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TEC and Scintillation Measurements using Low Earth Orbiting Beacon Signals Propagating Through the Disturbed Ionosphere Above HAARP

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ABSTRACT

During April, May, and June of 2014 the Canadian CASSIOPE satellite that carries the Enhance Polar Outflow Probe (ePOP) suite of plasma diagnostic instruments [1] operated in coordination with the High-Frequency Active Auroral Research Program (HAARP) Facility in Gakona, AK, USA. CASSIOPE/ePOP carries a Coherent Electromagnetic Radio Tomography (CERTO) three-frequency beacon that transmits coherent tones at 150.012 MHz, 400.032 MHz and 1066.752 MHz [2]. CASSIOPE/ePOP was launched into an elliptical Low-Earth Orbit with perigee of ~326 km, apogee of ~1470 km, and inclination of ~80.1°. The orbit allows for overpasses of the HAARP facility on a regular basis. A chain of receivers near HAARP recorded scintillation and Total Electron Content (TEC) on paths between ePOP and the ground during some of the 2014 HAARP operations. Most interesting are passes where the CERTO transmissions propagate directly through the ionospheric disturbance generated by the high power HAARP HF beam. Figure 1 shows the largest TEC increase observed of two TEC units (10^{16} m^2) as the satellite crossed directly over the disturbed region. During this pass the 150 MHz VHF signal suffered phase scintillations of up to 18 Radians and amplitude scintillations of up to 25 dB while the 400 MHz UHF signal recorded amplitude scintillations of 20 dB.

Recent HAARP campaigns have shown that the facility can produce localized regions of Artificial Ionization (AI) at altitudes between 150 and 250 km which were originally detected via optical emissions (cf. Pedersen et al. [3]). Bernhardt et al. [4] reported the largest and longest lasting (30 min to 5 hr) electron density AI clouds maintained by HAARP transmissions and showed scintillations at 233 MHz that reached 16 dB amplitude. The measurements reported here were accompanied by in-situ measurements of the HAARP HF wave using the Radio Receiver Instrument on ePOP [5] and numerous ground-based diagnostics [4] including the HAARP Ionosonde and measurements of Stimulated Electromagnetic Emissions (SEE). The combination of these diagnostics gives us insight into the interactions that are occurring in the disturbed region. We will discuss the new ePOP scintillation and TEC measurements and their implications.

A lot of our understanding of the ionosphere and the universe is inferred through remote sensing of radio signals and interpreting effects on these signals. Not all of the phenomena affecting radio propagation are completely understood. The HAARP facility has been transferred to the University of Alaska Fairbanks and it will be possible to conduct more experiments with ePOP in the near future. Also, the new high-power HF capability at the Arecibo facility in Puerto Rico was successfully tested in November 2016. These facilities allow for controlled and repeatable plasma physics and radio science experiments to be performed. The ePOP mission is scheduled to operate until at least March of 2017 before requiring additional funding. In addition, the STP-2 mission carrying 24 satellites is scheduled to be launched into a 24 degree inclination orbit in late 2016 with several beacon satellites. This launch will deploy the NPSAT1 micro-satellite built by the Naval Postgraduate School in Monterey, CA. The NPSAT1 instrumentation consists of a three-frequency CERTO beacon and plasma density probe to view the modified ionosphere over Arecibo to study radio propagation effect and ionospheric disturbances.

Key words: TEC and Scintillations, Low Earth Orbit (LEO) beacons, Ionosphere, Ionospheric Disturbances, Active Experiments

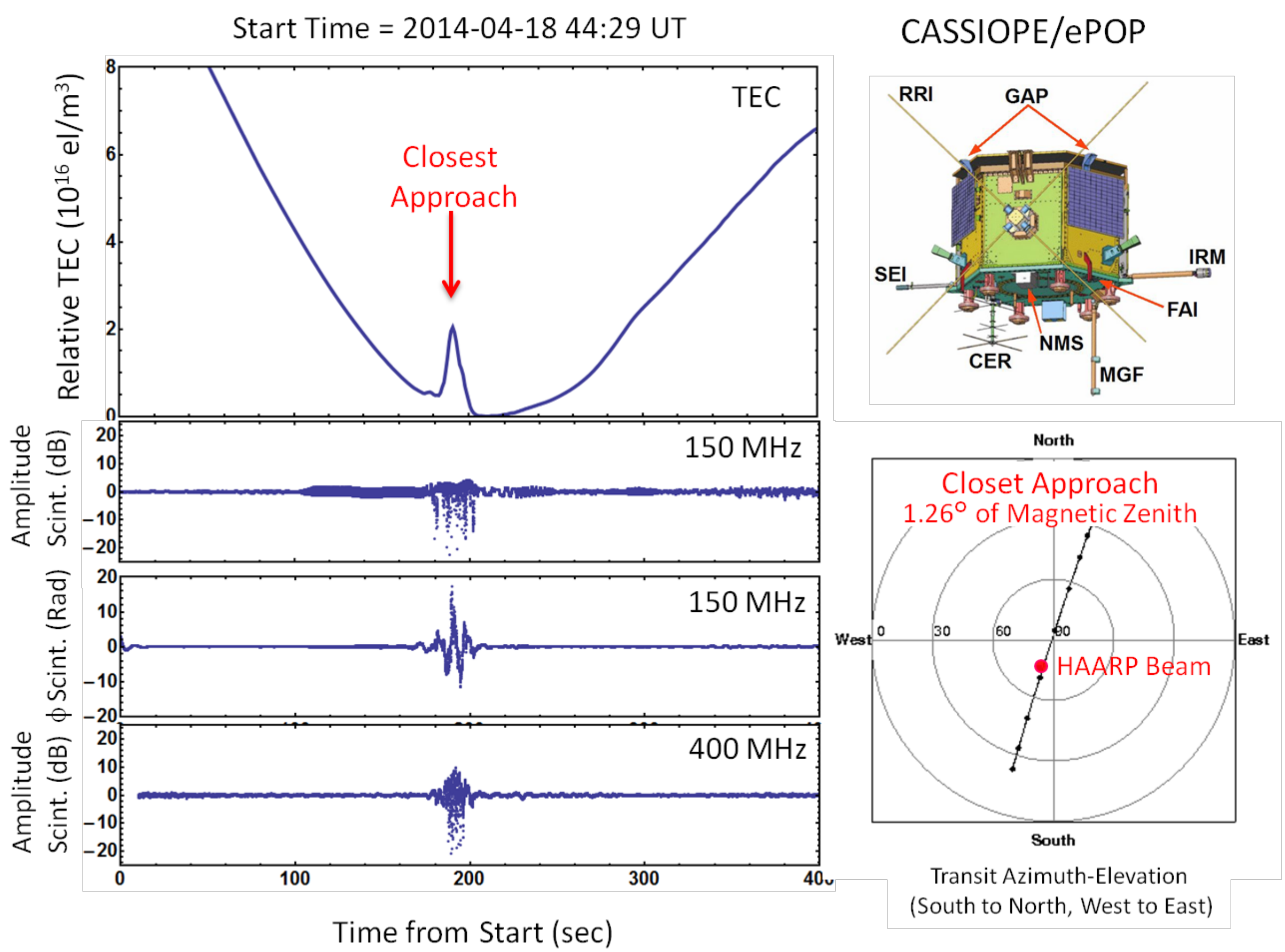

Figure 1 TEC, phase and amplitude scintillations from a HAARP overpass on April 18, 2014

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