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# STUDY OF THE IONOSPHERIC IRREGULARITIES BY THE INCOHERENT SCATTER AND TRANS-IONOSPHERIC RADIO MEASUREMENTS

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## Introduction

The structure of the high-latitude ionosphere is very complicated and varied. A radio wave, propagating through ionospheric electron density irregularities, may be suffered phase and amplitude fluctuations. The ionospheric irregularities which produced scintillations occur predominantly in the F-layer of the ionosphere at the altitudes range of 200-1000 km. The fluctuations of GPS/GLONASS signals are caused by the ionospheric irregularities with dimensions more than 10 km. The raw signals (under scintillating conditions) can be processed using the high samples rate GPS/GLONASS receiver in order to derive the scintillation parameters.

The method of incoherent scatter of radio waves allows to determine experimentally both regular variations of the basic parameters ionosphere, and their behaviors during perturbation of the various origins and providing the possibility to realize the most complete diagnostics of the ionospheric plasma including electron density irregularities characteristics. The aim of this work is the experimental study of the nature of the ionospheric irregularities, influencing on GPS/GLONASS signals parameters, by incoherent scatter and trans-ionospheric radio measurements simultaneously.

## General specifications

The method of incoherent scatter of radio waves allows to determine the variations of the ionosphere parameters plasma including electron density irregularities characteristics. For example the anomalous signals - coherent backscatter from plasma irregularities at slant distances of 1000-1190 km - were observed during 9-10 November 2004 strong geomagnetic storm by Kharkov incoherent scatter radar measurements1. For the same storm event the strong TEC fluctuations were observed at midlatitude permanent GPS stations.

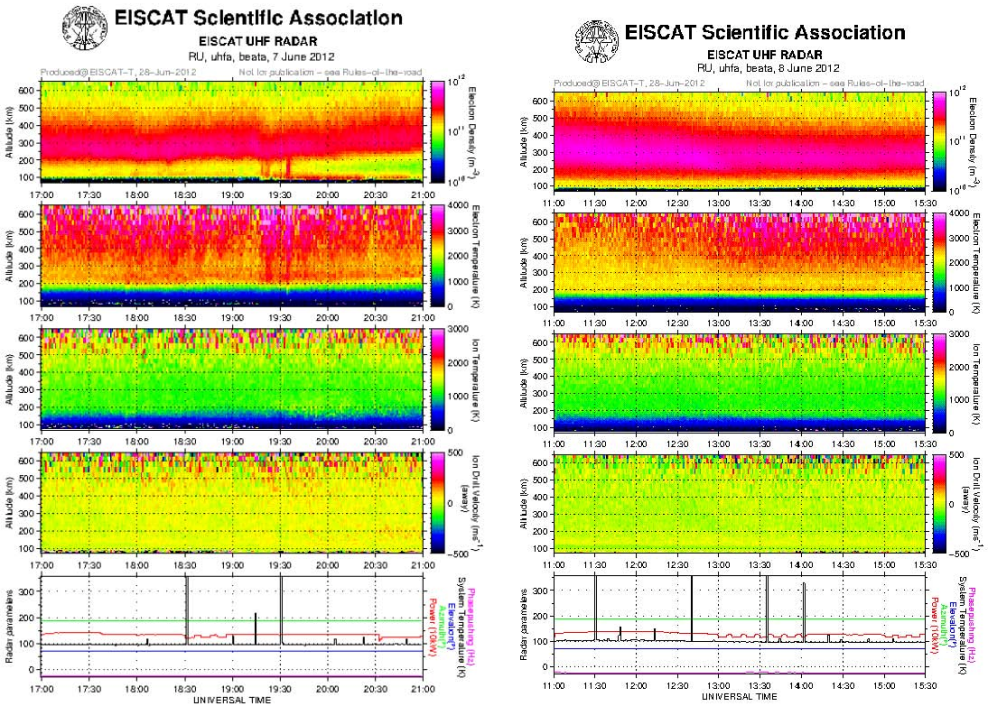


**Figure 1**. The main ionospheric parameters variations by EISCAT UHF IS radar measurements.

The EISCAT facilities position provides the unique opportunity to study the ionospheric irregularities' parameters associated with TEC fluctuations and GPS/GLONASS signals scintillations. To estimate the ionosphere irregularities we used the IS radar measurements (electron density and plasma temperatures profiles) and simultaneously registered on EISCAT site amplitude and phase fluctuations in GPS/GLONASS signals by use of the TRIUMPH- Javad GNSS receiver with high samples rate (100 Hz) and special scintillation GPS receiver (Septentrio PolaRxS) that provides S4 scintillation index measurements. The low frequency fluctuations were estimated using ROT and ROTI indices along the radio ray path2 between a GPS/GLONASS satellite and a ground station on EISCAT site.

## Results

The measurements were carried out on 7-12 June 2012, the active experiment with UHF IS radar and heating facility was on 7-8 June, other time was devoted to estimation of GNSS signal parameters day-to day variability.

The total durations of radar measurements was 8,5 h, that covers from 11:00 to 15:30 UT on 7 June 2012 and from 17:00 to 21:00 UT on 8 June. The heating facility was operated during 30 min between 18:30 and 19:00 7 June and 8 June during 1 hour from 13:00 to 14:00 and 30 min from 15:00 to 15:30. The UHF radar measurements provide information about height-temporal distribution of main ionosphere parameters – electron density, electron and ion temperatures and plasma drift velocity. Fig. 1 demonstrated variations of these parameters for radar experiment time. Unfortunately due to absorption of HF radio waves from heating facility caused by particles precipitation the heating effect was not pronounced in density and temperature variations.

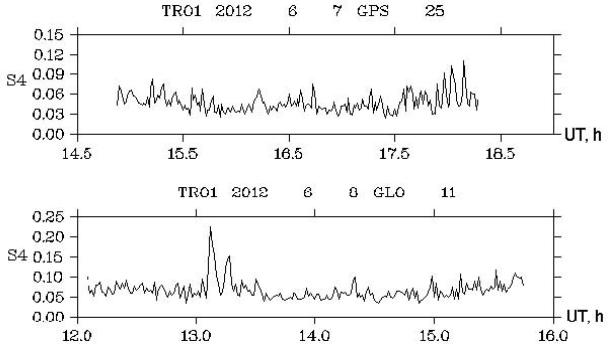


**Figure 2**. The S4 index variations for 7 and 8 June, EISCAT site placed GNSS receivers.

The analysis of amplitude and S4 index variation from GNSS receivers shows amplifications of fluctuations activity during period's corresponded to the heating facility runs. Fig. 2 presents variations of S4 index for GPS satellite N25 (7 June from 14:30) and GLONASS satellite N11 (8 June from 14:30). It was observed unusual rising of S4 index with factor 2 (after 18 UT) for GPS and with factor 3 (after 13 UT) for GLONASS satellites.

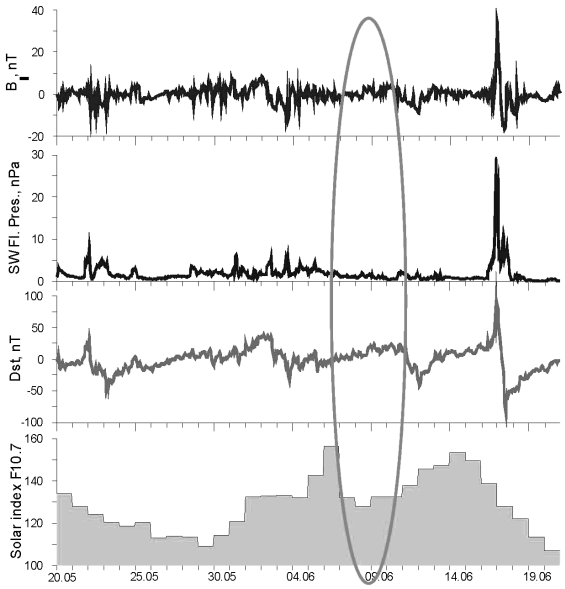


**Figure 3**. The space weather parameter for periods before, during and after experiment time.

It worth to note, that taking into account very quite space weather during experiment time (Dst index varied within limits of 10 nT, that not allow us to study storm-time ionosphere behavior, see Fig. 3), observed effects can be explained by increasing of ionosphere irregularities level caused by HF heating. These effects must be carefully studied in the future.

The practical aspect of this investigation is a detailed study of nature and impact level of the ionospheric irregularities that can influence on the GPS/GLONASS performance especially at high latitudes and during disturbances and to obtain new knowledge that may improve the reliability of the global navigation systems in Arctic and Antarctic regions.

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