Overview of scintillation events due to E region and F region as inferred from SAGA

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Introduction

Scintillation

- **Rapid fluctuation** in power and/or phase in received signals
- Caused by: **variation in electron density** in the ionosphere
- May be correlated across multiple receivers in space-time
- Allows characterization of ionosphere by observation of signal on ground that produce it

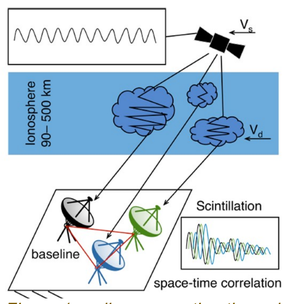


Figure 1: radio propagation through layer of irregularities sensed by a spaced array [3]

Previous Work

- Identified a phase/amplitude case [1]
- Only study of cases with phase data [2]

Objective: Use spaced-receiver method with amplitude data at high latitudes to calculate properties of irregularities. Compare to phase analysis and PFISR data.

Background

SAGA

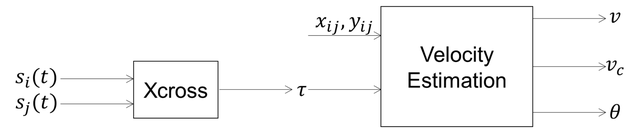
- SAGA: Scintillation Auroral GPS Array
- Collects: 100 Hz power and phase
- Signals are then detendred and filtered [2] scintillation signal

Velocity estimation

- Internal turbulent motion < bulk drift motion: characterized by drift velocity (v)
- Bulk movement velocity ► **"Frozen-in" irregularities** velocity
- Internal turbulent motion ► Characteristic velocity (v_c)
- Assumptions made (verified afterwards analysis):

►v_c<v ►Correlation peak>correlation threshold ►One irregularity layer

- **Spaced-receiver method** [4]:
  - ► s_i,s_j(t): Scintillation signal in receivers i and j
  - ► θ: Direction of velocity from East
  - ► τ: Delay time obtained from cross-correlation and auto-correlation curves
  - ► x_{ij},y_{ij}: 2D distance between pair of receivers i and j



- y: Measurements
- x: System State

$$y = Hx + v \quad \downarrow \quad [f(\tau)] = [f(\tau, x_{ij}, y_{ij})] \begin{bmatrix} v \\ v_c \\ \theta \end{bmatrix} + v$$

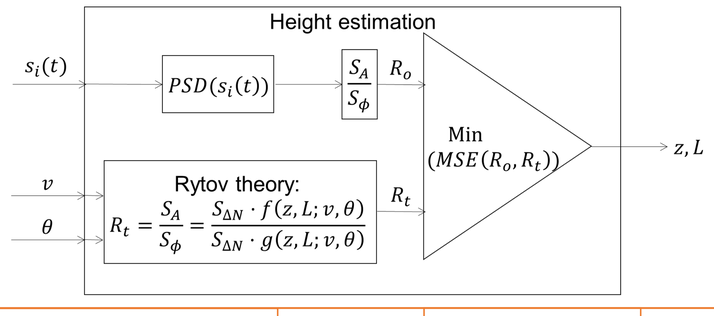
- H: Mapping matrix
- v: Noise (Monte Carlo simulation[4])

Height (z) and thickness (L) of scattering layer

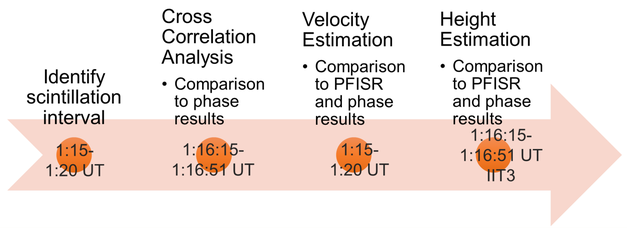
- Comparison between **observed** (Ro) and **theoretical** (R_t) scintillation phase and amplitude signal ratio **spectrum** [5]
- Theoretical ratio based on **Rytov weak scatter theory**

► S_A: Amplitude spectrum ► $S_{\Delta N}$: Electron density change spectrum (not known)

► S_ϕ: Phase spectrum



Methodology



- Update of the cross-correlation analysis and velocity estimation to use amplitude data
- Update of the Monte Carlo simulation
  - ►White Gaussian Noise: update standard deviation corresponding to amplitude values
- Comparison of velocity and height results with phase analysis and PFSIR data

Results

CASE: L1 Amplitude and Phase Case: F-region case, 16th November 2014 (DOY 320) 0:59-1:25 AM, PRN 32

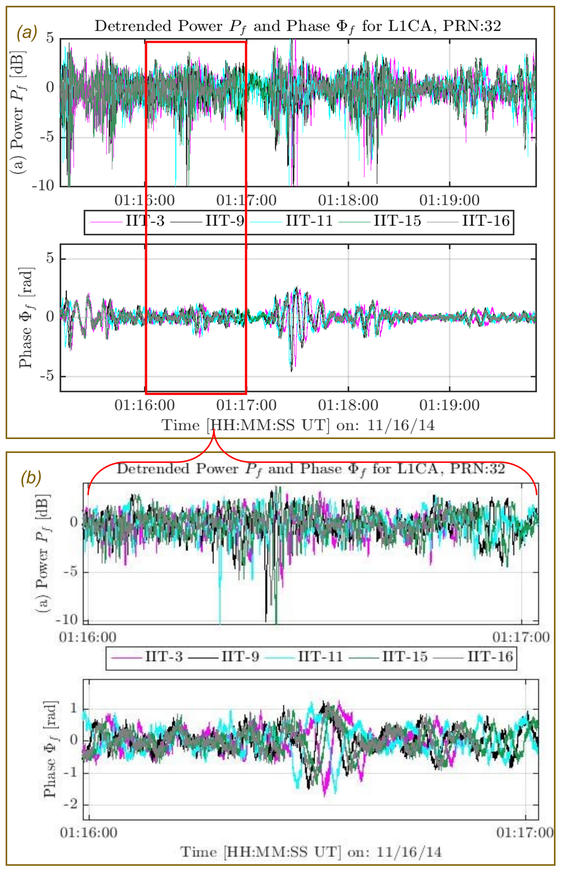


Figure 2: Detendred filtered power and phase at 100 Hz. From (a) 1:15-1:20 UT and (b) 1:16:15-1:16:51 UT

Identify scintillation interval

- 5 operational receivers
- Elevated power and phase scintillation values + space-time correlation in signals ►not noise
- Study of time period 1:16:15-1:16:51 UT for velocity and height estimation

Cross correlation analysis

Phase

Amplitude

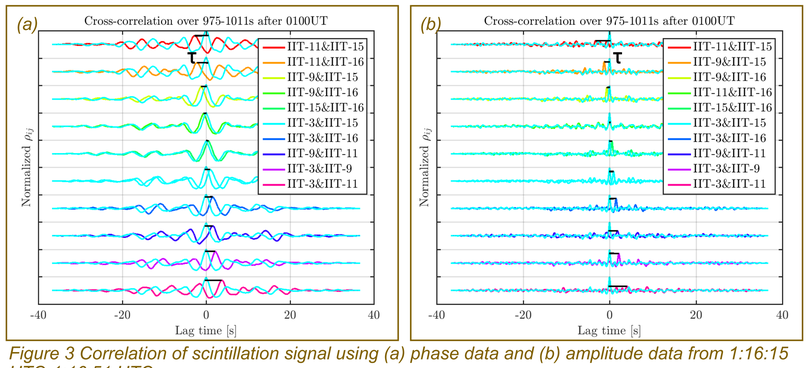


Figure 3 Correlation of scintillation signal using (a) phase data and (b) amplitude data from 1:16:15 UTC-1:16:51 UTC.

- Estimation of parameters needed for velocity estimation: τ

Velocity estimation

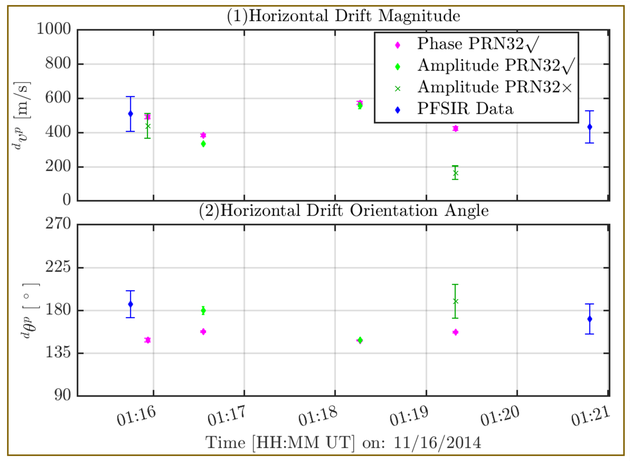


Figure 4: (1) Velocity drift magnitude, orientation angle estimation with phase and amplitude data for time periods: 1:15:38-1:16:15 UT, 1:16:15-1:16:51 UT, 1:17:45-1:18:48 UT and 1:18:48-1:19:51 UT (2) SRI International data [6] at 66° latitude: 1:15:45 UT and 1:20:48 UT

- Amplitude data: 2 samples of time don't satisfy all hypothesis
- Amplitude and phase analysis coincide for the 2 other samples
- Discarded estimations when assumptions not satisfied (*Amplitude PRN32X*)
- Velocity of ≈300/600 m/s towards ≈west (180°)

Height and thickness of scattering layer

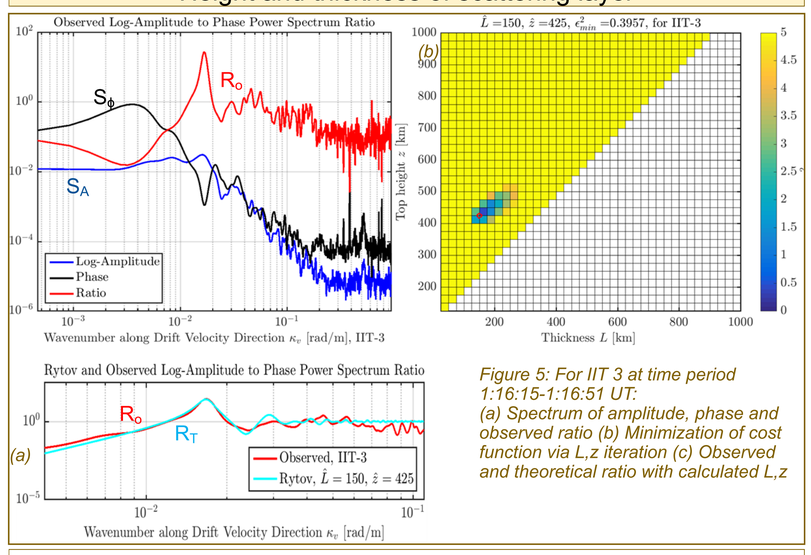


Figure 5: For IIT 3 at time period 1:16:15-1:16:51 UT: (a) Spectrum of amplitude, phase and observed ratio (b) Minimization of cost function via L,z iteration (c) Observed and theoretical ratio with calculated L,z

- Amplitude analysis: input v=331m/s and Θ=158° on height estimation
- Scintillation signal on receiver IIT3
- Good fit of R_t to R_o with estimated L,z

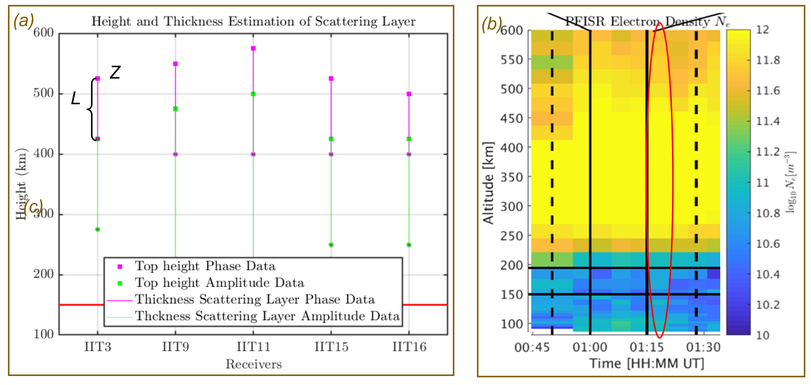


Figure 6: (a) Height and thickness estimation of the scattering layer at time period 1:16:15-1:16:51 UT (b) PFISR Electron Density [6]

- Phase ► 400/500 km
- Amplitude ► 300/400 km
- F Layer in all receivers in both
- Higher electron density according to PFISR data at 200/450km analysis

Conclusion

- Velocity, height and thickness are calculated with SAGA amplitude data
- Amplitude estimation agrees with phase analysis and PFSIR results:
  - ► Amplitude analysis more cases with discarded estimations compared with phase analysis

Acknowledgments

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4. CEDAR student travel support

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