A Combined Ground and Space Ionospheric Observation Network with Inter-segment Coordination (IONIC)

Andrew K. Kennedy[(1)] and Kerri L. Cahoy[(1)]
(1) Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA, 02139, USA

We analyze the capabilities of a proposed novel, cooperative sensing system, IONIC, for mapping of the ionosphere's structure. The IONIC (Ionospheric Observation Network with Inter-segment Coordination) system consists of two components: a ground-based dual-frequency GNSS (Global Navigation Satellite System) receiver network (the ground segment) and a space-based constellation of small form-factor satellites known as CubeSats (the space segment).

Both segments make measurements of TEC (total electron content, the integral of electron density along a line of radio wave propagation through the ionosphere), providing data that is used in post-processing to map out large-scale structures in the ionosphere. The ground-based receivers provide TEC measurements by comparing the propagation of multiple different frequencies of GNSS signal from the GNSS satellites to the receivers. The CubeSats provide TEC measurements both through GNSS radio occultation (RO) measurements, where the signal from a GNSS satellite passes through the ionosphere as it propagates to the CubeSat GNSS receiver, and through multi-frequency inter-CubeSat radio crosslinks that also have signal paths through the ionosphere.

We perform a high-level assessment of the utility of the data provided by IONIC for mapping the ionosphere. We examine the temporal and spatial availability of RO and crosslink TEC measurements for the space segment, and evaluate how useful these measurements are for augmenting existing ground-based ionospheric GNSS networks. Measurement availability depends on the orbital geometry of the constellation of satellites, so we examine both an ideal geometry case (a Walker Star type pattern) and an ad-hoc geometry case based on historical CubeSat launches. We establish measurement quality metrics in addition to temporal and spatial availability by considering the intersatellite and ground link budgets. We then present results in terms of the spatial distribution (over the Earth's surface) of measurements from both the ground and space segments. We next examine the temporal spacing of space segment measurements, to determine how often a given ground receiver can augment its measurements with those from the satellites. We consider the quality, temporal, and spatial coverage metrics iteratively with our constellation design and plan for mission operations and duration. This work results in a constellation architecture design product for an ideal and ad-hoc IONIC constellation, namely a map showing the measurement quality, spatial, and temporal coverage that can provide meaningful augmentation to existing ground-based ionospheric GNSS networks.