UDC 629.78

EXPERIMENT ON TOMOGRAPHY OF THE UPPER IONOSPHERE WITH A NANOSATELLITE USING A NAVIGATION RECEIVER

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The ionosphere is the ionized layer of the Earth's upper atmosphere in the altitude range from 60 to 1000 km. The ionosphere is constantly changing dynamically under the influence of various factors, such as phenomena in the magnetosphere and lithosphere, events on the Sun, and many others, and no ionosphere model can fully consider these factors [1].

The most important of the ionospheric parameters is the density of free electrons.

When a radio signal passes through the ionosphere, it forms an ionospheric phase delay, which is described by the following expression [2]:

$$\tau_p^{ion} = -k\frac{TEC}{f^2},$$

where k is the coefficient of proportionality; $TEC = \int_T^R N_e(s)ds$ is total electron content (TEC); f is carrier frequency; N_e is the electron density along the radio signal propagation path.

Monitoring of the ionosphere is relevant in the applied aspects for prediction of the conditions for short waves propagation in satellite navigation and communication systems [3]. According to the COSPAR Committee on Space Research, the study of the ionosphere is also relevant in a fundamental aspect: the current forecast of electron density in high resolution allows getting more information about nature of the ionosphere [4].

Due to the constant variability of the ionosphere, it seems promising to study the ionosphere using computed tomography methods, which makes it possible quickly to obtain information about changes in the ionosphere. In this work acceptable method from the point of view of implementation costs and sufficient coverage of a large area is investigated. This method is using of the nanosatellite capable of receiving global navigation satellite system (GNSS) satellite signals.

Calculation TEC is possible by pseudoranges and carrier phases data. In combination of these two methods, carrier phases data determine a low error and pseudoranges data determine unknown initial phase [5]:

$$TEC = \frac{1}{\chi}\frac{f_1^2 \cdot f_2^2}{f_1^2 - f_2^2}[(\Phi_1 - \Phi_2) + B_{rs}];$$

$$B_{rs} = \sum_{i=1}^{N}\frac{1}{\sigma_i^2}[(P_{2i}^{rs} - P_{1i}^{rs}) - (\Phi_{1i}^{rs} - \Phi_{2i}^{rs})] \Big/ \sum_{i=1}^{N} 1/\sigma_i^2,$$

where $\Phi_1 = L_1 \cdot \lambda_1$ and $\Phi_2 = L_2 \cdot \lambda_2$ are carrier phase delays for frequencies f_1 and f_2, respectively; L_1 and L_2 are measurements of the carrier phases; P_1 and P_2 are pseudorange delays for frequencies f_1 and f_2, respectively; s is GNSS satellite number; σ_i is the standard deviation of the pseudorange noise.

In this work we have presented ionosphere tomography algorithm using the low orbit nanosatellite with the navigation receiver. Also, software for handling tomography data has been developed. The software makes it possible to calculate the TEC values for a tomographic experiment. Approbation for developed software based on data from the low orbit satellite constellation COSMIC-2 has been completed. Preliminary analysis of tomographic experiment based on analysis of maps of piercing of the ionosphere by sounding beams to determine possible areas of reconstruction has been performed.

References

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