Simulation of the Effects from Equatorial Plasma Bubbles Detected by the C/NOFS Planar Langmuir Probe on Propagation of Transionospheric Radio Signals

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Abstract

The Communication/Navigation Outage Forecasting System (C/NOFS) [1] is based on a non-geostationary equatorial satellite successfully launched in an elliptical orbit with 400-km perigee, 850-km apogee and orbital inclination of 13º on April 16, 2008. Due to its orbital period, the satellite is able to track the evolution and motion of plasma bubbles at 90-min intervals. The Planar Langmuir Probe (PLP) onboard C/NOFS measures ion density fluctuations with high-resolution (512 Hz). The C/NOFS PLP summary data are immediately available in individual daily files with 1-Hz resolution, but high-resolution data (512 Hz) are also available on request. One-second records, consecutively spaced by approximately 7.5 km along the satellite orbit, associate the Universal Time (s) to the associated average ion density N_i (cm^{-3}), standard deviation of the ion density δN_i (cm^{-3}), ratio $\delta N_i/N_i$, as well as satellite latitude (degrees), longitude (degrees), and altitude (km). Data corresponding to one orbit are represented in Figure 1.

It is well accepted that the structures displayed in this Figure are aligned with the geomagnetic field lines. The structures generally drift eastward across the field lines in the evening to post midnight sector and may drift westward near dawn. They also drift across satellite links, affecting signals received on the ground.

The present work will show and discuss results from the processing described next.

Initially, the above C/NOFS PLP data will be mapped into amplitude scintillation-index S_4 time series, with basis on single-scattering or phase-screen models [2], [3] and the assumptions of the second paragraph. This formulation simulates the transmission of transionospheric signals from a geostationary satellite to an Earth station. Statistical distributions of the following parameters will be discussed: (1) S_4; (2) duration of events with S_4 above a specified threshold; and (3) spacing between such consecutive events.

Next, the previous formulation will be applied to simulate the transmissions from the same satellite to two spaced Earth stations. At each time step, the minimum of the two S_4 values will be retained. The statistical analysis described in the previous paragraph will then be applied to the resulting time series and the results interpreted in terms of possible mitigation effects of spatial diversity on amplitude scintillation, for different receiver distances.

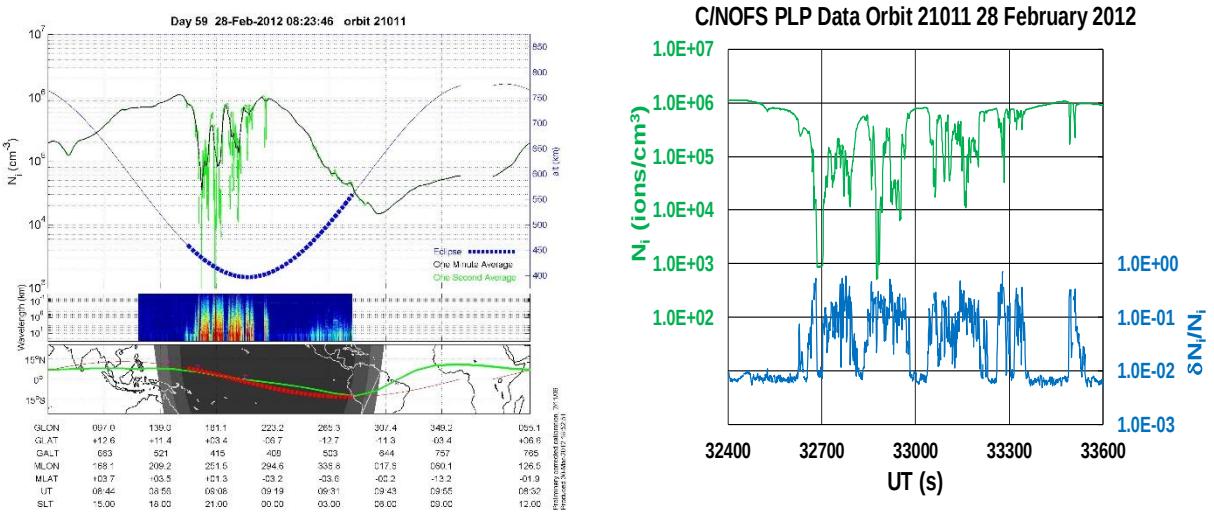

Figure 1. **Left:** C/NOFS PLP data from satellite orbit 21011 (between consecutive crossings of the geographic equator), on 28 February 2012. Upper panel: one-minute (black line) and one-second (green line) average ion density, with respect to the left vertical axis; and satellite altitude (blue dotted line), according to the right vertical axis. Central panel: power spectral density from the 512 Hz PLP data. Bottom panel: map with the C/NOFS satellite ground track (red dotted line) and geomagnetic equator (green). The thick dotted lines indicate when the C/NOFS satellite is in darkness. **Right:** C/NOFS PLP data from the disturbed section of the same orbit, between 22:37 UT (81420 s) and 22:52 UT (82320 s). The green curve (left vertical axis) reproduces the one-second average ion density N_i (ions/cm^3). The blue curve (right vertical axis) represents the ratio $\delta N_i/N_i$.

It is expected that the above results be affected by different geophysical conditions. In particular, the effects from different longitude sectors and levels of solar activity on the results will be discussed.

In addition to its potential scientific value, the information resulting from the proposed work may be useful in the design of operational procedures, as well as in the development of mitigation techniques for the adverse effects of the ionosphere on satellite-based communication and navigation systems.

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