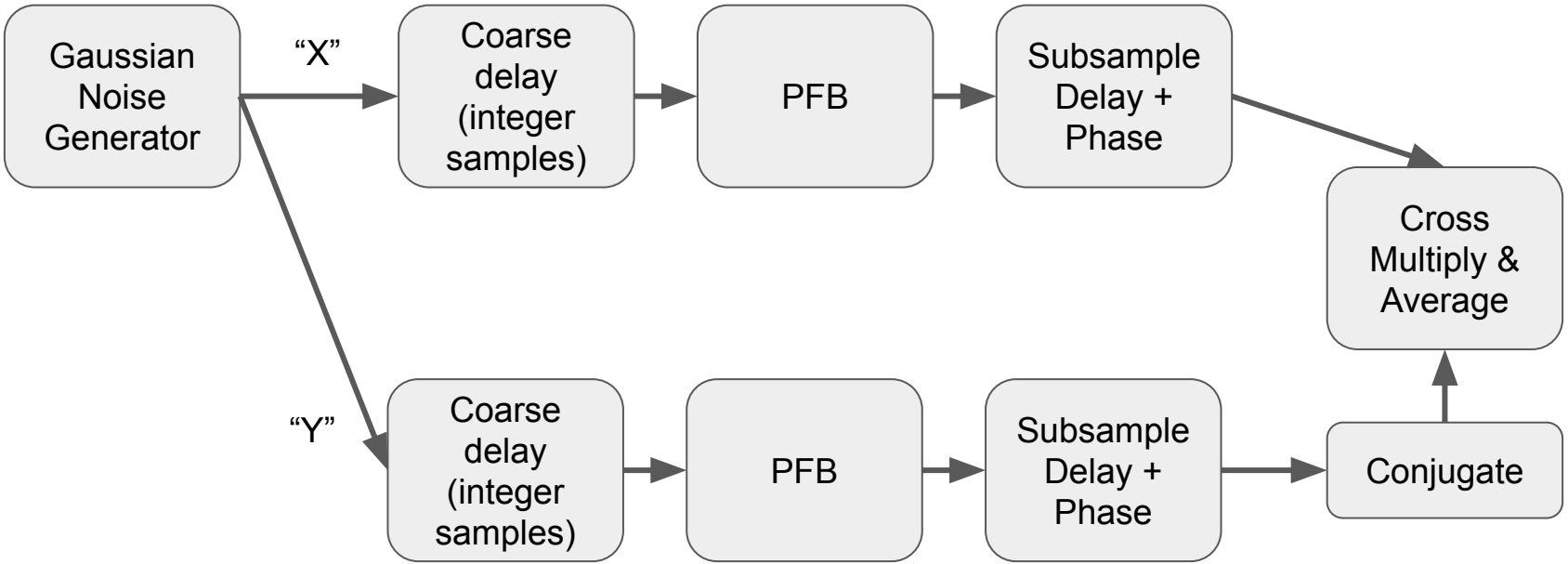
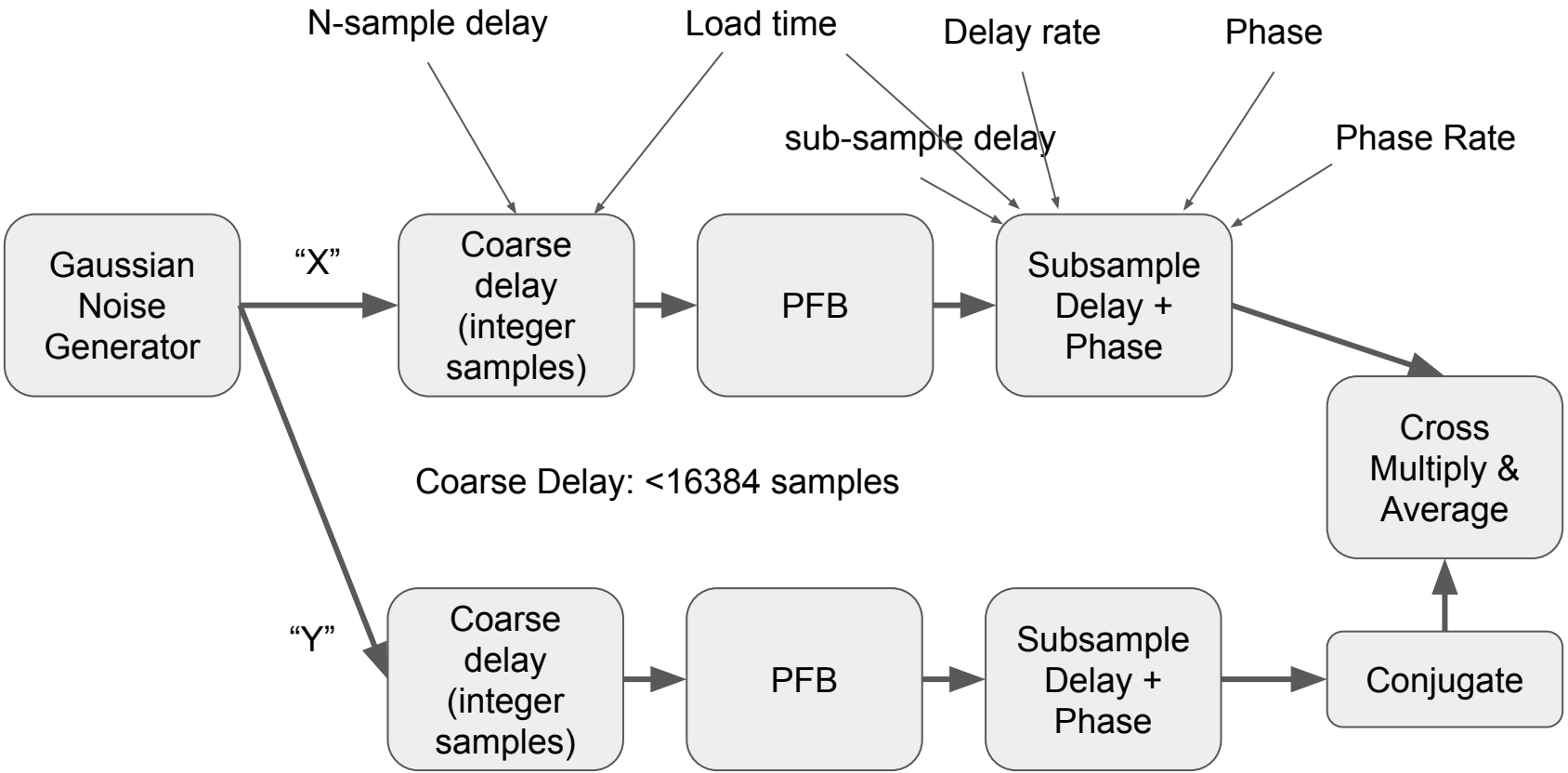
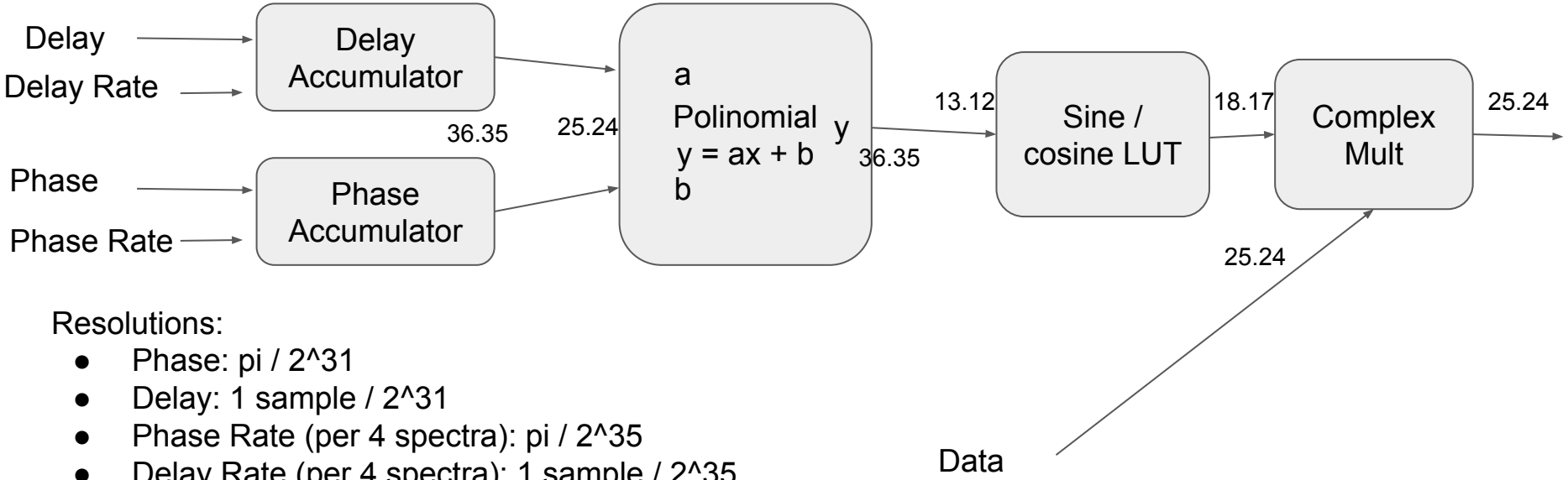
The Test Setup



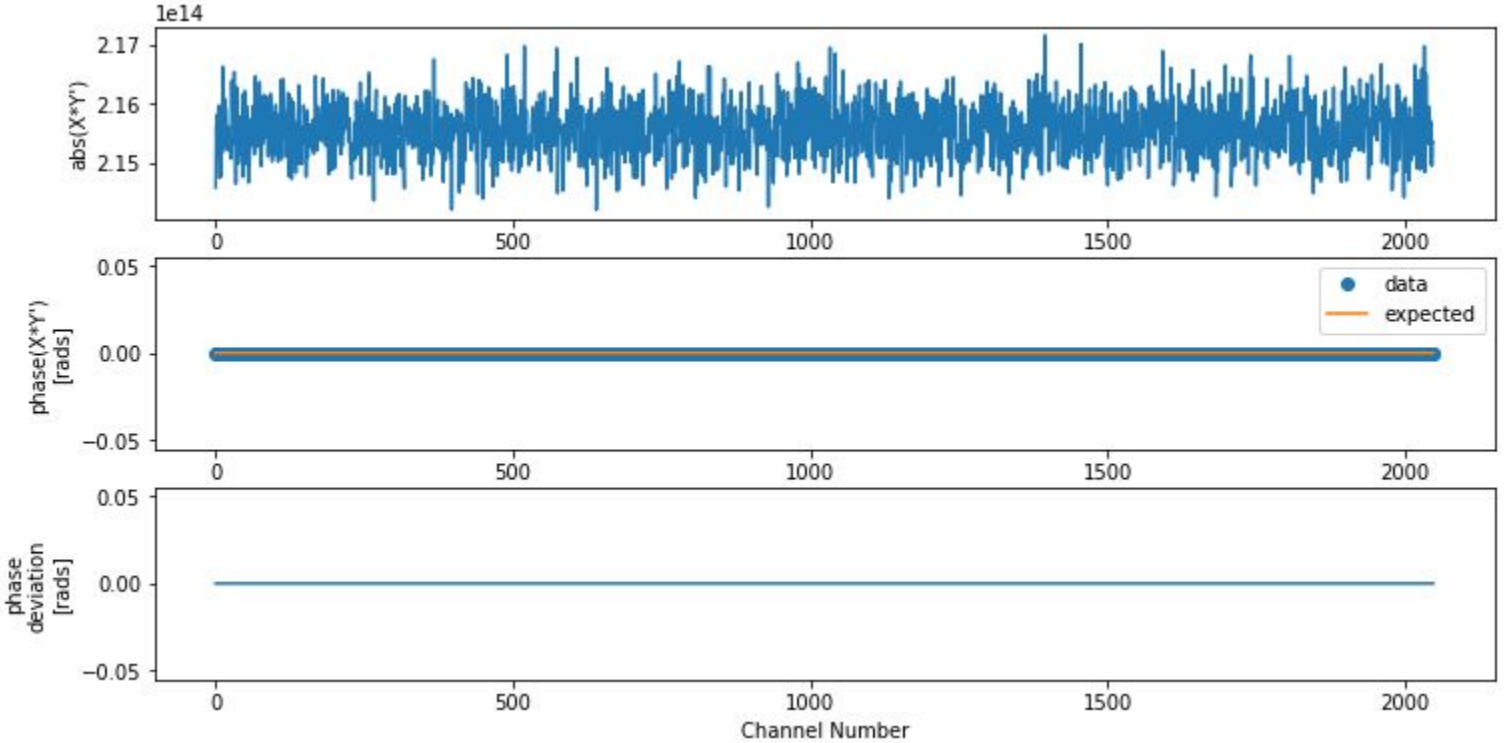

N-sample delay
Load time
Delay rate
Phase
sub-sample delay
Phase Rate
Gaussian Noise Generator
"X"
Coarse delay (integer samples)
PFB
Subsample Delay + Phase
Cross Multiply & Average
Coarse Delay: <16384 samples
"Y"
Coarse delay (integer samples)
PFB
Subsample Delay + Phase
Conjugate



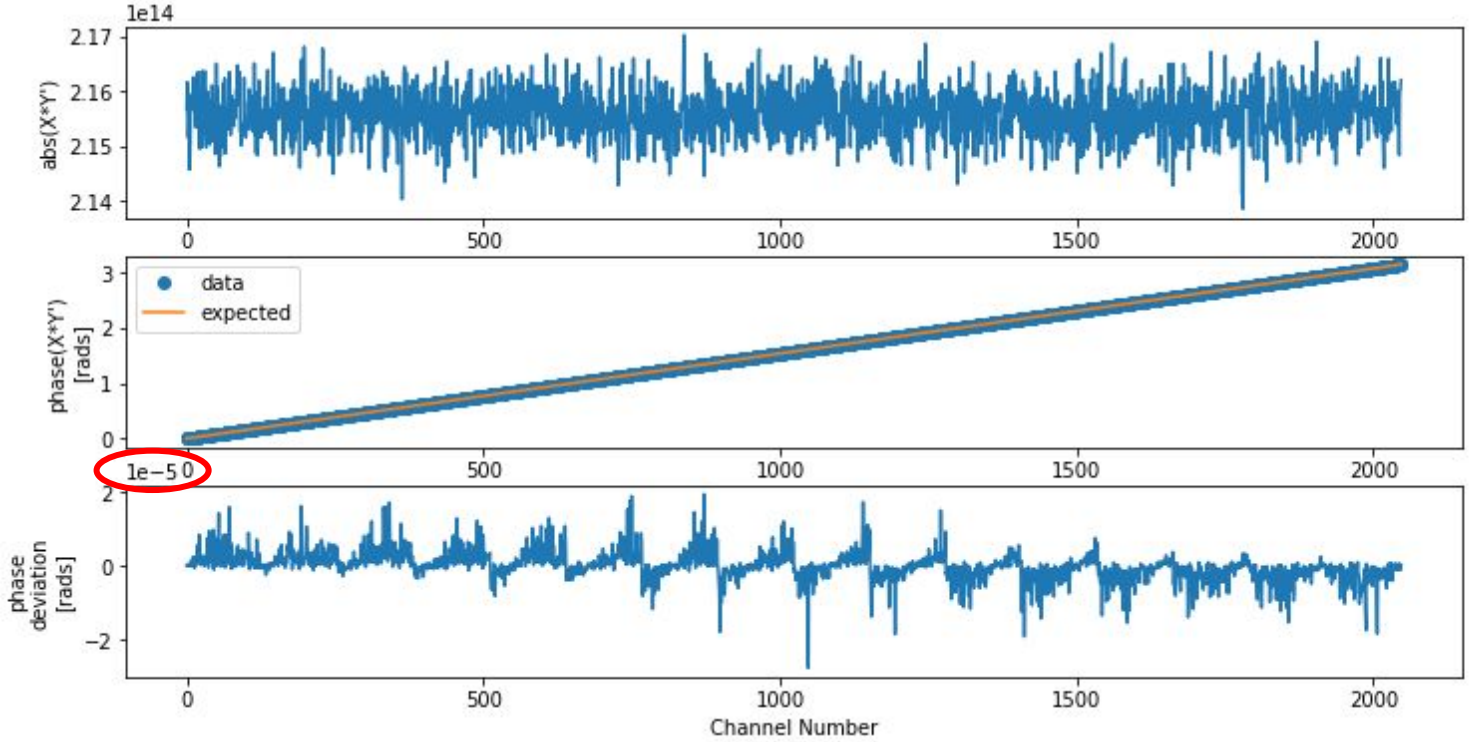
Resolutions:

- Phase: pi / 2^31
- Delay: 1 sample / 2^31
- Phase Rate (per 4 spectra): pi / 2^35
- Delay Rate (per 4 spectra): 1 sample / 2^35
- Phase Accumulator: pi / 2^35
- Delay Accumulator: 1 sample / 2^35
- Polynomial a coefficient: pi / 2^24
- Polynomial b coefficient: 1 sample / 2^24
- Polynomial y output: pi / 2^35
- LUT depth: 8192
- LUT output precision: 18.17 + 18.17 bit complex
- Data resolution: 25.24 + 25.24 bit complex

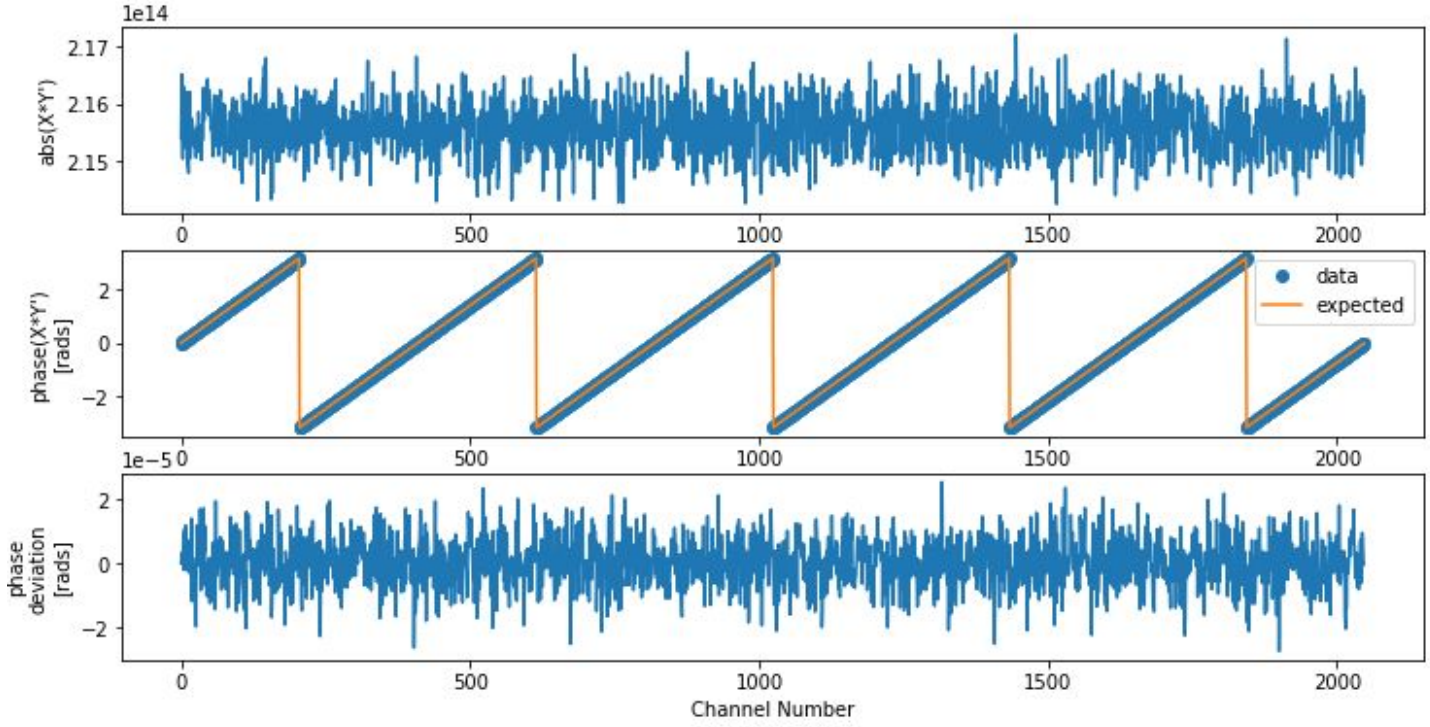
Test 1: Static Coarse Delays
X-Delay = Y-delay = 0



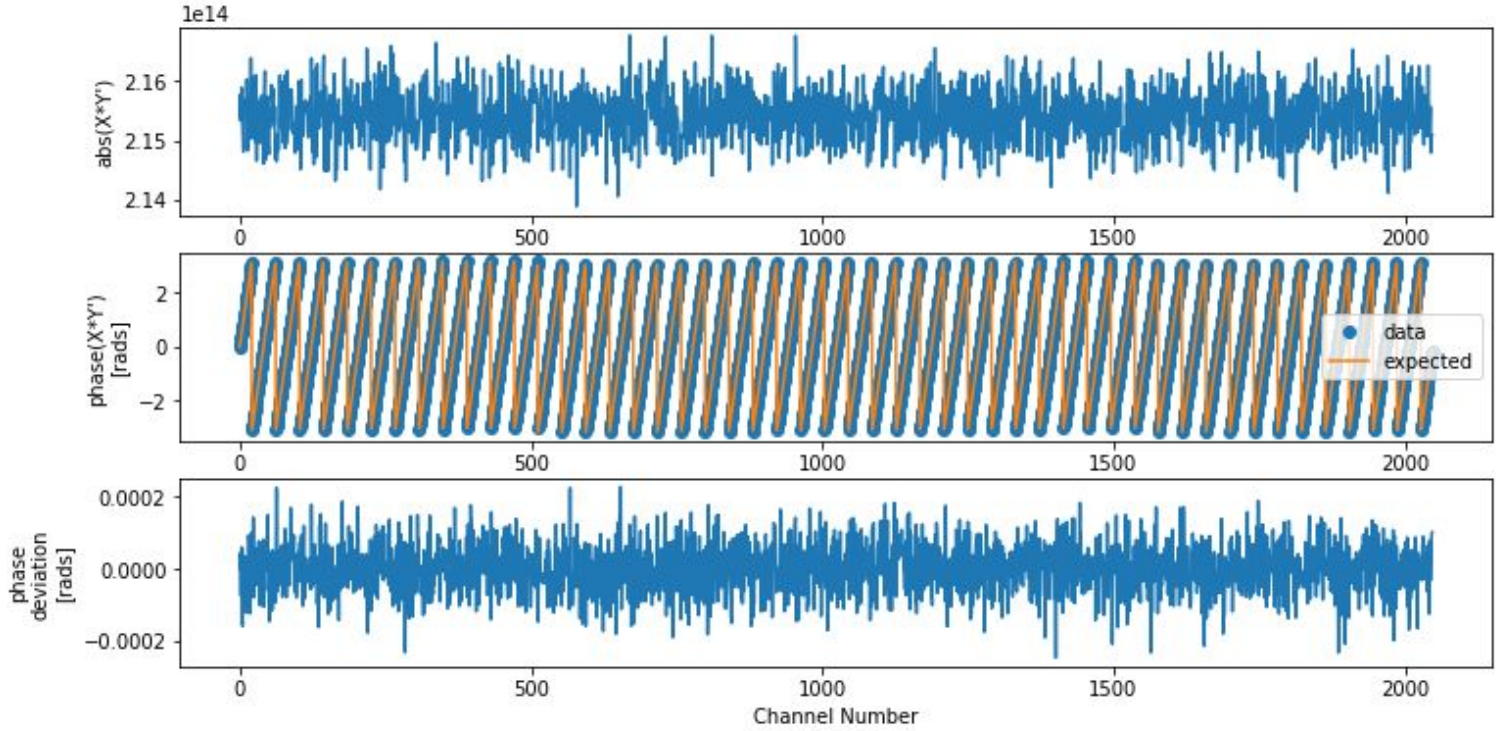
Test 1: Static Coarse Delays
X-Delay = 1 Sample; Y-Delay = 0



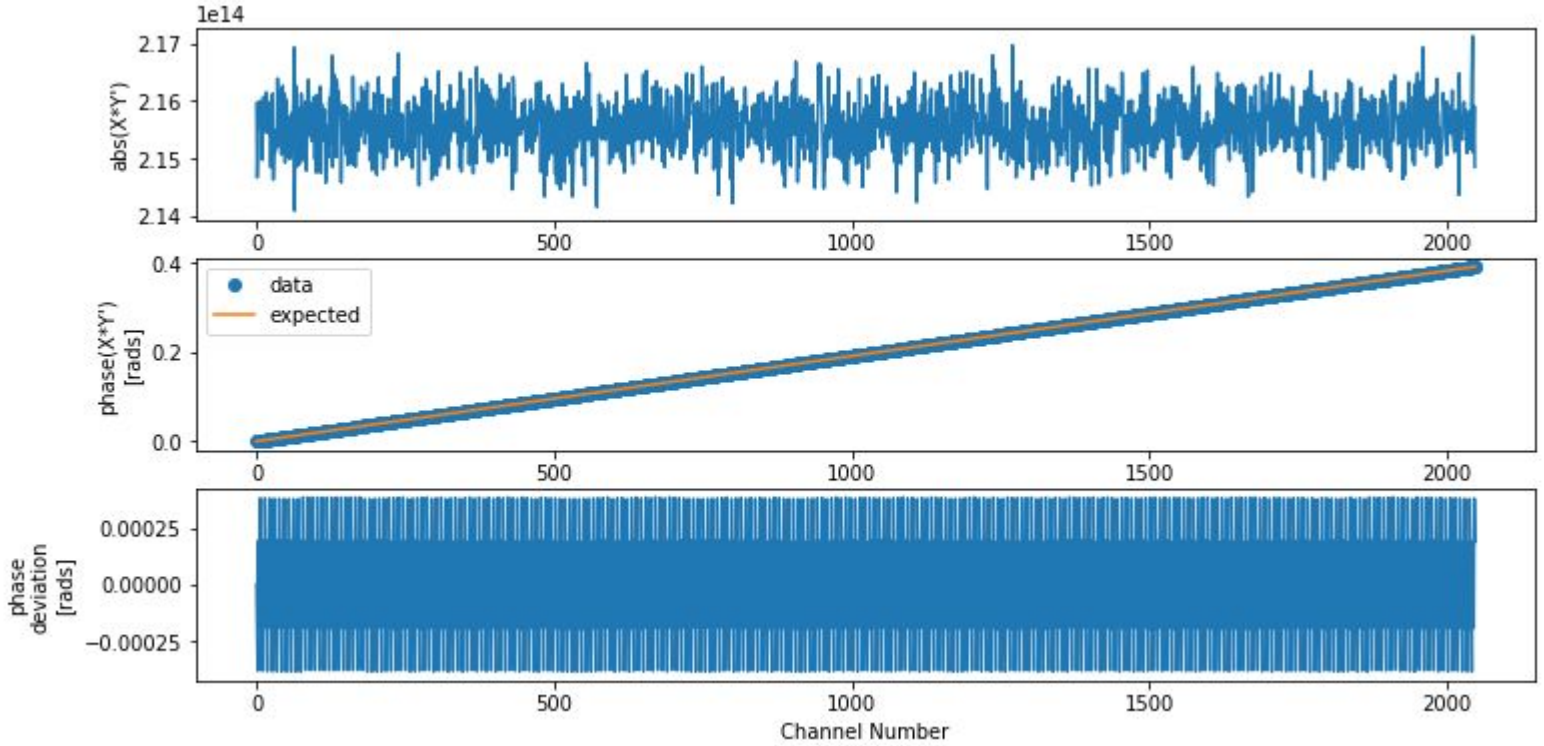
Test 1: Static Coarse Delays
X-Delay = 10 Sample; Y-Delay = 0



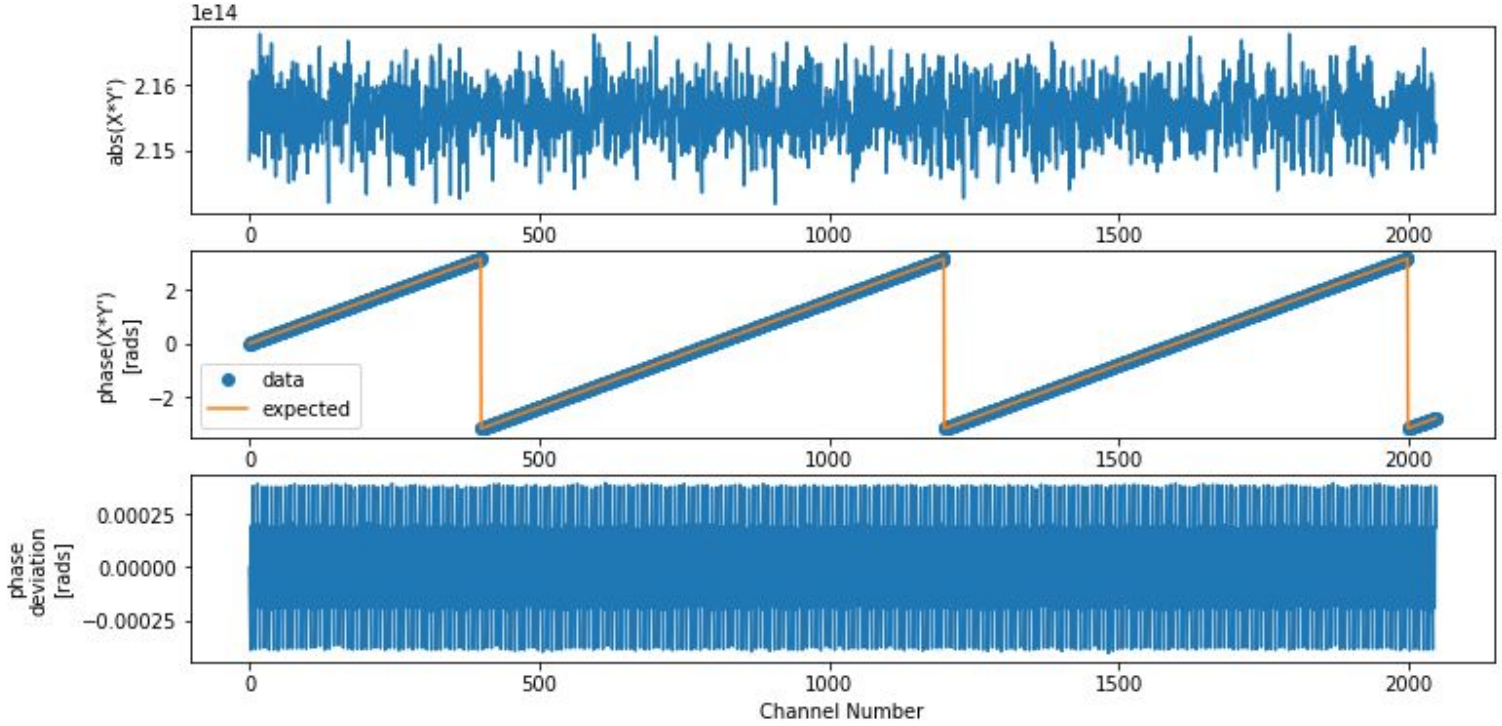
Test 1: Static Coarse Delays
X-Delay = 100 Sample; Y-Delay = 0



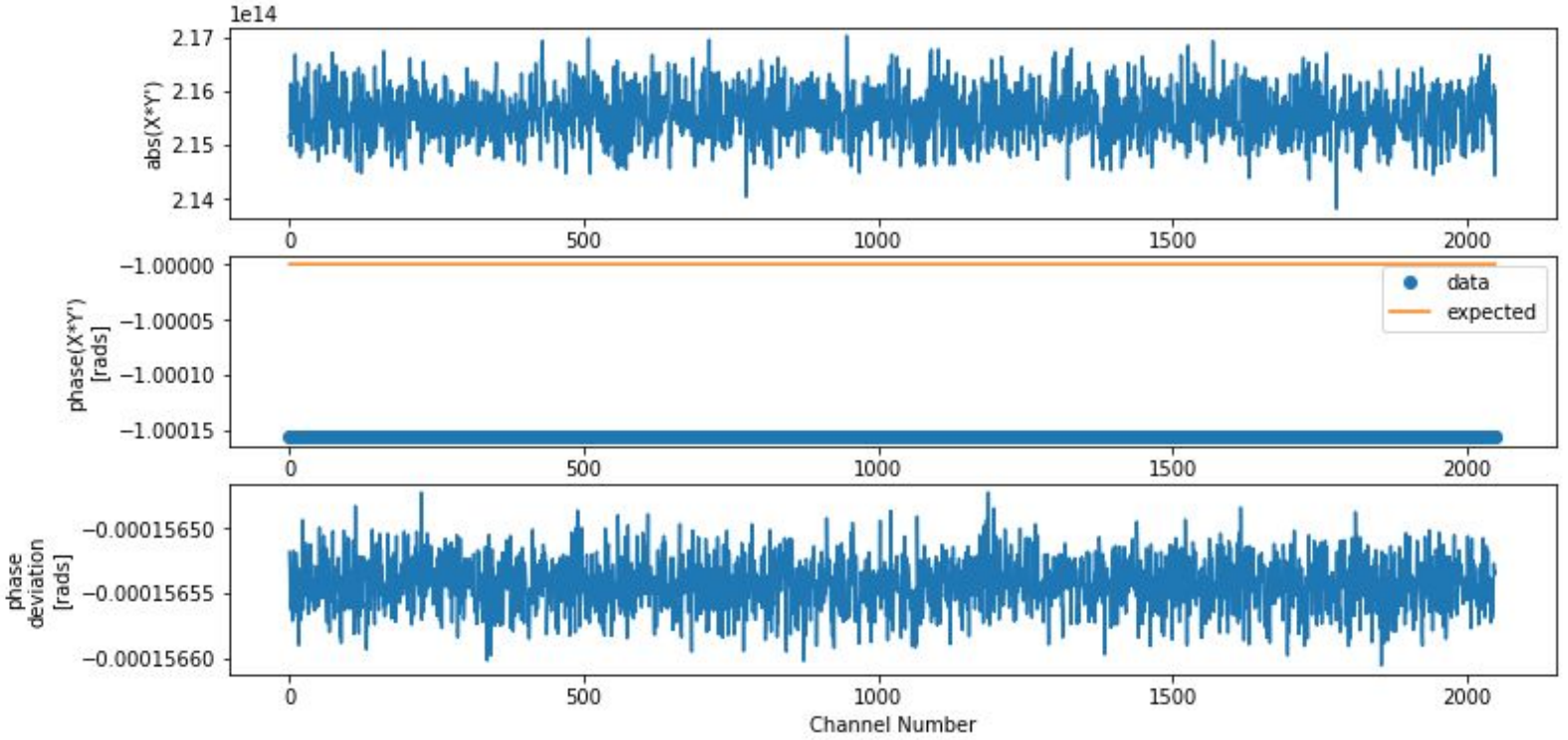
Test 2: Static Fine Delays
X-Delay = 0.125 Sample; Y-Delay = 0



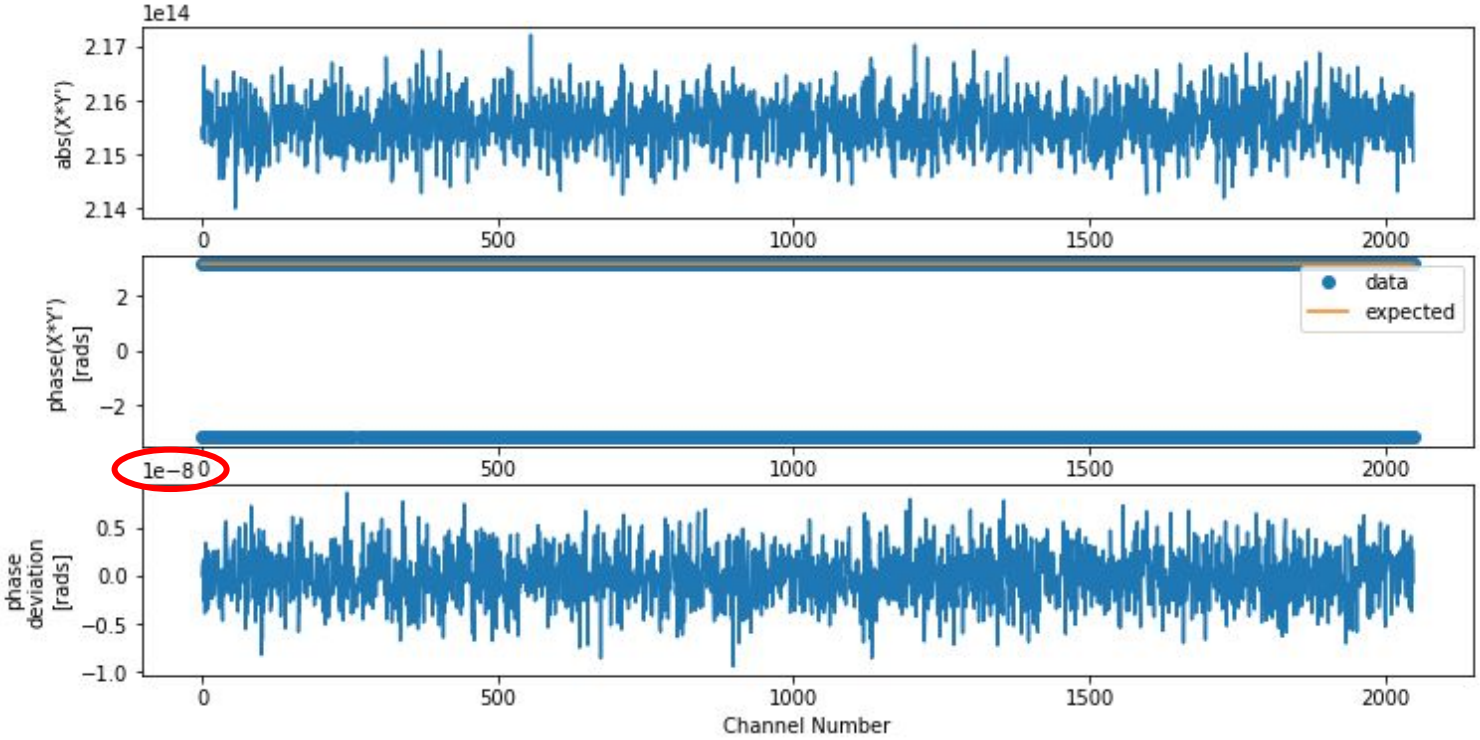
Test 3: Static Coarse+Fine Delays
X-Delay = 5.125 Sample; Y-Delay = 0



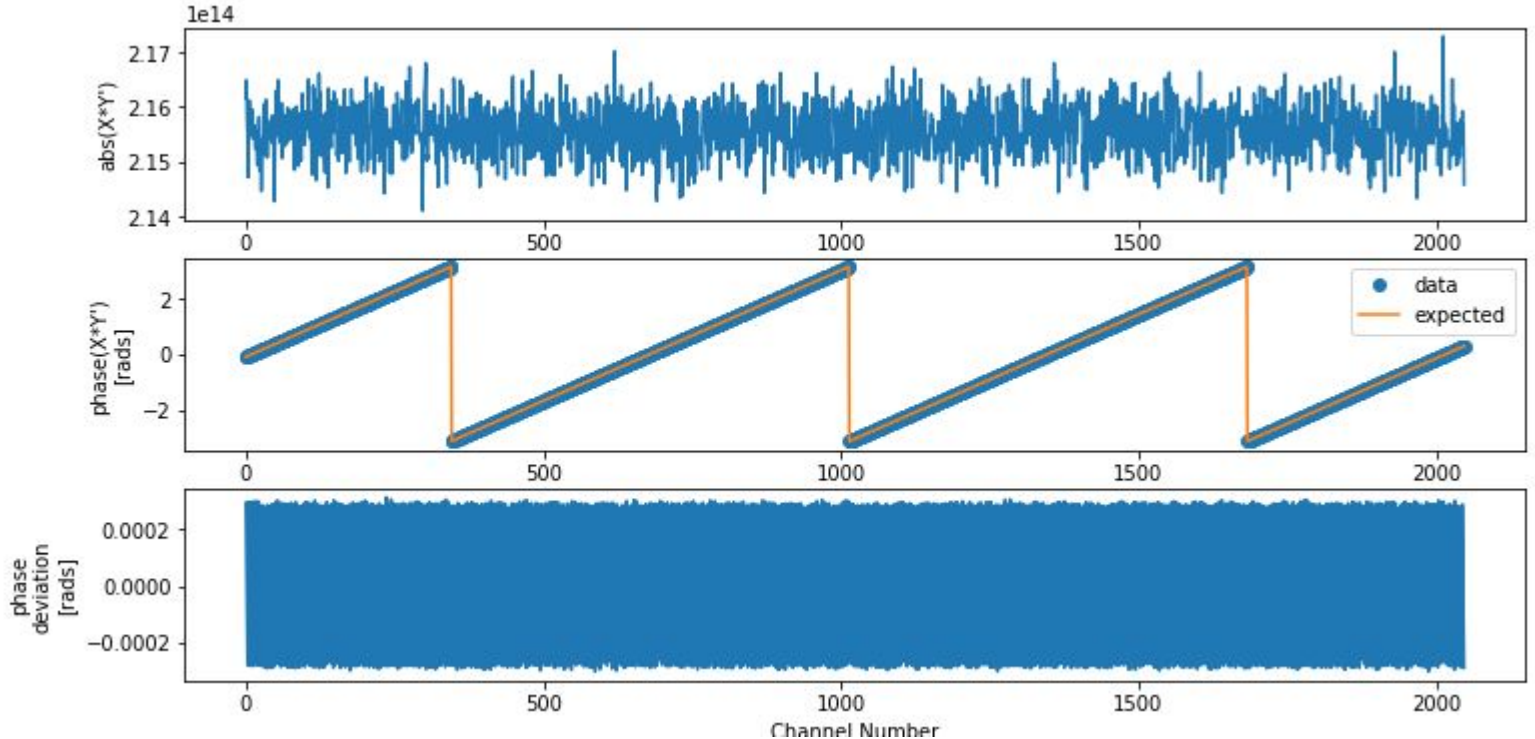
Test 4: Static Phase Shift
X-Delay = 1 rad; Y-Delay = 0



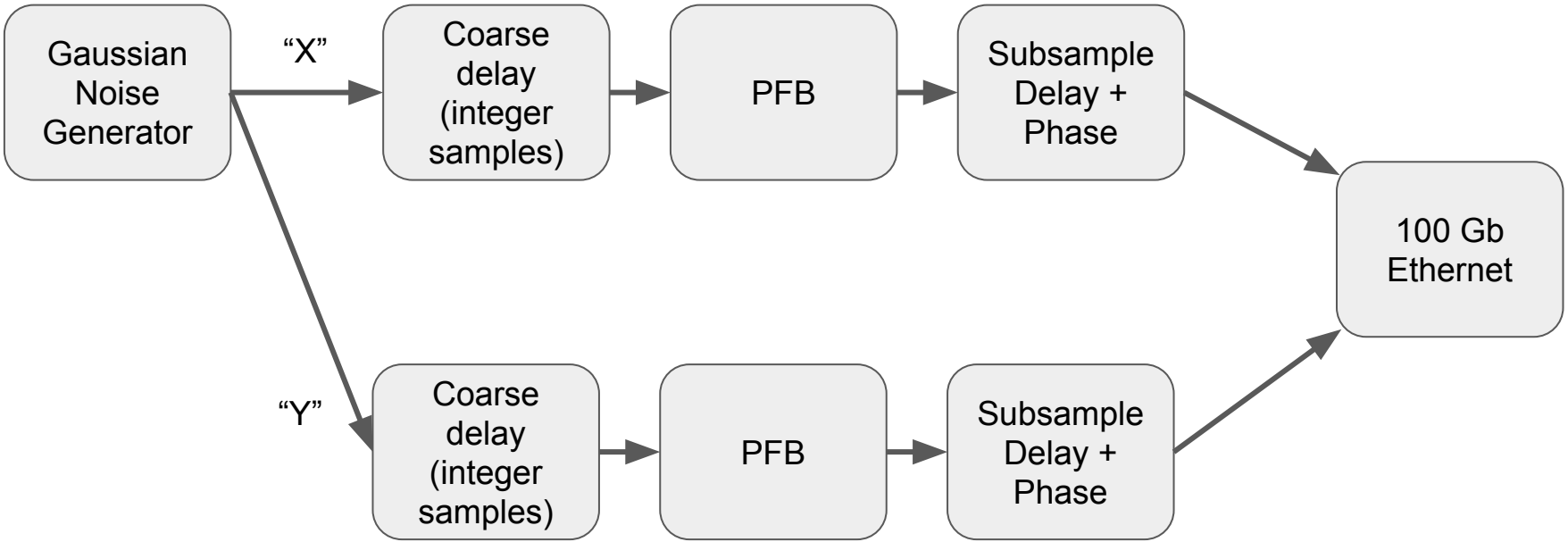
Test 4: Static Phase Shift
X-Delay = -pi rad; Y-Delay = 0



Test 5: Static Phase Shift + Delay
X-Delay = 6.125 samples + 0.1 rad; Y-Delay = 0



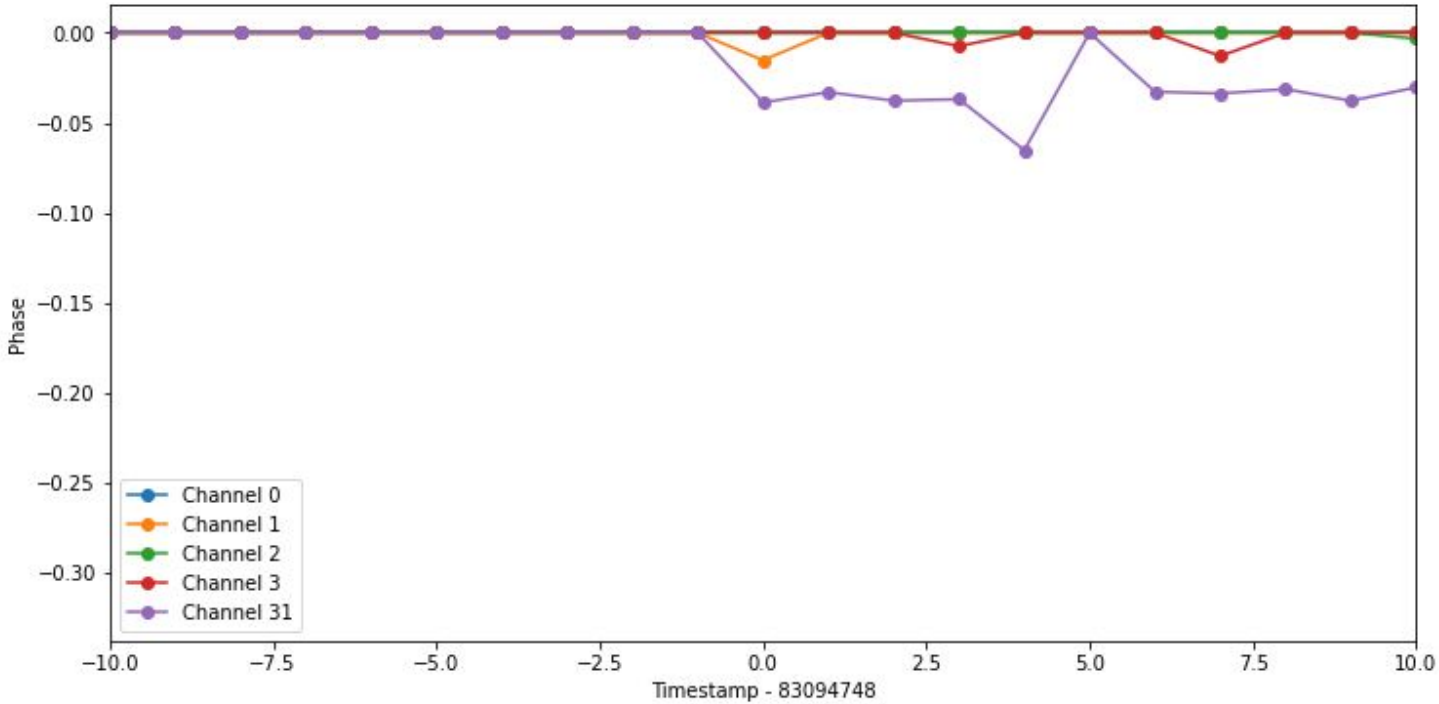
The Test Setup: Timing



Test 6: Subsample Delay Timing

1. Start with no delays on X or Y
2. On Spectrum 83094748, apply 0.3 sample delay to X
3. Capture Packets
4. Plot conj(X) * Y for time samples ~83094748

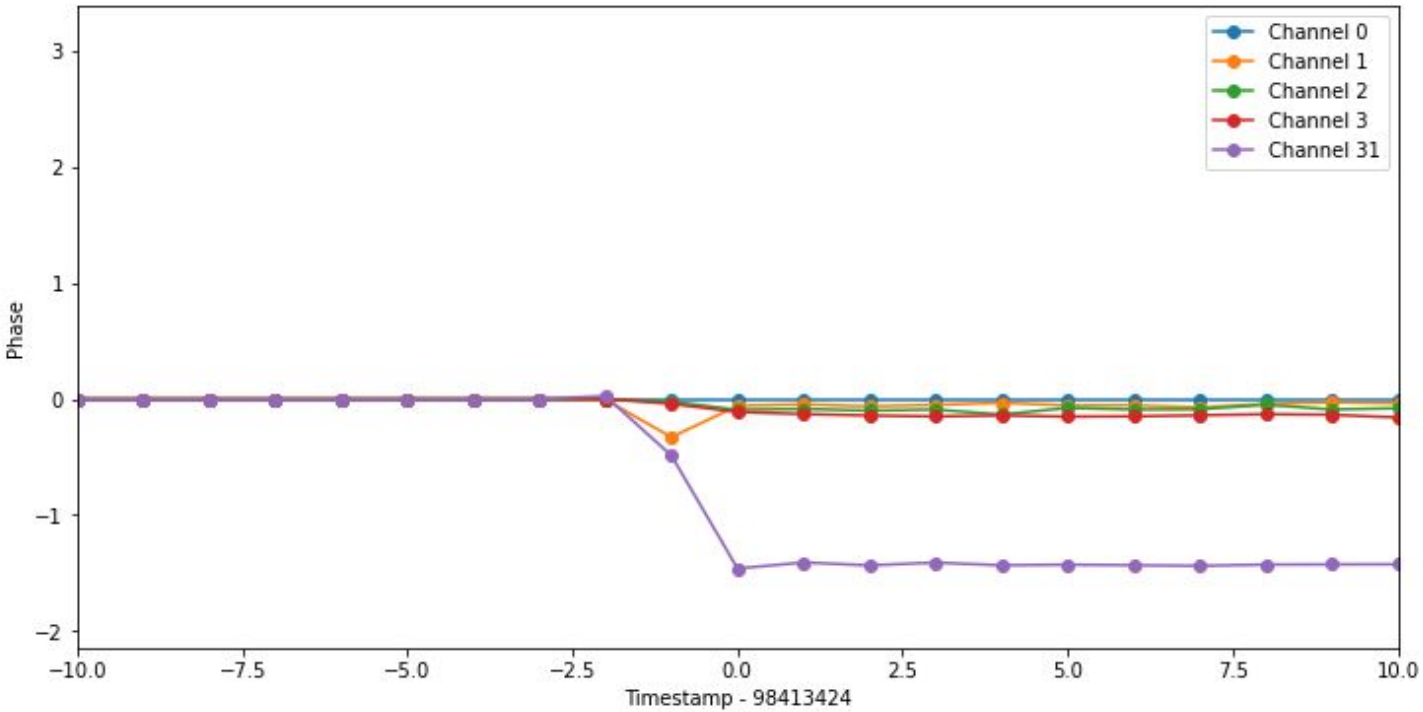
Test 6: Subsample Delay Timing



Test 7: Coarse Delay Timing

1. Start with no delays on X or Y
2. On Spectrum 98413424, apply 30 sample delay to X
3. Capture Packets
4. Plot conj(X) * Y for time samples ~98413424

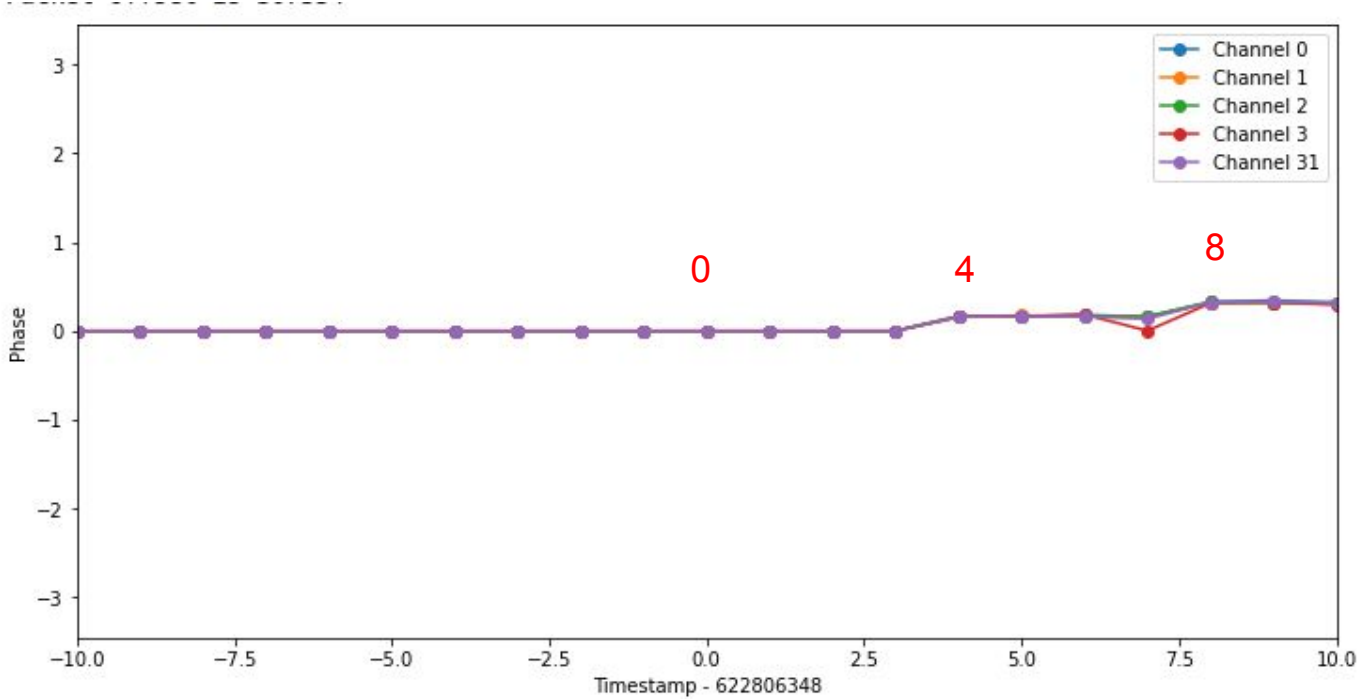
Test 7: Coarse Delay Timing



Test 8: Fine Delay Rate Timing

1. Start with no delays on X or Y
2. On Spectrum 622806348, apply 20000 rads / second phase rate to X
3. Capture Packets
4. Plot conj(X) * Y for time samples ~622806348

Test 8: Fine Delay Rate Timing

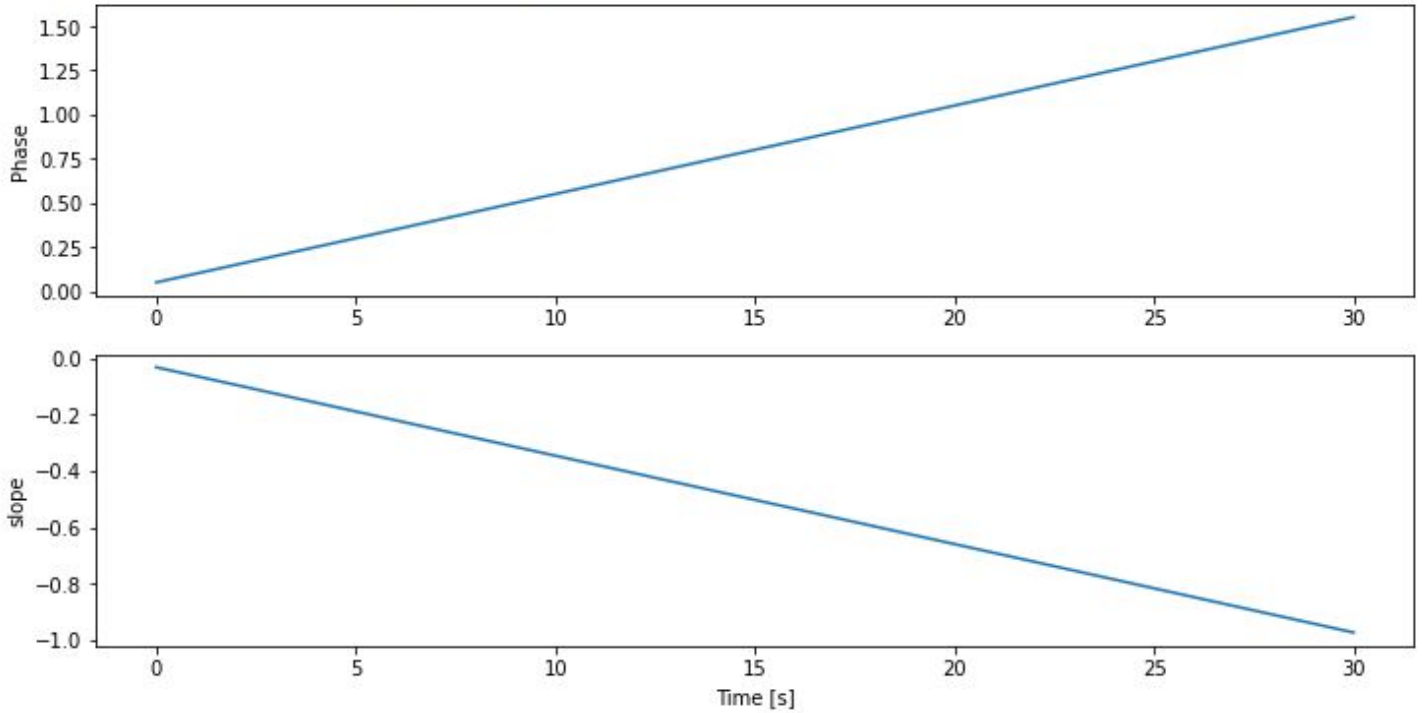


Test 9: Delay / Phase Rate Magnitudes

1. Set delay / phase tracking to start at 0, and increment by 0.05 radians per second, and 0.01 samples per second
2. Poll Firmware ever ~1ms for reported phase / delay applied over a period of 30s

Test 9: Delay (a.k.a. “slope”) Rate / Phase Rate Magnitudes

```
Phase dp/dt: 0.049991 Radians per second
Slope ds/dt: -0.009997 ADC samples per second
```



Summary

1. Phase / Delay magnitudes appear consistent with <10^-3 radian precision (<0.1 degree)
2. Timing of subsample-delay loads verified
3. Timing of phase-rate additions verified
4. Timing of coarse delay load consistent with PFB implementation (I think)
5. Internal firmware reports of long term (30 seconds) delay / phase increment consistent with API commands

TODO

1. Tweak API Coarse/Fine delay allocation
   - Currently using floor(DELAY) for coarse delay. Should either round, or allocate based on direction of delay increment.

2. Add calibration coefficients to API
   - Already in firmware

3. Add auto-calculation of phase coefficients to API, based on LO