27th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Small Space Science Missions (2)

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IONOSPHERE MEASUREMENT: POINT-TO-POINT TOTAL ELECTRON CONTENT ESTIMATION USING UHF INTER-SATELLITE RANGING FOR CUBESAT CONSTELLATION

Abstract

The ionosphere, which is the upper ionized layer of the atmosphere, affects the transmission of radio waves and causes degradation in the performance of satellite-based navigation, communication, and surveillance systems. Measurements by satellites are used to validate the numerical models of the ionosphere by estimating the total electron content (TEC) along the propagation path of the radio waves from satellite to ground, which is simply the total number of electrons along ray path from a transmitter to the receiver; the delay experienced by a signal traveling in the ionosphere is proportional to the TEC along the signal path. Consequently, mapping the state of the ionosphere in real-time is an important scientific study for the dynamic nature of the ionosphere which would as well help in maintaining the accuracy of these radio-based systems. Various techniques to mitigate these ionospheric effects were developed in the past decades; a widely distributed network of global navigation satellite system (GNSS) receivers provides 3D distributions of the electron density in the ionosphere on the regional scales and its temporal fluctuations. A constellation of CubeSats can be used to estimate TEC along the UHF links between these satellites and a network of ground stations; the time delay of the propagating signals is used to derive a single value of TEC and hence multiple measurements of vertical and slant TEC can

be used to derive a global map of the ionosphere. The advantage of using the UHF band is its higher vulnerability to ionospheric effects. This paper will propose the design requirements and hardware implementation and testing of a payload for a CubeSat used for time-stamped signal transmission and reception using the UHF communication band in addition to on-board processing to derive TEC values between two satellites as well as satellite and ground stations. The development of this payload is part of Space Precision Atomic-clock TIming Utility Mission (SPATIUM) project which was proposed by the Laboratory of Spacecraft Environmental Interaction Engineering (LaSEINE) of Kyushu Institute of Technology, Japan in collaboration with Nanyang Technological University, Singapore to measure the electron density distribution using a constellation of inter-communicating Cube-Satellites equipped with a highly precise atomic clock in different LEO orbits and a network of ground stations. SPATIUM-I is currently in orbit down-linking signals to be processed in the ground station, SPATIUM-II is currently under development to demonstrate the on-board processing of Up-link signals to the satellite.