Data Analysis and Fitting: Calibration

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Electron Density Determination

- ISR equation for received power:

$$P_r = \frac{P_t \tau_p}{R^2} K_{sys} \frac{N_e}{\left(1 + k^2 \lambda_{De}^2\right)\left(1 + k^2 \lambda_{De}^2 + T_e/T_i\right)}$$

$$\lambda_{De} = \sqrt{\frac{\epsilon_0 k_B T_e}{e^2 N_e}} \quad k = \frac{4\pi}{\lambda_{Tx}} \quad R = \text{Range} \quad \tau_p = \text{Pulse Length (s)}$$

- K_{sys}: the "System Constant" involves antenna gain, effective area, etc. For PFISR $K_{sys} \sim 10^{-19} \ \mathrm{m^5 s^{-1}}$.
- Can determine K_{sys} by comparing estimated N_e to absolute N_e measurements, e.g.:
  - ISR plasma line data
  - Ionosonde f_{0F2}
  - Faraday rotation (e.g. Jicamarca)
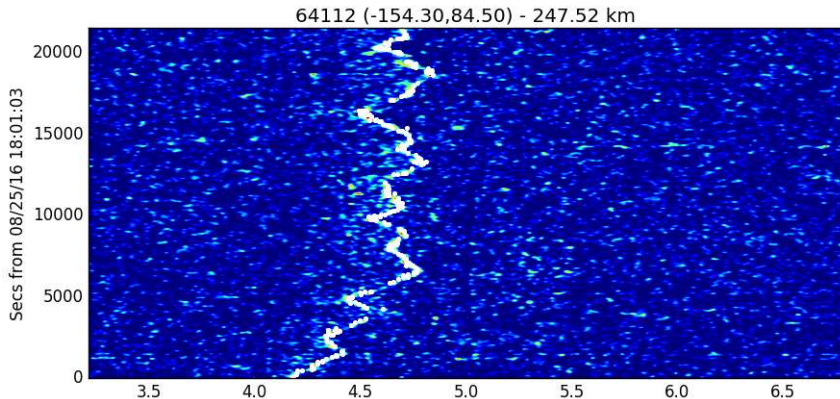- Lags estimates need to be calibrated too!

Enhanced Plasma Lines
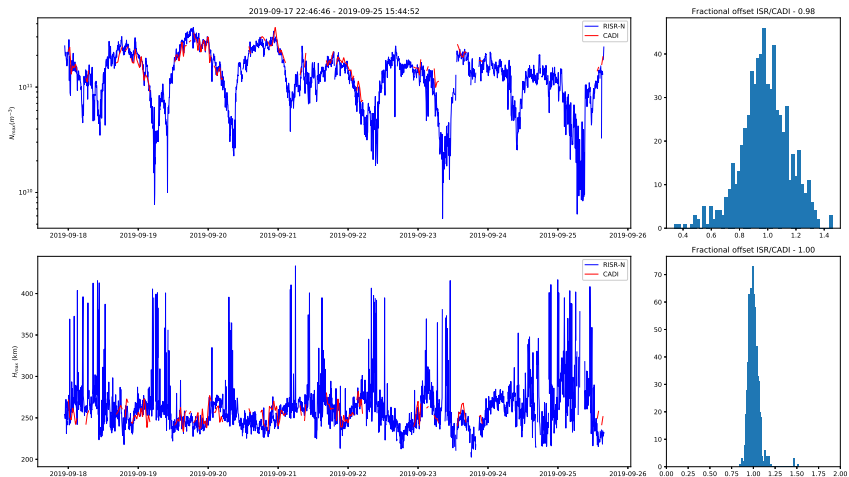
Millstone Hill plasma line data:

Enhanced Plasma Lines

$$\omega^2 = \omega_{pe}^2 + \frac{3}{2}k^2 v_{th}^2 + \Omega_e^2 \sin^2 \alpha$$

64112 (-154.30,84.50) - 247.52 km
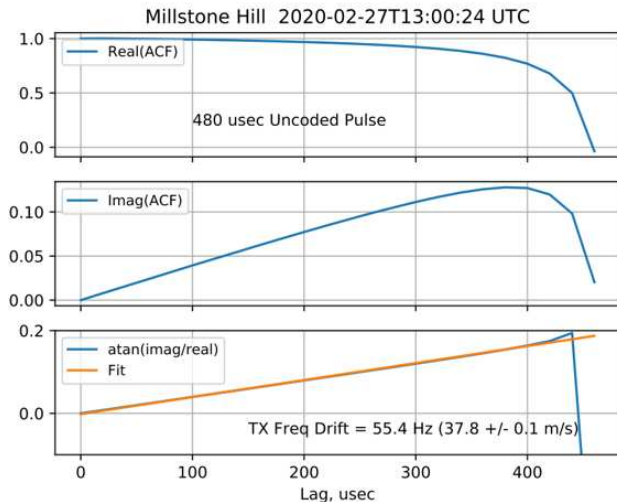
Comparisons with Ionosondes

Tx Pulse Chirp: Klystron Example

- Electrons slow down slightly as they travel through the main cavity of the klystron (TX amplifier)
- This causes a frequency offset of ≈ 0.1 ppm that will systematically bias ionospheric velocities.
- Sample Tx pulse, compute ACF, fit phase slope

Tx Pulse Chirp: Klystron Example

Millstone Hill 2020-02-27T13:00:24 UTC

480 usec Uncoded Pulse

Real(ACF)

Imag(ACF)

atan(imag/real)
Fit

TX Freq Drift = 55.4 Hz (37.8 +/- 0.1 m/s)

Lag, usec

Summary

ISR is performed by hardware that requires calibration:

- Calibration of received power into absolute electron density using:
    - ISR plasma line data
    - Ionosonde data
    - ...
- There may be other quirks of the hardware that need to be accounted for.