URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Auroral Ionospheric Irregularity Properties via Estimation and Inverse Modeling of GNSS Scintillations

Seebany Datta-Barua*(1), Kshitija B. Deshpande(2), Donald Hampton(3), and Gary S. Bust(4)
(1) Illinois Institute of Technology, Chicago, IL, 60616, e-mail: sdattaba@iit.edu
(2) Embry-Riddle Aeronautical University, Daytona, FL, USA; e-mail: deshpank@erau.edu
(3) University of Alaska Fairbanks, Fairbanks, AK, USA; e-mail: dhampton@alaska.edu
(4) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA; e-mail: gary.bust@jhuapl.edu

When Global Navigation Satellite System (GNSS) signals traverse the ionosphere, variations in plasma density cause the received signal at the ground to scintillate, i.e., exhibit a rapid fluctuation in power and/or phase. Scintillation at high latitudes near the auroral zone can be frequent, and are typically observed, with standard GNSS receiver processing, as phase scintillations. Scintillation is an undesirable effect for navigation purposes, because it degrades signal quality and can lead to poor tracking, cycle slips, and loss of lock on satellites needed for robust positioning. One of the challenges to understanding the irregularities producing scintillation is that they are not directly sensible with established sensing methods such as incoherent scatter radar. A motivating premise behind this work is that, while undesirable for navigation, scintillation of a received signal is beneficial for ionospheric study because it can be used to investigate the properties of and the physical mechanisms producing exactly those irregularities that scatter the signal.

In prior work, an array of scintillation auroral Global Positioning System (GPS) receivers (SAGA) was used to provide a means of remotely sensing precisely those irregularities that led to the scintillation [1, 2]. Meanwhile, a multiple phase-screen model, SIGMA, was developed to simulate received signal fluctuations for user-provided satellite and receiver geometries, as well as scattering layer parameters [3]. Combined with an inverse modeling best fit to observed scintillation power spectral density, an estimate based on the model could be made of scattering layer parameters, such as height and thickness of the irregularities [4]. These were done for a limited number of individual case studies.

In this work we use SAGA data and SIGMA modeling to examine a number of scintillation events, some of which occur at GPS L1 (1575 MHz), some at GPS L2 (1227 MHz), some of which are phase-only scintillations, and others of which involve amplitude fluctuation as well. We perform an assessment using SAGA to estimate drift velocity, and then using SAGA and SIGMA each to independently estimate the height and thickness of the scattering layer. The estimates of SAGA-derived and SIGMA-derived height and thickness are compared to each other, and to data from the independent but collocated Poker Flat Incoherent Scatter Radar and all-sky auroral imaging camera.

1. Y. Su, S. Datta-Barua, G. S. Bust, and K. B. Deshpande, "Distributed sensing of ionospheric irregularities with a GNSS receiver array," *Radio Science*, **52**, 8, August 2017, pp. 988-1003, doi:10.1002/2017RS006331.

2. Y. Su, G. S. Bust, K. B. Deshpande, and S. Datta-Barua, "Estimating height and thickness of an ionospheric irregularity layer with a closely-spaced GNSS receiver array," *Proceedings of the 30th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2017),* Portland, Oregon, September 2017, pp. 3375-3388.

3. K. B. Deshpande, G. S. Bust, C. R. Clauer, C. L. Rino, and C. S. Carrano, "Satellite-beacon Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA) I: High-latitude sensitivity study of the model parameters," *J. Geophys. Res. Space Physics*, **119**, 2014, pp. 4026–4043, doi:10.1002/2013JA019699.

4. K. B. Deshpande, G. S. Bust, C. R. Clauer, W. A. Scales, N. A. Frissell, J. M. Ruohoniemi, L. Spogli, C. Mitchell, and A. T. Weatherwax, "Satellite beacon Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA) II: Inverse modeling with high-latitude observations to deduce irregularity physics," *J. Geophys. Res. Space Physics*, **121**, 2016, pp. 9188–9203, doi:10.1002/2016JA022943.