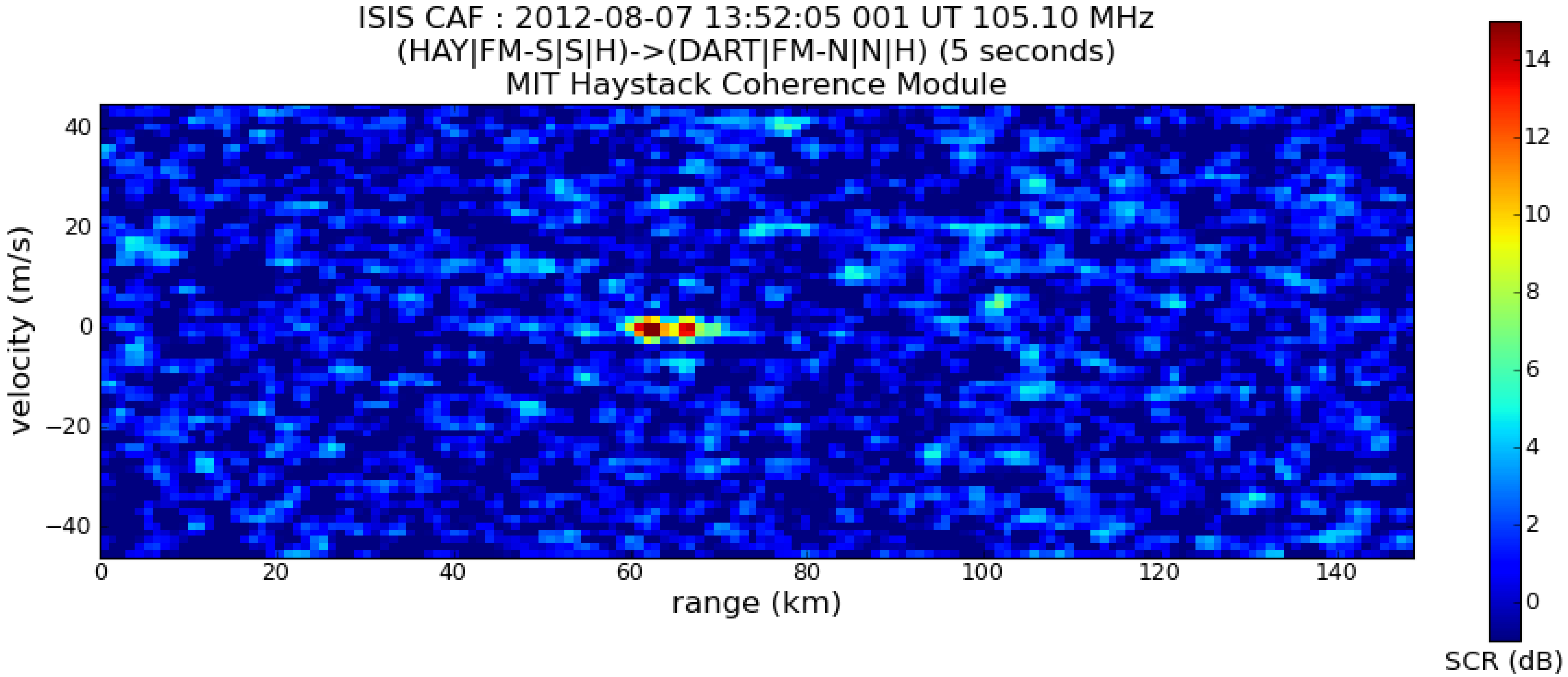


# ISIS Array Data (Commercial)



# ISIS Array Data (Coherence Module)



# Conclusions & Future

- Module can output signals stabilized to GPS
- Output frequency of coherence module is close to commercial quality
- Keep testing loop filter conditions to find better performance
- Upgrade hardware (better crystal oscillator could be worth extra cost in long run)

# Acknowledgements


- Mentors
  - Jim Marchese
  - Frank Lind
- Haystack Community
- NSF