THE EAST-SIBERIAN GROUND-BASED RADIO INSTRUMENT NETWORK FOR THE IONOSPHERIC INVESTIGATION

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ABSTRACT

In the Institute of Solar-Terrestrial Physics (Irkutsk, Russia), a radio instrument network has been created for investigation of the upper atmosphere. The network includes the Irkutsk incoherent scatter (IS) radar, the multi-position chirp-ionosonde for investigating the ionosphere using the methods of vertical, oblique-incidence and backscatter sounding includes 1 receiving station and 3 transmitting stations located at Norilsk, Magadan, and near the IS radar. Continuous observations of the ionosphere are made with the Digisondes at Norilsk and Irkutsk. This paper presents the network description and some examples of comprehensive investigations of in the ionosphere during years of high and moderate solar activity, including the events from October 2003.

INTRODUCTION

The ground-based radio technical tools working in various ranges of wave lengths appear to be one of the main sources of experimental data about the Earth upper atmosphere. The contemporary ionosphere research requires the global spreading of the observed phenomena and the use of various radio and radar methods [Rottger, 1999].

The ground-based radio instrument network is worked out in the Institute of Solar-Terrestrial Physics (ISTP) for observations of the upper atmosphere over the East-Siberian region. This set of different diagnostic tools makes it possible to carry out comprehensive investigations of the upper atmosphere over a sufficiently extensive territory of the north-eastern region of Russia in the longitude sector from 90°E to 150°E, from subpolar to mid-latitudes (right up to 50°N).

INSTRUMENTS DESCRIPTION

The Irkutsk IS radar is located in 120 km to the north-west of the Irkutsk. The radar is a monostatic, pulsed, frequency scan radar unit [Gherebtsov et al., 2002]. The IS radar consists of :

- doubly sectionalized antenna system with antenna switch;
- transmitters;
- multichannel receiving system;
- radar control and signal recording devices.

The principal technical data of the IS radar are listed below.

Frequency range	154...162 MHz
Transmitter peak power	1.6 MW
Number of transmitters	2
Pulse length	50 - 820 ms
Pulse repetition frequency	24.4 Hz
Type of antenna	sectoral horn
Antenna gain	35...38 dB
Beam’s angular size	0.5° x 10.0°
Scan sector	±30°
Polarization	linear
Input amplifier noise temperature	150 K
Number of receiving channels	4
Passbands of receivers	25, 50, 100, 300 kHz.

Irkutsk IS radar is used to measure electron densities, electron and ion temperatures, and plasma drift velocities.

The Irkutsk IS radar mainly differs from the similar systems by its possibility to emit and to receive only one linear field polarization. The registration of IS-signals fading in accordance with Faraday rotation of the electromagnetic wave polarization plane makes it possible to define the profile of electron densities (N_e) without using of such external calibration tool as ionosonde [Shpynev, 2003].

The observations made during the regular world days (RWD) have as a main goal the obtaining of the data set during various seasons of the year with various indices of solar and magnetic activity that are necessary, for example, for the verification of international reference ionosphere models (for instance, IRI). Fig. 1 demonstrates that during the periods of equinox the divergences of model and experimental meanings N_e are very significant. So, for the summer equinox the experiment gives the much wider height profile of F2 region with the lower (of 50%) meanings N_e and in the daily range is observed the one maximum N_mF_2 at 23 LT, when, at the same time, according to the model, there exists the additional day maximum on 12 LT.

The special experiments that are directed to the research of the ionosphere response to the powerful geomagnetic disturbances are based on the forecast data of the solar activity and are held during the various flares and bursts of the coronal substance. This made possible to register the great number of powerful disturbances of the last years. During such disturbances at the Irkutsk radar are regularly observed the mid-latitude coherent echoes – the powerful signals caused by the wave scattering in plasma instabilities of E-layer (Fig 2).

Multi-positional installation that uses the signals with linear frequency modulation (FCMW) of ISTP is the basic one in the Russian network of chirp-ionosondes, as it includes 3 of the 4 of its transmitting points [Ivanov et al., 2003]. With the network the ionosphere sounding in wide regions and the research of HF signals is carried out in various geophysical conditions. The transmitting point of ionosonde is combined with the IS radar (52.9°N, 103.3°E), the receiving point is located near the Tory region in ~100 km to the south-west of Irkutsk (51.7°, 103.1°). Chirp-ionosonde is made for the oblique-incidence and backscatter ionosphere sounding and can be used for the slight-oblique sounding (the length path is about 120 km, the path middle point is in ~75 km to the west of Irkutsk). The transmitting points in Norilsk (69°N, 88°E), Magadan (60°N, 150.7°E) with the using of the transmitter in Khabarovsk (48.3°N, 135.1°E) make it possible to cover all the East-Siberian region of Russia by the paths and to research the large-scale ionosphere phenomena dynamic (Fig3). Thus, for example, the abnormal signals propagating out of the large circle arc can contain the information about the main ionospheric trough border location.

The principal technical data of the FCMW sounder are listed below.

Sounding types	VS, OS, BS
Frequency range, MHz	1 - 30
Scan rate, kHz/sec	10 - 1000
Number of frequency discreet samples	600
Number of range discreet samples	512
Information output	Color display
Information storage	HDD, CD-ROM
Registered parameters	Amplitude, propagation time, signal-to-noise ratio, Doppler spectra, angle spectra
Transmitters power, Watt	300 - 2500
Receiver antennas	Vertical rhomb, Wideband dipole

In the end of 2002 the ISTP ionosphere observatories in Irkutsk and Norilsk were equipped by the Digisondes (DPS-4) made by the Center for Atmospheric Research (Massachusetts University of Lowell, USA) [Reinisch et. al, 1997]. The Digisondes are used for the regular ionosphere monitoring.

On the basis of interferometry methods, the technology of a global GPS detector (GLOBDET) was developed in the ISTP for global high-sensitivity detection and monitoring of ionosphere irregularities from GPS data. GLOBDET makes possible to analyze ionospheric disturbances with amplitudes as high as 10^{-3} of the background value of total electron content [Afraimovich et al., 1998].

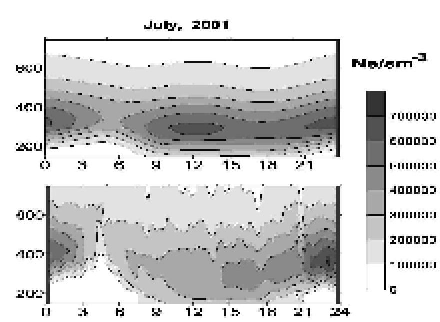

Fig.1 Comparison of the IRI model (top panel) and experimental ISR data (bottom panel).

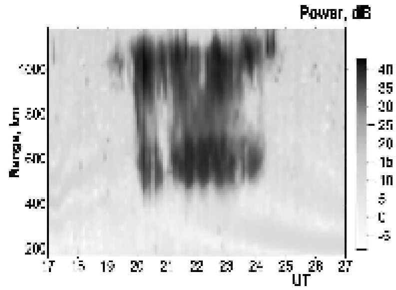

Fig.2 Range-temporal distribution of the mid-latitude coherent echo power measured by IS radar (July 15 2000).

There is an application of GLOBDET technology in investigations of geomagnetic disturbances, solar flares, earthquakes, rocket launch ionosphere responses and so on.
Comparison of the GLOBDET methods and DPS-4 data during initial phase of the strong geomagnetic storm on October 29 2003 are shown in Fig.4. The filtered out total electron content (TEC) variations dI(t) measured with IRKT station at the two rays (receiver - PRN02 and PRN03) are shown in the figure by the dashed and solid lines, respectively. The solid line with triangles corresponds to f_0F2 values measured by Irkutsk Digisonde. The scale of rough electron density values is given in Fig.4 right part. The storm sudden commencement SSC (6:11 UT) is also marked. The TEC and f_0F2 variations are similar and indicate a well-defined minimum around 7:30 UT which is behind SSC for about 1.5 hours. The relative amplitude of the TEC variations in a minimum is about 5-7%. A decrease from 11 to 8 MHz in critical frequency foF2 corresponds to 45-50% reduction in electron density in the vicinity of F-region peak The relation between TEC variation amplitude (5-7%) and electron density reduction (45-50%) gives grounds expect that the disturbance is located in the vicinity of F-region peak and its vertical scale shall be no more than 200 km.

SOME RESULTS OF THE ELECTRON CONTENT COMPLEX MEASUREMENTS DURING THE MAGNETIC STORM ON OCTOBER 29-31 2003.

The powerful magnetic storm on October 29-31 was the superposition of two large magnetic disturbances from the sun flares on October 28 (X17.2) and 29 (X10.0). Ionosphere response to the magnetic storm was researched with the ISTP radio physical instrument complex. The next results on the basis of simultaneous measurements at Digisonde DPS-4, chirp-ionosonde and IS radar was obtained. At undisturbed conditions on November 1 and during the interval between the storms on October 30 all the three instruments give the close electron density (N_e) profiles. The data of all the instruments are good correlated in the initial phase of the first storm and in the main phase of the second one. The significant differences are observed in the beginning of the first storm recover phase. The N_e profiles measured on October 30 by the three instruments are showed in Fig.5. Digisonde, chirp-ionosonde and IS radar data are marked by dotted line, line with circles and solid bold line, respectively. These measurements show that at 05:00, 05:15, 05:30, 05:45 UT the three instruments give the noticeably different results, at 06:00 the results are quite close and at 06:45 Digisonde and FMCW-ionosonde profiles are practically coincided. At 05:15 and 05:30 IS radar and chirp-ionosonde give the most close maximal electron density values, but the N_e values at height ~250 km differ by ~$2{\cdot}10^5$ см$^{-3}$. Digisonde and IS radar data are also differed. The observed differences are substantiated by the strong horizontal ionosphere irregularities. The mutual location of diagnostic tools makes it possible to estimate the spatial gradient of the maximal N_e value as $2{\cdot}10^5$ см$^{-3}$ / 100 km.

Fig.3 Map of the East-Siberian chirp-ionosonde network.

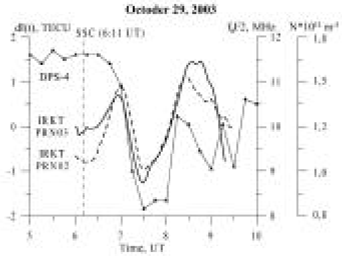

Fig.4 Comparison of the GPS and DPS-4 data during initial phase of the strong geomagnetic storm on October 29 2003.

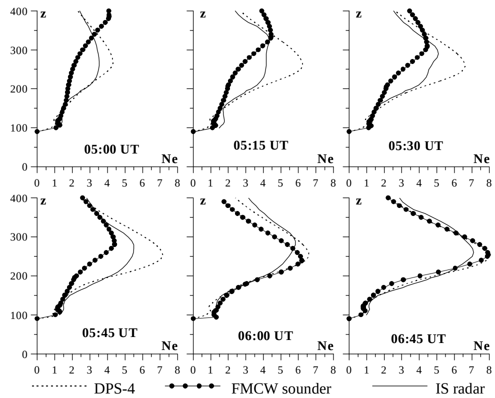

Fig.7 Comparison of the electron densities profiles (N_e) measured by DPS-4, chirp-ionosonde and IS radar in the beginning of the recover phase of geomagnetic storm on October 30 2003.

CONCLUSION

In the ISTP, a radio instrument network has been created for investigation of the upper atmosphere. The network includes the Irkutsk incoherent scatter (IS), the multi-position chirp-ionosonde, including 1 receiving station and 3 transmitting and two Digisondes. This set of diagnostic tools working in the wide range of electromagnetic waves lengths allows to make the complex mutually expanding upper atmosphere researches over north-eastern region of Russia in the longitude sector from 90°E to 150°E, from subpolar to mid-latitudes (right up to 50°N). It can provide ground-based support to satellite observations in this region.

The mutual location of the IS radar, Digisonde and chirp-ionosonde near Irkutsk with the using of the GLOBDET methods makes it possible to research the spatial and temporal characteristics of the irregular ionosphere.

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