Double-demodulation Scheme ALPS-IIc Heterodyne Detector

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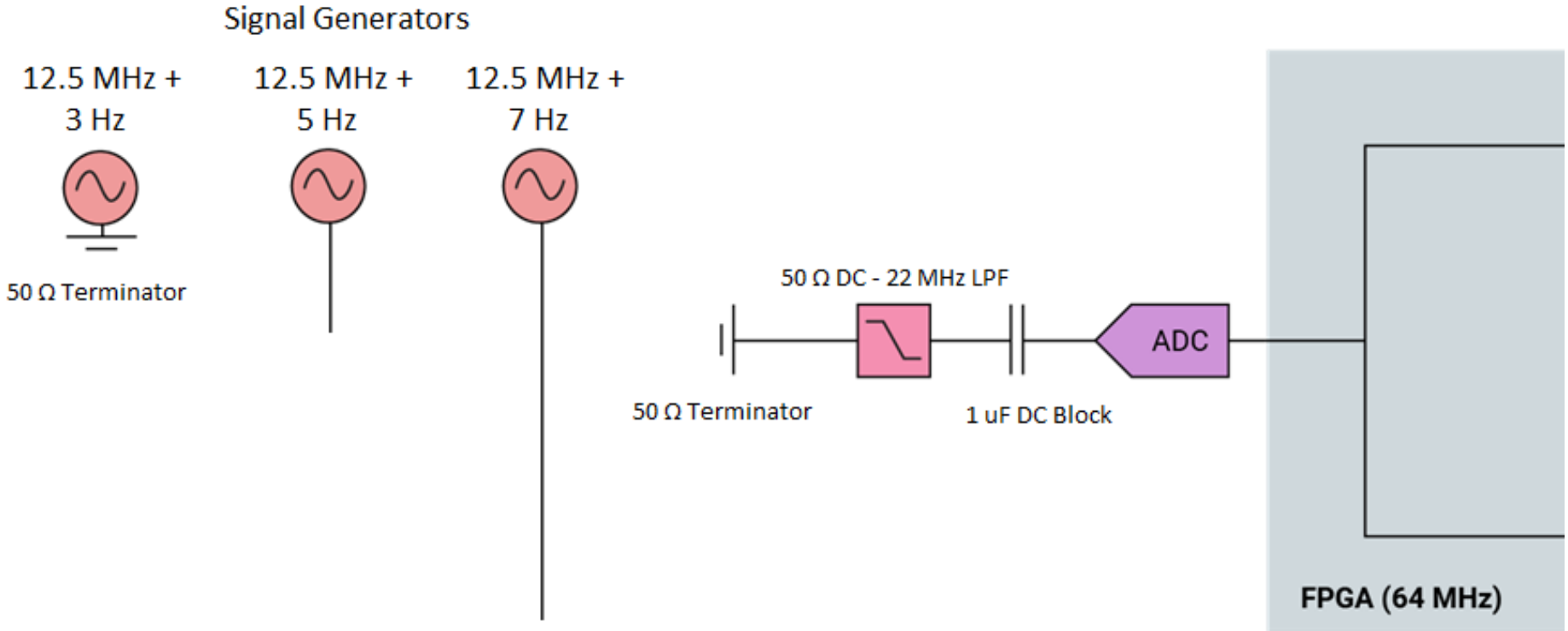
Preliminary Results Mainz Meeting 7 March 2017

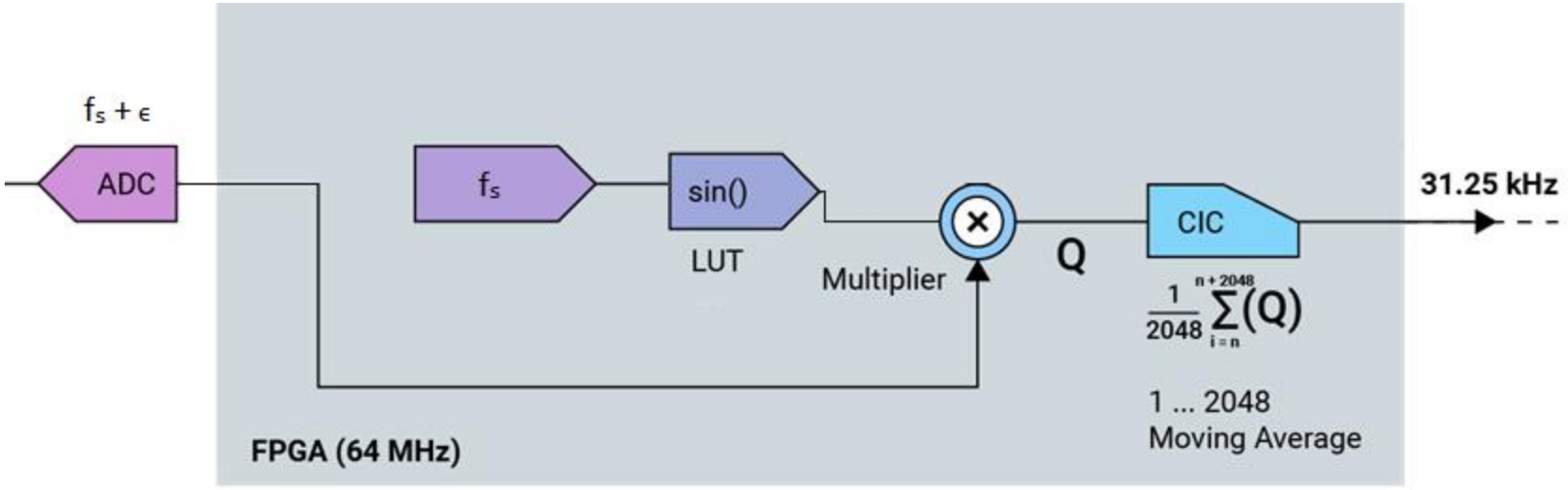
(Very) Weak Signal

- 3 Signal generators phase locked to ADC/FPGA clock
- Not physically connected to ADC



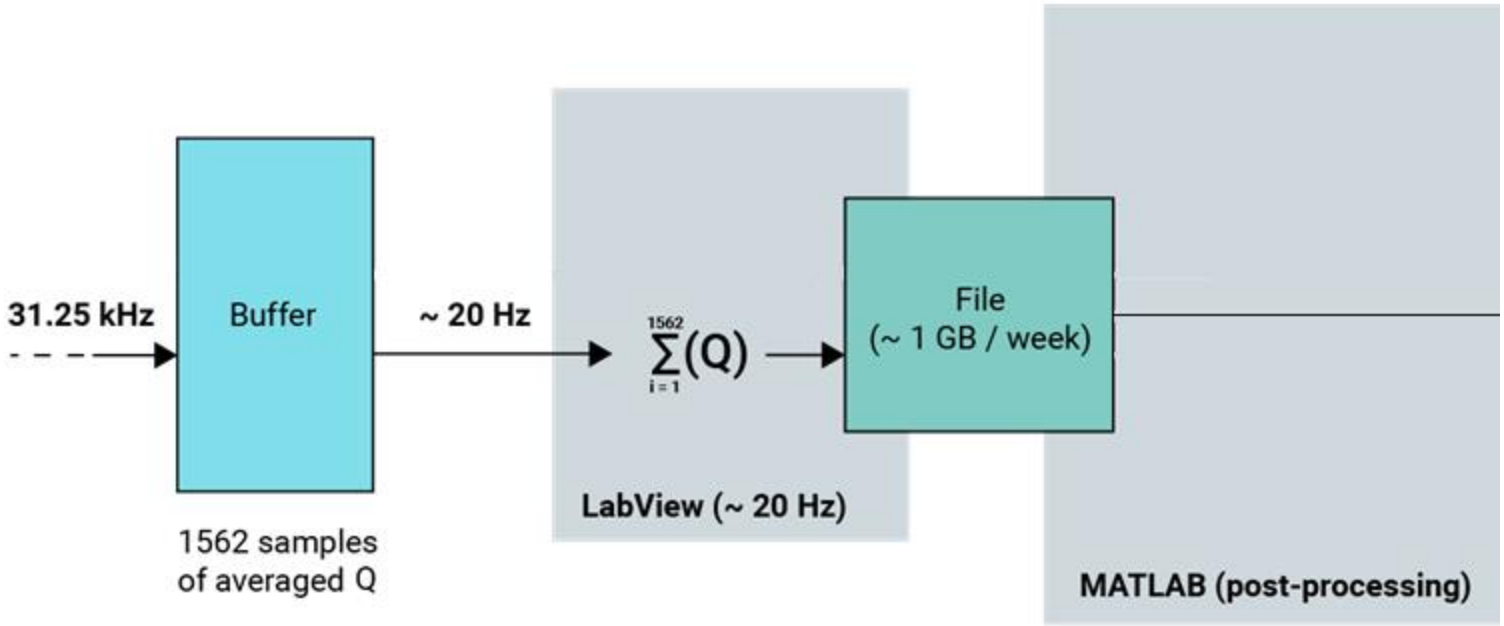
1st Demodulation (FPGA)

- 64 MHz sampling rate (31.25 kHz output data rate)
- Only multiplication by sine at f_s on the FPGA



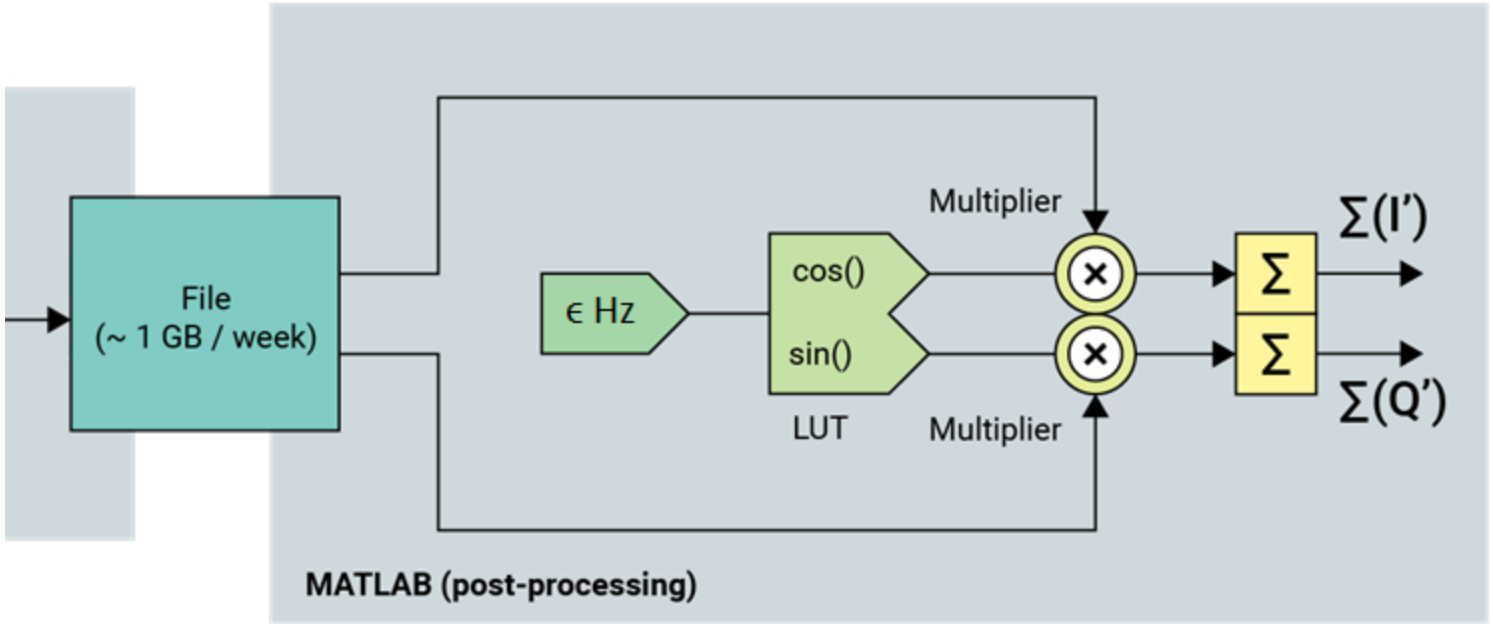
Data Transfer and Reduction

- Summation 1562 samples of Q
- File size does not exceed 1 GB / week

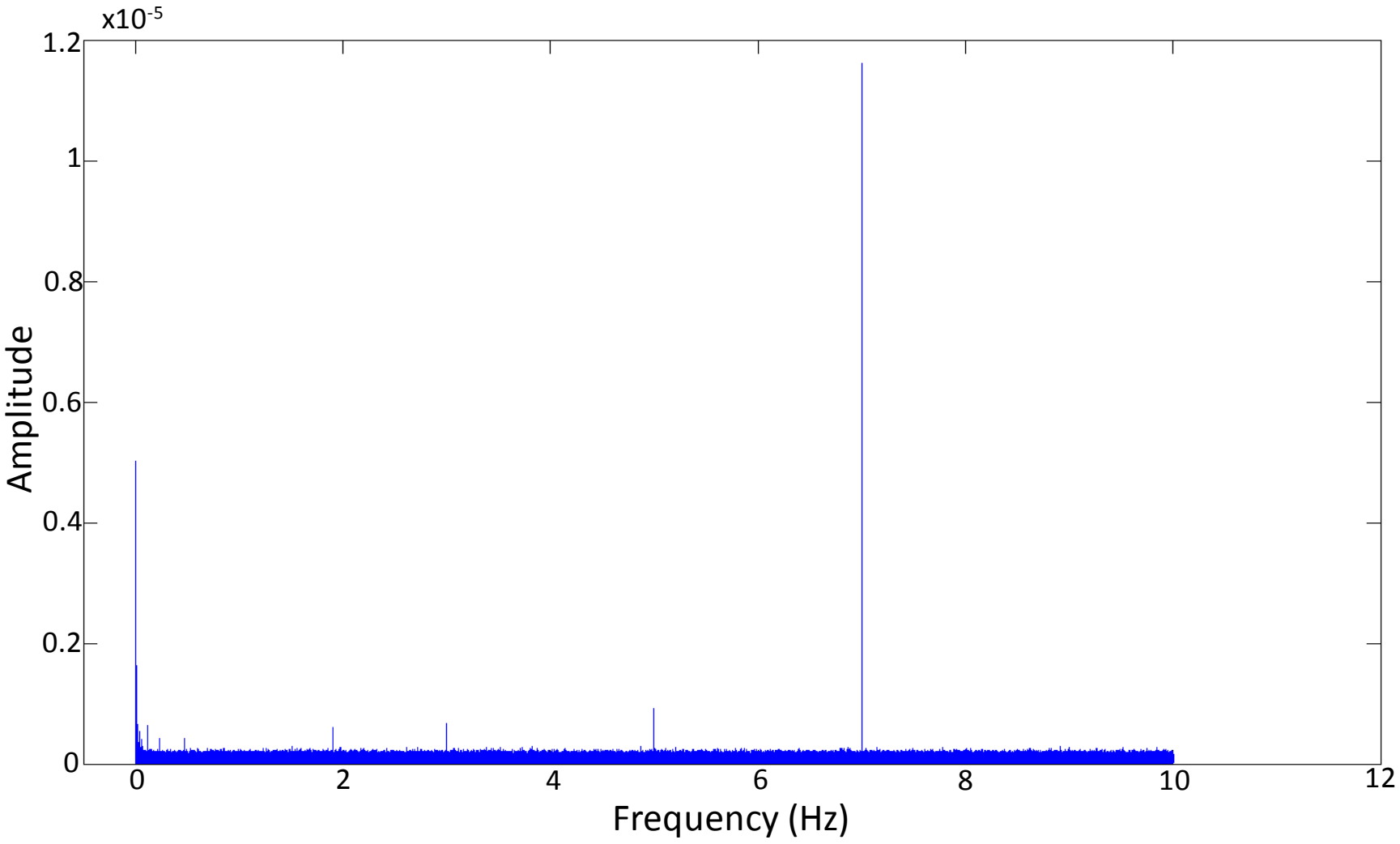


Data Transfer and Reduction

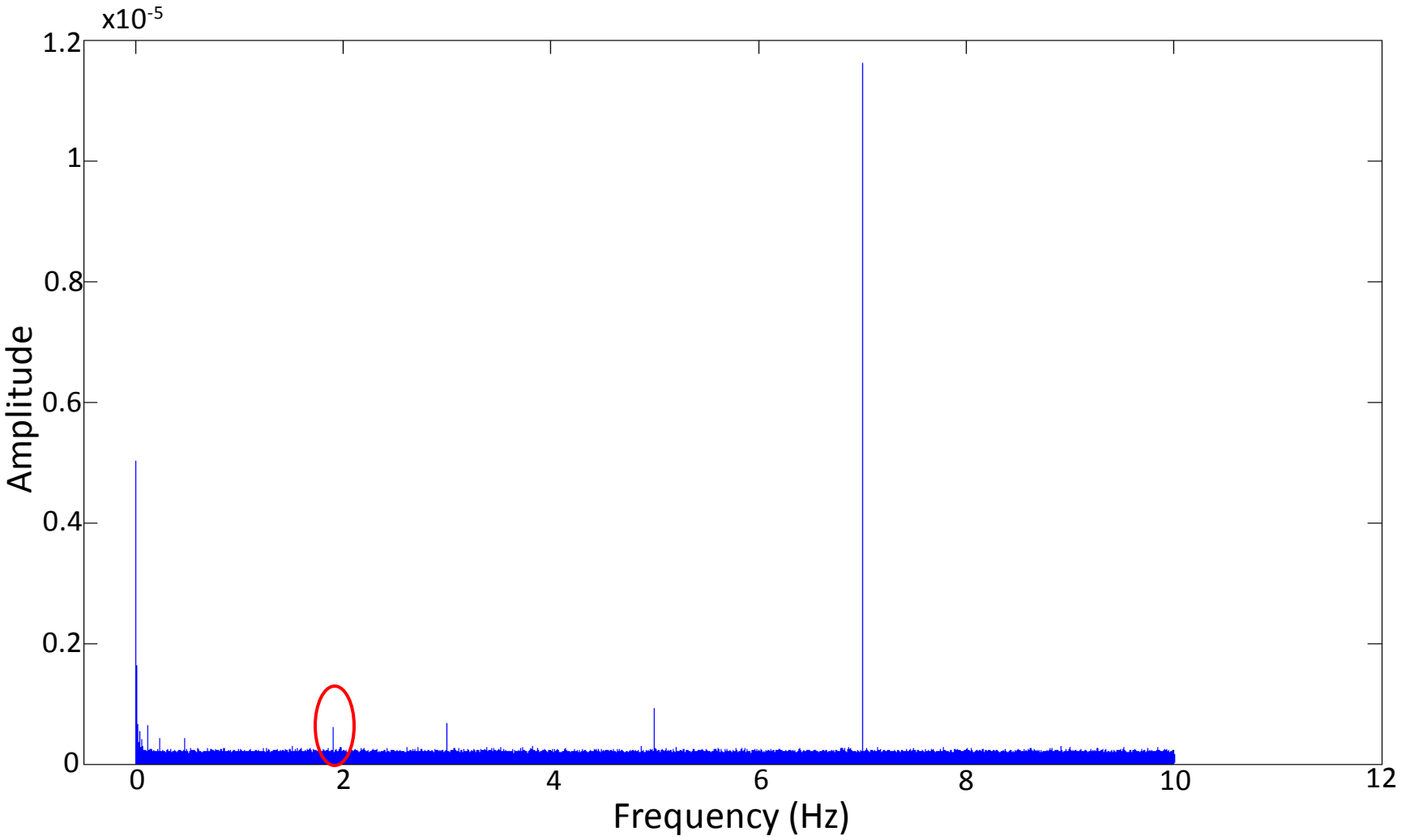
- Data imported into MatLab
- MatLab LUT used to generate sine/cosine for second stage demodulation



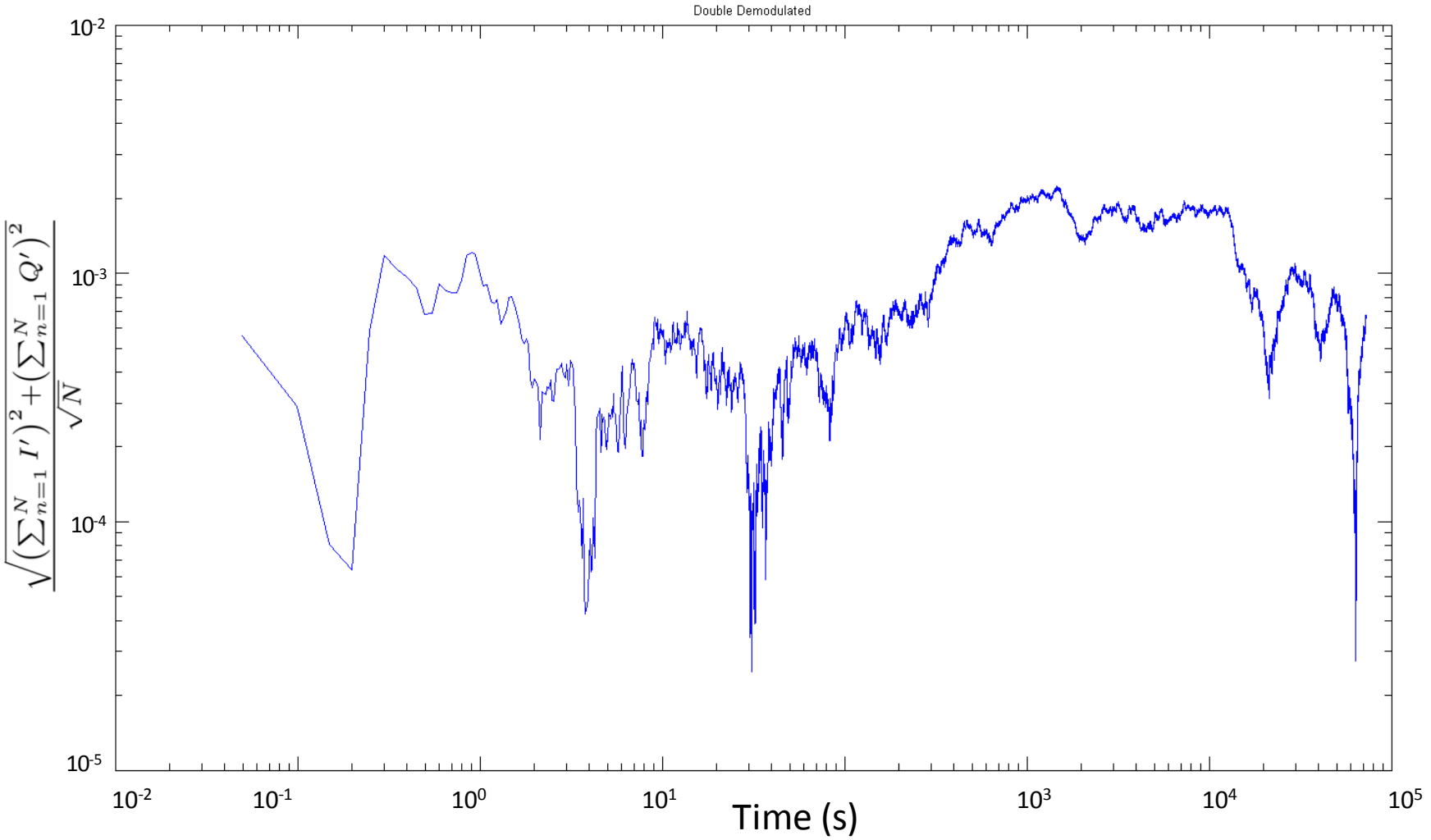
3, 5, and 7 Hz Modulation in Q Data



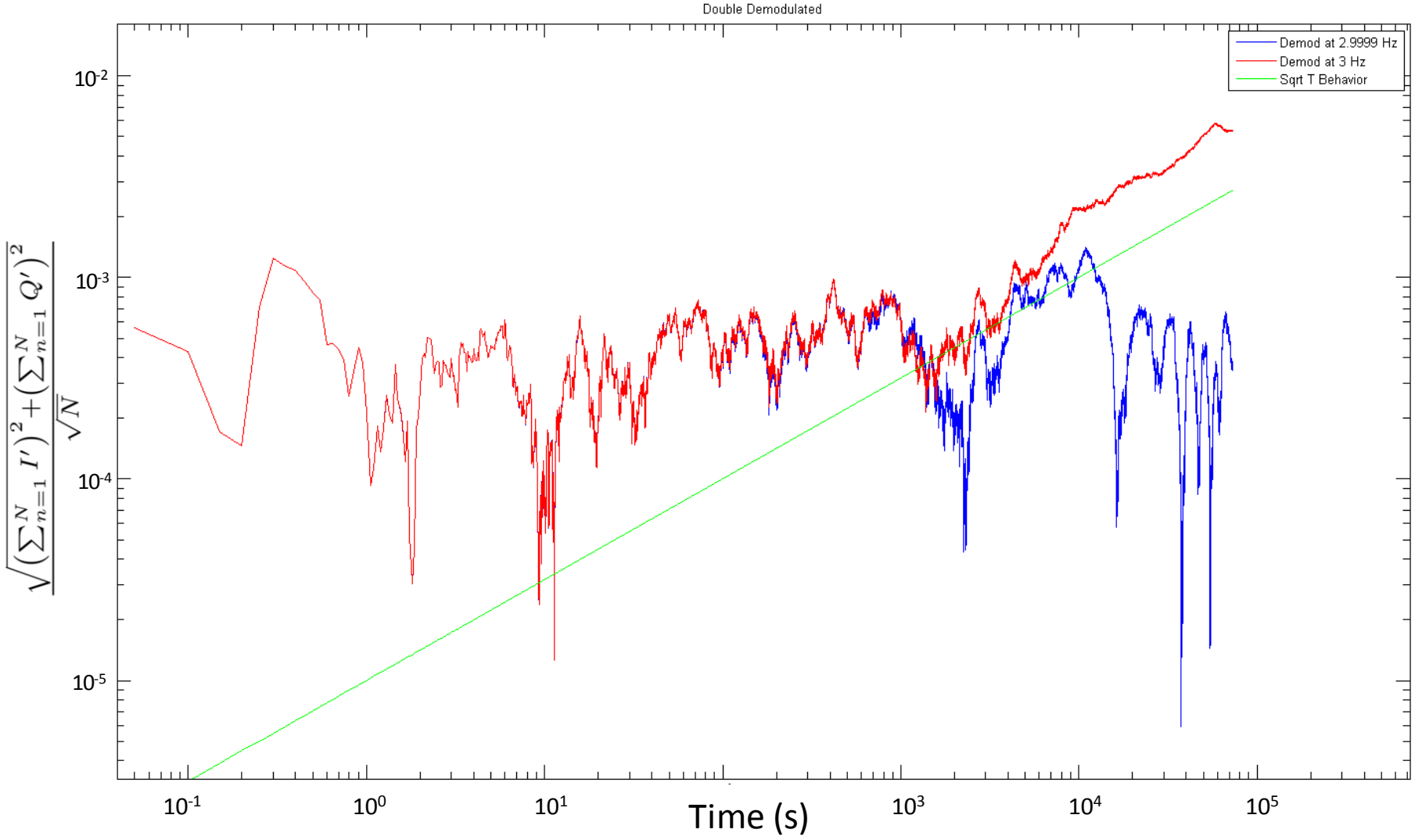
3, 5, and 7 Hz Modulation in Q Data

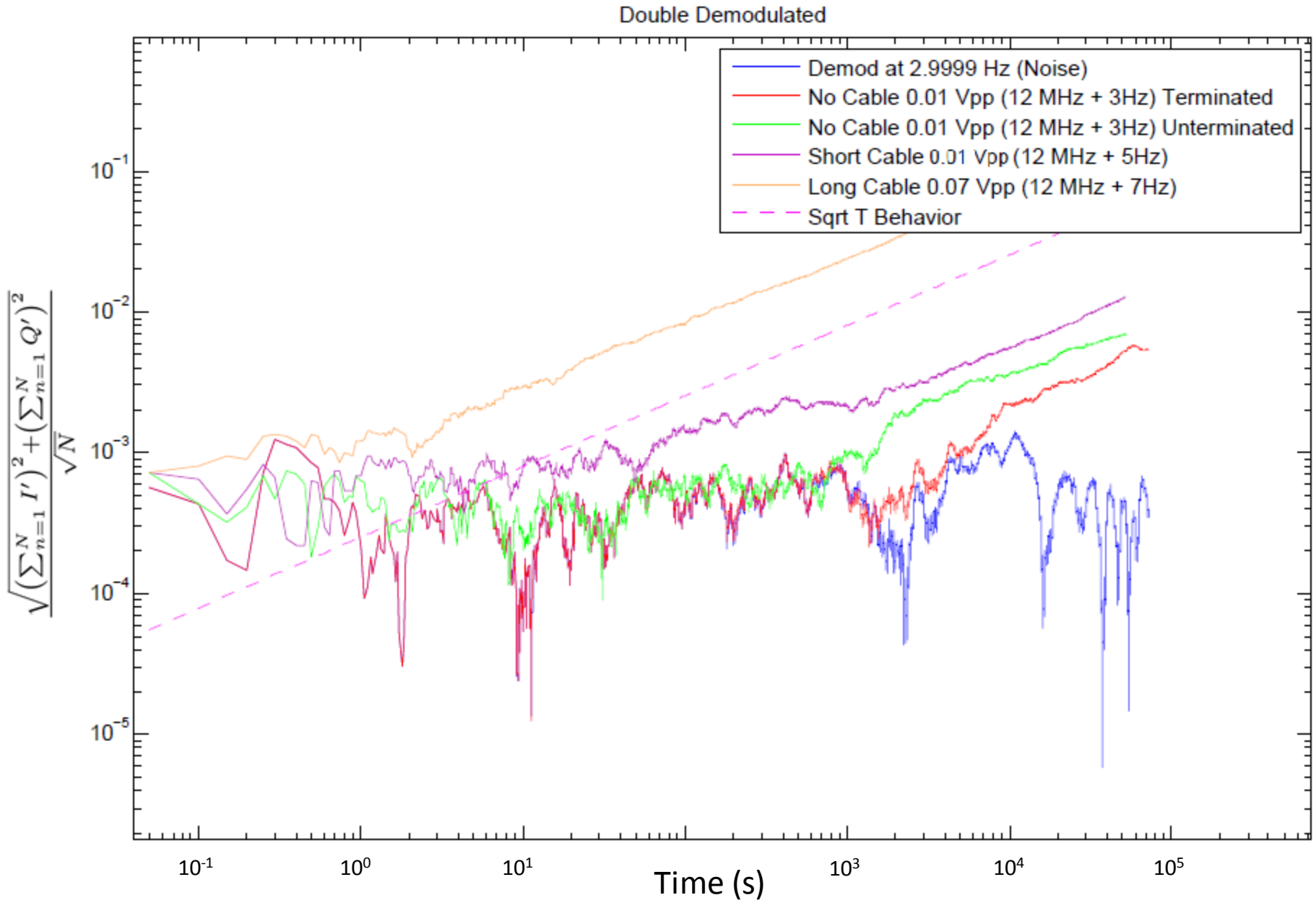


1.9073 Hz Demodulation



Demodulation On/Off Resonance




Double Demodulated
Demod at 2.9999 Hz (Noise)
No Cable 0.01 Vpp (12 MHz + 3Hz) Terminated
No Cable 0.01 Vpp (12 MHz + 3Hz) Unterminated
Short Cable 0.01 Vpp (12 MHz + 5Hz)
Long Cable 0.07 Vpp (12 MHz + 7Hz)
Sqrt T Behavior
$\frac{\sqrt{\left(\sum_{n=1}^{N} I'\right)^2+\left(\sum_{n=1}^{N} Q'\right)^2}}{\sqrt{N}}$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-1}
10^{0}
10^{1}
10^{3}
10^{4}
10^{5}
Time (s)

Summary

- Secondary demodulation in post-processing
  - Shifts spurious signals away from DC
  - Preserves real signal
- Weak wireless signals, clean 20 hour run
- ~ 20 Hz data rate (<1 GB / week)

Summary

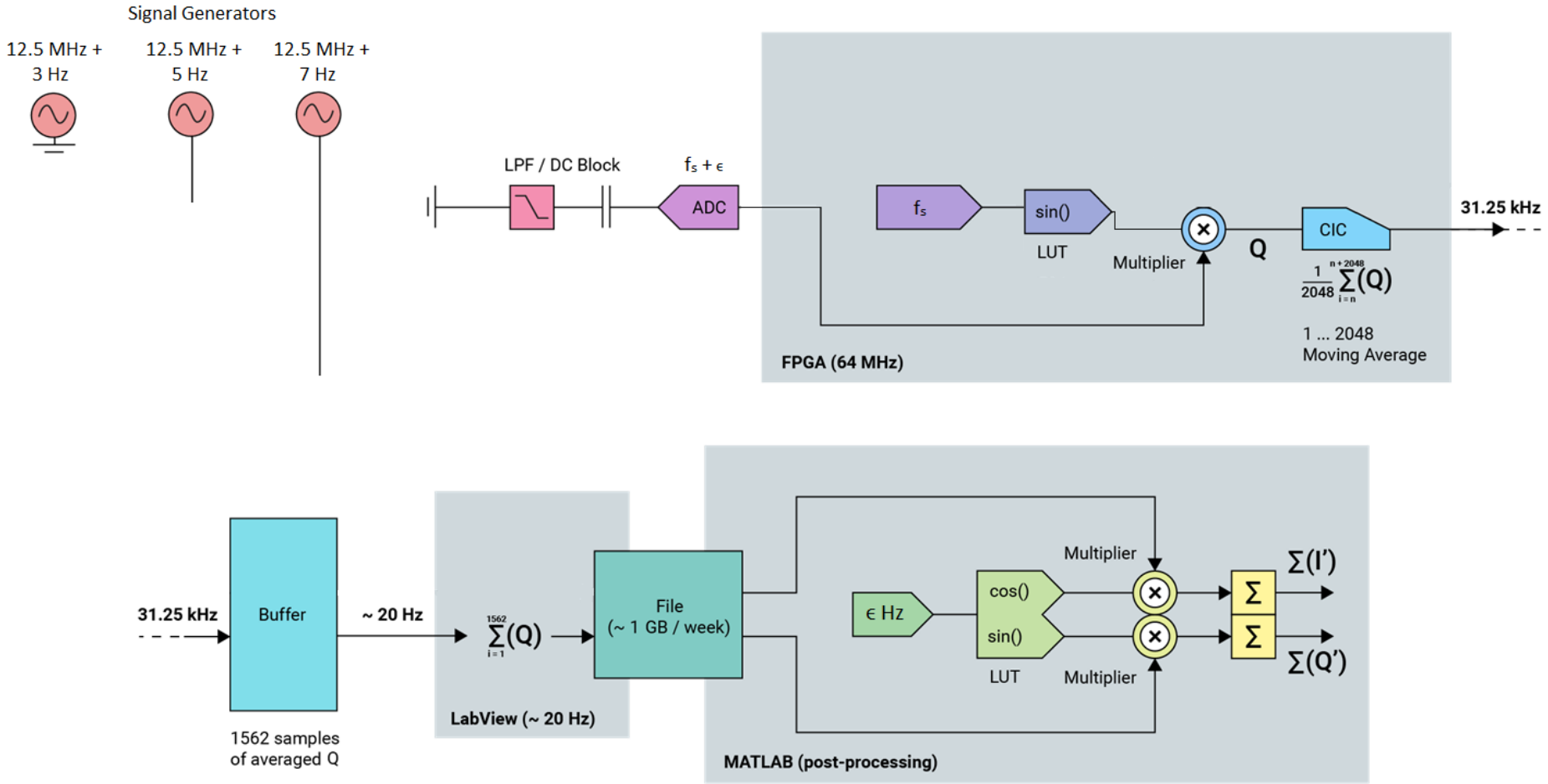
- Shortening antenna reduces amplitude of signal as expected

- Demodulation off "resonance" by 10^{-4} Hz causes signal to vanish

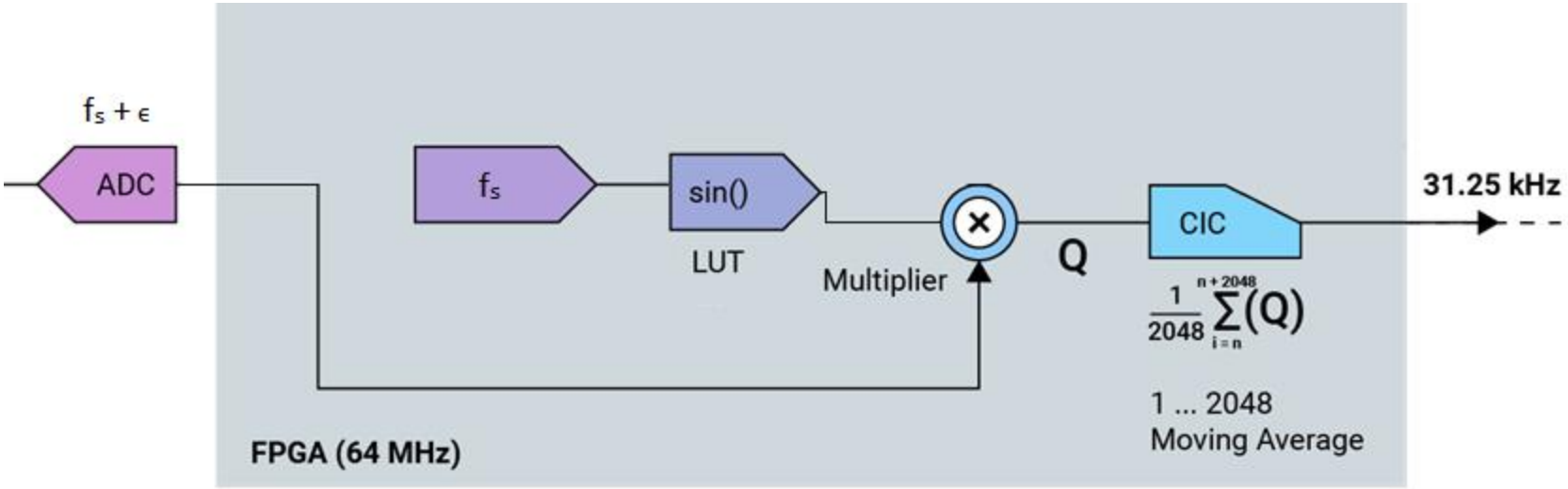
Current challenges

- Longer data runs with weaker signals
  - Move terminated function generator farther away
- Solve buffer read/write skips (LabView)
  - 20+ hour run gave 3 buffer skips
  - Background Windows processes likely to blame
  - Write clock time to know when skips happen
  - Pad with 0s
- Set up optical input signals
  - Connect Photodetector output to ADC
  - Shot-noise floor measurement
  - Calibration of device

Double-demodulation Scheme



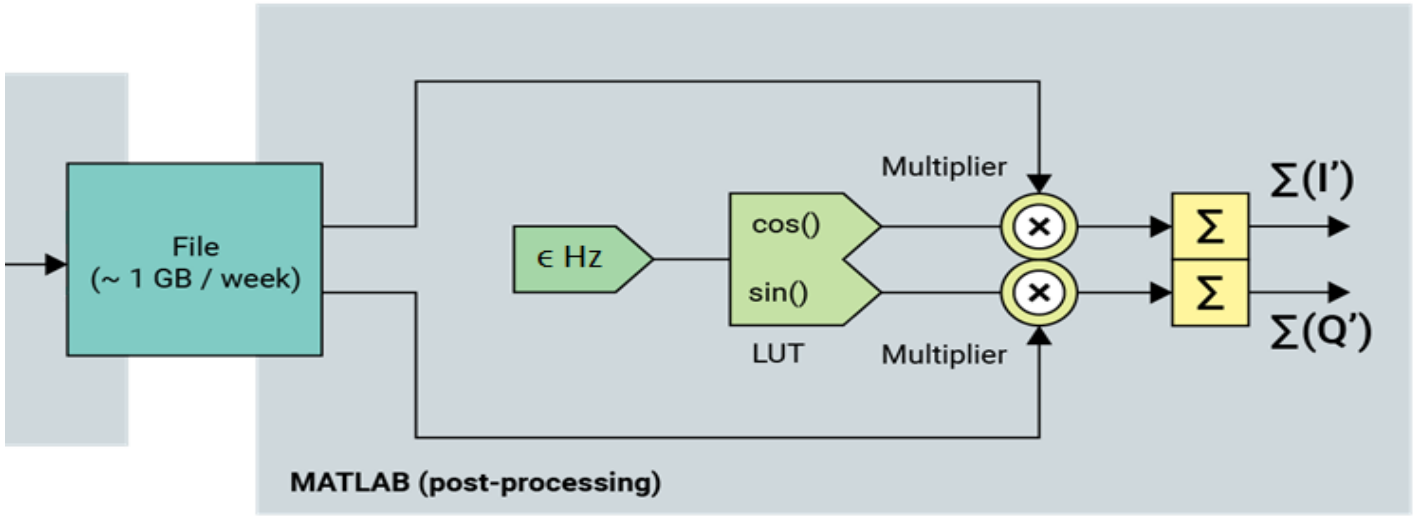
Double Demod Math



$$A\sin\left((f_s+\epsilon)t+\phi\right)\times 1\sin\left(f_s t\right) = \frac{A}{2}\cos\left(\epsilon t+\phi\right) - \frac{A}{2}\cos\left((2f_s+\epsilon)t+\phi\right)$$

Input Signal

LUT output



$$\mathrm{I} : \frac{A}{2}\cos\left(\epsilon t + \phi\right) \times 1\cos\left(\epsilon t\right)$$

$$\mathrm{Q} : \frac{A}{2}\cos\left(\epsilon t + \phi\right) \times 1\sin\left(\epsilon t\right)$$

FPGA Output MatLab LUT

$$\mathrm{I} : \frac{A}{2}\cos\left(\epsilon t + \phi\right) \times 1\cos\left(\epsilon t\right) =$$

$$\frac{A}{4}\cos\left(\phi\right) + \frac{A}{4}\cos\left(2\epsilon t + \phi\right)$$

$$\mathrm{Q} : \frac{A}{2}\cos\left(\epsilon t + \phi\right) \times \sin\left(\epsilon t\right) =$$

$$\frac{A}{4}\sin\left(-\phi\right) + \frac{A}{4}\sin\left(2\epsilon t + \phi\right)$$

$$\mathrm{I} : \frac{A}{4}\cos\left(\phi\right) \quad \Rightarrow \sum_{n=0}^{N} \mathrm{I} : \frac{AN}{4}\cos\left(\phi\right)$$

$$\mathrm{Q} : \frac{A}{4}\sin\left(-\phi\right) \Rightarrow \sum_{n=0}^{N} \mathrm{Q} : \frac{AN}{4}\sin\left(-\phi\right)$$

$$(\sum_{n=0}^{N} \mathrm{I})^2 + (\sum_{n=0}^{N} \mathrm{Q})^2 = \frac{A^2 N^2}{16}$$

$$\frac{\sqrt{(\sum_{n=0}^{N} \mathrm{I})^2 + (\sum_{n=0}^{N} \mathrm{Q})^2}}{\sqrt{N}} = \frac{A}{4}\sqrt{N}$$