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Multi-point measurements using low-orbital and high-orbital radio tomographic systems

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About a dozen of currently operating multi-point receiving networks measuring transmissions from low-orbiting (LO) navigational systems exists at present in different regions of the world: in Europe, America and Asia. Numerous radio tomographic (RT) experiments based on LO satellite systems revealed a complexity and variety of the shapes of the ionospheric trough. A series of specific features in the structure and dynamics of the equatorial anomaly were observed. RT images of traveling ionospheric disturbances provided the information about the parameters of perturbations and allowed investigation of atmospheric-ionospheric coupling. RT study of strong ionospheric disturbances caused by anthropogenic factors, in particular by rocket launching, industrial explosions, powerful high-frequency radiation and so on, are carried out. Using methods of statistical radio tomography, distributions of the intensity of ionospheric plasma fluctuations were obtained. LO RT method allows also determination of plasma fluxes by analyzing the time-consecutive RT images of the ionosphere. With a several receiving chains spaced a few hundred kilometer apart available, it is possible to study three-dimensional structure of the ionosphere. The main substantial limitation of LO RT is the necessity to install multi-point systems of receivers. With the deployment of global navigational systems like GPS, GLONASS, Galeleo, a new powerful research tool emerged. Low angular velocity of GPS satellites makes it essential to allow for time changes of the ionosphere, which necessarily leads to the statement of 4D tomography problem (three spatial coordinates and time). However, unlike the two-dimensional LO RT, here an additional procedure is needed of the found solutions interpolation in the region of missing data. Examples of 4D

ionospheric images reconstructed from the real GPS data in different regions of the world are present in the paper. The tomographic results are compared with independent ionosonde measurements. Specific spatial-temporal features of ionospheric structure observed under various solar-geophysical conditions are analyzed. Examples are shown of high-orbital (HO) RT results comparison with LO RT images. HO RT resolution is much lower than that of LO RT. As a rule, horizontal resolution is not higher than 100 km in Europe and over the major part of USA. It is shown that LO and HO RT combination provides great advantages and makes it possible to obtain 3D ionospheric images over extended regions owing to HO RT and to improve the resolution owing to LO RT systems involved. General problems of ionospheric imaging of the near-Earth environment, various schemes of sounding, problems of the uniqueness, limitations and accuracy of ionospheric imaging are considered in the paper. Scenarios are analyzed of various multi-satellite LO RT and HO RT systems employment together with ionosondes and radio occultation data measured along satellite-to-satellite paths, which would allow realization of effective regional and global monitoring of the near-Earth environment. The work was supported by RFBR grants No. 04-05-64671 and 05-05-65145.