Remote sensing of ionosphere and upper atmosphere based on low-orbital and GNSS radio tomography

V.E.Kunitsyn (1), E.D.Tereshchenko (2), E.S.Andreeva (1), B.Z.Khudukon (2), M.A.Kozharin (1), M.O.Nazarenko (1) and I.A.Nesterov (1)

(1) M.Lomonosov Moscow State University, Faculty of Physics, Moscow, Russia, (2) Polar Geophysical Institute of the Russian Academy of Sciences, Murmansk, Russia (Email: kunitsyn@phys.msu.su /Phone: +7 - 495- 9392089)

A dozen of currently operating multi-point receiving networks that carry out measurements of 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 ionospheric structures observed under disturbed and quiet conditions. Various shapes of the ionospheric trough were detected. A series of specific features in the structure and dynamics of the equatorial anomaly were studied. RT images of traveling ionospheric disturbances provided 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, is performed. By means of statistical radio tomography, distributions of the intensity of ionospheric plasma fluctuations were retrieved. LO RT method allows also determination of plasma fluxes from a time-sequence of RT images of the ionosphere. Manifestations of particle precipitation in electron density distributions were observed repeatedly in LO RT images of the ionosphere. With a several receiving chains spaced a few hundred kilometer apart, it is possible to study the three-dimensional structure of the ionosphere. In spite of its high efficiency, LO RT employment is basically limited due to the necessity to arrange multi-point receiving systems. Deployment of global navigational satellite systems (GNSS) like GPS, GLONASS, Galileo provided a new powerful tool for ionospheric research. 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 shown. Tomographic results are compared with independent ionosonde measurements. Specific spatial-temporal features of ionospheric structure under various solar-geophysical conditions revealed by RT are analyzed. Examples of high-orbital (HO) RT images comparison with LO RT results are shown. 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. Combination of LO and HO RT exhibits great advantages making 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