Monitoring Ionospheric Scintillation Effects on Precise Positioning in the North America Region

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**Introduction**

- NOAA 2012 SBIR topic to develop SWPC product for ionosphere-induced denial of service for GPS customers
- Phase I work (six months):
  - Survey of user community/potential customers (poster)
  - Feasibility study of scintillation effects nowcast
  - Focused on continental US
Nowcast based on ROTI

- **Total Electron Content (TEC)** measured using phase difference between L1 and L2 GPS signals

- **Rate of TEC (ROT):** 
  \[ ROT = \frac{\Delta TEC}{\Delta t} \]

- ROT measurements indicate small-scale variations on top of a slower, larger scale trend

- **Rate of TEC Index:** 
  \[ ROTI = \sqrt{\left< ROT^2 \right> - \left< ROT \right>^2} \]

- Use ROTI to determine presence of amplitude and phase scintillation
Advantages of ROTI over $S_4$ and $\sigma_\phi$

- Can be measured using thousands of standard GNSS receivers already deployed around the globe
- Not susceptible to receiver clock/oscillator error
- Directly measures ionospheric TEC irregularities
Published work has established correlation between ROTI and both phase and amplitude scintillation at low latitudes.

At high latitudes, amplitude scintillation is suppressed, so need to study relationship.

We examined GPS L1 scintillation data from Yellowknife, Canada (62.3ºN).

Data courtesy of Susan Skone, University of Calgary.
GPS Observations

Good correlation between ROT and phase scintillation

Little amplitude scintillation
Difference in data rate affects comparison

Magnitude of single-frequency signal scintillation is also affected by
- irregularity spectrum
- observation geometry
- radio wavelength
- speed of plasma
- etc.
Using standard GPS data collected from the CORS network, regional snapshot ROTI maps can be produced for every 5- to 15-minute intervals

- ROTI measurements with corresponding coordinates of 400-km ionospheric piercing points assigned to 2 by 2 degree cells

- Feasibility study performed using archived data
ROTI Map

Quiet Day (Kp ≤1)

Storm Day (Kp ≥6)

~450 stations
Ionospheric irregularities/scintillation seen at middle latitudes in the contiguous United States during a major geomagnetic storm.
Analyzed GPS data from high-latitude CORS stations (~65°N)

Used JPL’s GNSS Inferred Positioning System and Orbit Analysis Simulation Software (GIPSY-OASIS)

Compared positioning results for storm day to quiet day

Expect scintillation impact on real-time positioning applications would be worse than results from post-processing
On quiet day, the variation over the day is small ($\sigma_{\text{max}} < 0.07\text{m}$)
On storm day, the variation grows substantially (Δ up to 3m)
To translate ROTI map to user experience, three more steps must be taken:

- Calculate current location of GPS satellites and IPP location relative to user
- Get ROTI value for link from ROTI map
- Translate ROTI values to user impact

In Phase I, notional receiver model developed for translating ROTI to measurement impact
Conclusion

◆ We have produced:
  ◆ ROTI maps to observe scintillation activities in the North America region
  ◆ User impact nowcast for GPS precise positioning
◆ Showed correlation between:
  ◆ ROTI and L1 phase scintillation in the polar region.
  ◆ ROTI and precise positioning errors
◆ Phase II work (if awarded):
  ◆ Develop real-time processing using streaming CORS data
  ◆ Further develop user impact algorithm