Data Analysis and Fitting: Calibration

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Objectives

- Introduction to IS radar data calibration
- Review methods for calibration

The System Constant

- Radar equation for IS Radar:

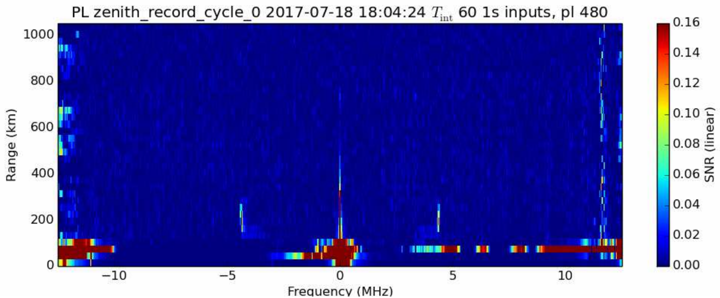
$$P_r = \frac{P_t \tau_p}{R^2} K_{sys} \frac{N_e}{\left(1 + k^2 \lambda_{De}^2\right)\left(1 + k^2 \lambda_{De}^2 + T_e / T_i\right)}$$

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

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

Enhanced Plasma Lines

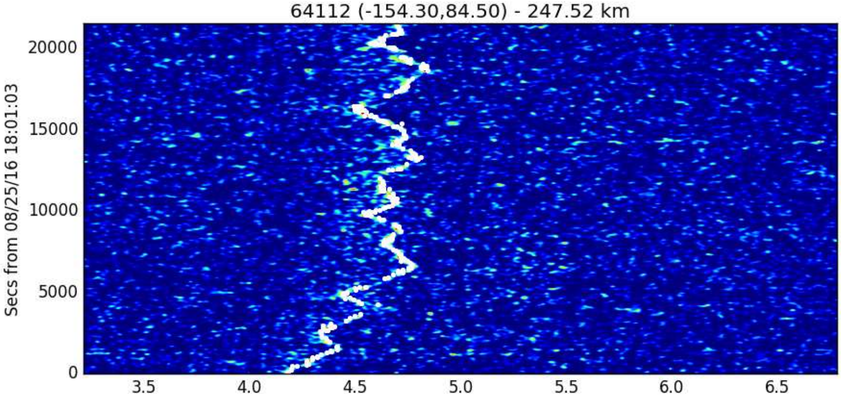
Millstone Hill plasma line data:



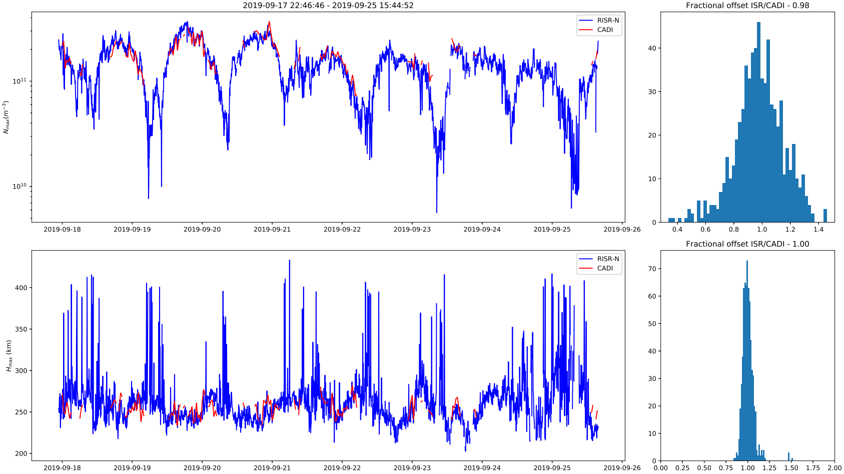
Further reading: Nilsson et al. (1997) "Enhanced incoherent scatter plasma lines" `doi:10.1007/s00585-996-1462-z`

Enhanced Plasma Lines

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



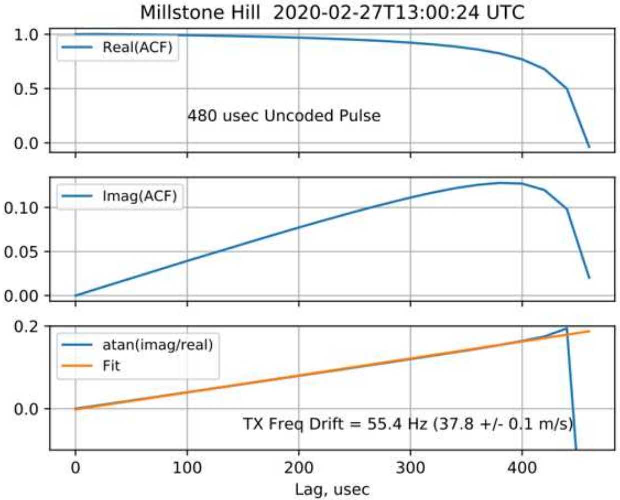
Comparisons with Ionosondes



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 $\approx$0.1 ppm that will systematically bias ionospheric velocities.
- Sample Tx pulse, compute ACF, fit phase slope

Tx Pulse Chirp: Klystron Example



Summary

Radar data is obtained using real hardware and requires calibration:

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

Important Distinction for Data Analysis:

- "Calibrated": Indicates that the electron density is calibrated in absolute units.
- "Uncorrected": Electron density obtained without the $(1 + T_e/T_i)^{-1}$ factor.