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On the Source of GPS Scintillation by Substorm Irregularities

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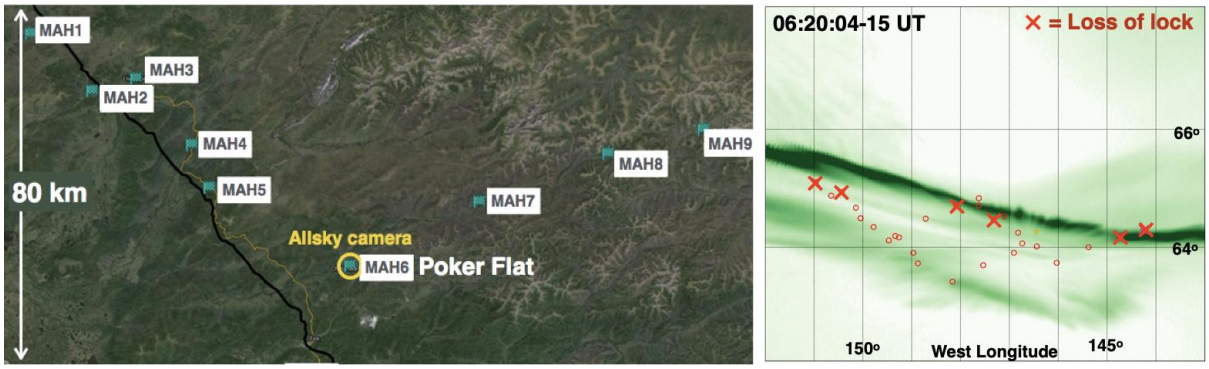
The Mahali Experiment was an array of nine Global Navigation Satellite System (GNSS) receivers deployed to in the vicinity of the Poker Flat Research Range (PFRR) in October–November 2015 [1]. The receivers covered an area of ~100 x 150 km, with receiver spacing 10–20 km. Mahali was the first GNSS receiver array with spatial sampling and coverage optimized for the study the magnetosphere-ionosphere dynamics associated with geomagnetic storms and substorms. Initial findings included the discovery of receiver loss-of-lock events that were clustered along the trailing edge of auroral westward traveling surges associated with a substorm expansion phase [2] and absent at the leading edge. Further investigations from a multi-sensor study involving the Mahali array, PFRR all-sky imager (ASI), and the Poker Flat Incoherent Scatter Radar (PFISR) revealed that the physical driver of these catastrophic signal distortions were likely transient density irregularities forming at an altitude of 120 km [3].

This paper builds upon this work through a detailed analysis of the signal scintillations underlying these loss-of-lock events. The 1-Hz measurements from the Mahali installation at PFRR (MAH6 in the figure below) are compared with measurements from a co-located scintillation receiver recording 100-Hz samples of C/N ratio. The high-rate data reveals diffraction effects (i.e., amplitude scintillation) caused by small-scale spatial irregularities, thus providing a means of partitioning phase-versus-amplitude- scintillation. The results are contextualized using direct images of the ionospheric plasma by the electronically scannable PFISR facility, and indirect measurements of particle precipitation characteristics using ASI redline (630 nm) and blue line (427.8 nm) emissions. This data fusion approach allows us to assess the efficacy of 1-Hz, or even lower sampling rate, GNSS data as a proxy diagnostic of scintillation occurrence and the irregularity spectrum.



Left: The Mahali receiver array. Right: Ionospheric piercing points (350 km) for three GPS satellites each viewed by the 9-element array on 7 October 2015 during a geomagnetic substorm. The X's mark locations of receiver loss-of-lock occurrences.

References

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[2] Semeter, J., Mrak, S., Hirsch, M., Swoboda, J., Akbari, H., Starr, G., Pankratius, V. (2017). GPS signal corruption by the discrete Aurora: Precise measurements from the Mahali experiment. *Geophysical Research Letters*, 44, 9539– 9546. https://doi.org/10.1002/2017GL073570

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