Applying an S4 Scintillation Index to High Frequency Radar Pulses

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INTRODUCTION

- Ionospheric scintillation is a rapid fluctuation of radio-frequency signal phase and/or amplitude, generated as a signal passes through the ionosphere(Tsai et al., 2017).
- Ionospheric scintillation phenomena i.e., amplitude(σ_Φ index) and phase fluctuation (s4 index).

OBJECTIVES

- Our objective is to calculate amplitude scintillation(s4) and Signal-to-Noise ratio(SNR) of high frequency signal.
- Develop source code for calculating S4 and SNR of HF signal.

BACKGROUND

•Magnetoionic Effects (due to the radio physics of an electromagnetic wave propagating through a magnetized plasma)

- Differential mode delay - single pulse dispersed.
- Self-mode fading - self-interference of a propagation mode.
- Faraday fading - rotation of electriceld vector along ray path.

•Plasma Density Irregularity(that make the propagation medium inhomogeneous)

METHODOLOGY

- CASSIOPE spacecraft e-POP RRI MISSION
- RRI is a digital radio receiver, part of the Enhanced Polar Outflow Probe (e-POP)
- RRI (Radio Receiver Instrument)(Fig 2.) consist Four, 3-m monopole antennas.
- Study radio emissions at 10 Hz to 18 MHz. And sampling frequency is 62.5MHz.

RRI's science includes:

- Study HF radio propagation in the ionosphere.
- Study ionospheric density structures.

•Super Dual Auroral Radar Network (SuperDARN) site at Saskatoon.
•SuperDARN radar is major source of HF emission.
•Transmission frequency on April, 1, 2015 is 17.5MHz(Fig 1.).

TECHNIQUE AND TOOLBOX USED

- Find the position of pulses in our signal.
- The pulse repetition frequency is not constant.
- Select data form top of the pulse without edges.
- Calculate S4 index for those selected data.
- The S4 index can be calculate as suggested by Groves et al. (1997)

$$S4 = \sqrt{\frac{< I^2 > - < I >^2}{< I >^2}}$$ I =signal intensity & 〈 〉=mean

S4>0.3 called as scintillation event.

- RRI data provider: https://epop-data.phys.ucalgary.ca

- 'RRI Toolbox' used here is written in PYTHON script. https://github.com/GWPerryNJIT/ePOP-RRI.
  - With this toolbox we can read RRI data easily
  - All useful parameters: monopole voltages, time & position of satellite and pulse detection algorithm available.

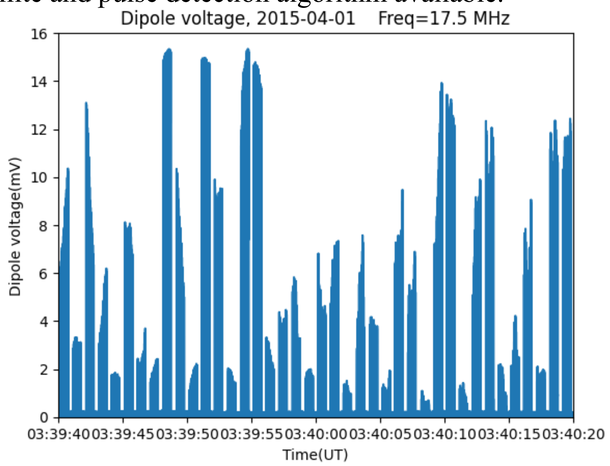


Fig 1; HF signal received by RRI receiver on April 1, 2015.
•This signal consist some background noises which need to be filter out.

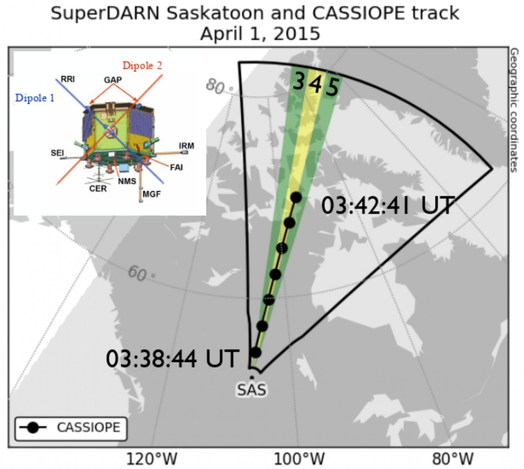


Fig 2 Canada's Cassiope satellite carries e-POP. And the track of CASSIOPE on April 1, 2015 from 03:38:44 UT to 03:42:41 UT

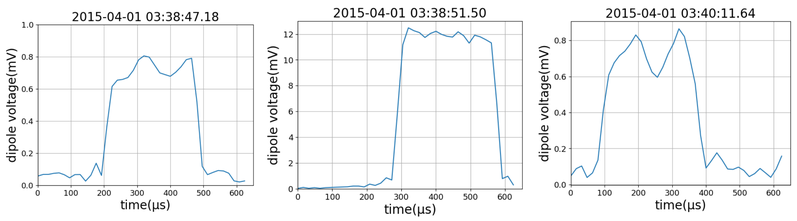


Fig 3; some random pulses. •Shortest interpulse period is around 1500 micro- seconds. And this value in not constant. •Beam switching period is 1 seconds.•Pulse width is 300 micro-seconds.

DATA SELECTION TECHNIQUE

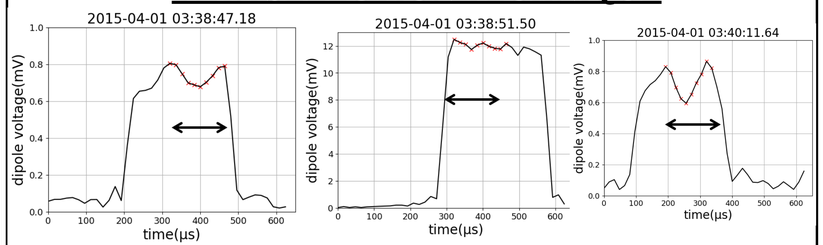
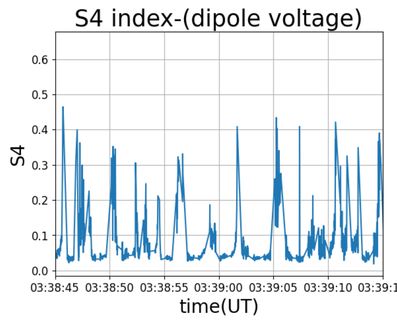


Fig 4; showing 10 consecutive data points (red "x" marks) whose sum is highest.

- For s4 index calculation, 10 consecutive data point is taken as shown in Fig. 4. Doing so is effective way to neglect pulse edges.



RESULT

Fig 5; S4 scintillation index of selected data.

- Fig 5 is s4 index of 10 consecutive data points of each pulse

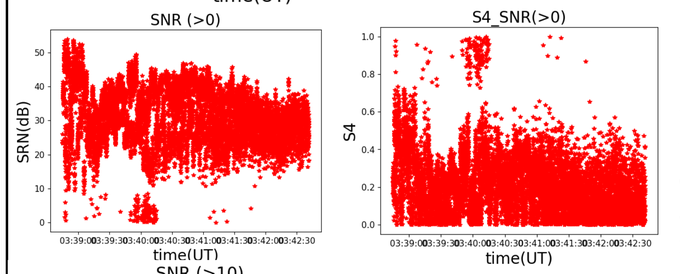


Fig 6; signal to noise ratio(with cutoff 0) and its S4 index.

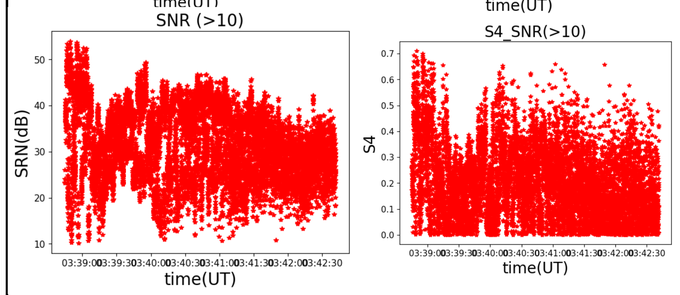


Fig 7; signal to noise ratio(with cutoff 10) and its S4 index.

- Fig 6 and 7 displays signal to noise ratio and their corresponding S4 index at different cutoff(0 and 10)

CONCLUSION

•Higher value of S4 index is obtain around pulses which indicates high perturbation.
•This project successfully develope a way to calculate s4 index of HF signal. And our future work is to analyze phase scintillation and develope standard source code.
•S4 index of pulses with low signal-to-noise-ratio (SNR; low is defined as 0<SNR<10) is high in comparison to the other pulses.

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