Observations results of mid latitude coherent backscatter with the Kharkov incoherent scatter radar

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The ionosphere plasma characteristics are responding on variations of solar and magnetic activity. The research of an ionosphere structure and dynamics is important as for understanding physics of processes, proceed in it, and for radiophysical problems solution. The method incoherent scatter (IS) of radio waves allows determining experimentally both regular variations of the basic parameters ionosphere, and their behavior during perturbation [1]. The equipment and measurement technique accuracy, developed by authors, are allows obtaining certain data about behaviour of an ionosphere during various origin and intensity ionosphere perturbations. In paper observations results of main parameters IS of signal and ionosphere plasma during magnetic storms 30.05.2003 and 9-10.11.2004 are presented. During a main phase of ionosphere storm can be observed reconfiguration of F_2 layer, that changing altitude dependence of plasma parameters, coherent backscatter phenomena. Altitude dependences of correlation and spectra function, cross section and drift velocity of ionosphere plasma, time-altitude distributions of scatter signal power are presented. The comparison of obtained results and matching with space weather characteristics is made. The aim of this paper is the account of the results on investigation of the ionosphere responses to strong magnetic storm from the Kharkiv IS radar observations.

The presented radar observations were carried during a main phase of geogeomagnetic storm with index Kp = 8 for May 2003 and 9 for November 2004 events. The incoherent scatter radar located near Kharkiv, Ukraine (geographic coordinates: 49.6°N, 36.3°E, geomagnetic coordinates: 45.7°N, 117.8°E) was used to observe the processes in the ionosphere. The radar is operate with 100-m zenith parabolic antenna at 158 MHz with peak transmitted power of ~2.0 MW. The double-frequency measuring channel mode with compound sounding signal was employed. That provided ~ 20-km resolution in range ~100–400 km and ~ 100-km in range ~200–1100 km. The signal integration over 1.5–15-min intervals when the input signal-noise ratios are of 10–0.2 permits the ionosphere parameters to be determined with accuracy of about 3–10%.

In first time the phenomenon - high-power backscatter signal “coherent backscatter ” was observed during geogeomagnetic storm 29-30 may 2003. A usually observable spectrum of a dispersing medium (see fig. 1) has two identical on magnitude of a symmetrical extremum appropriate iono-acoustic waves.

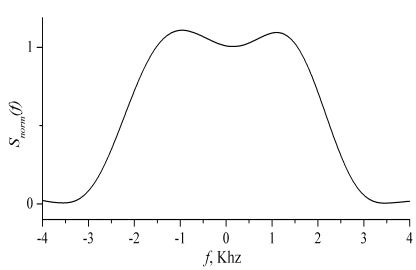


Fig. 1 Typical incoherent signal spectrum.

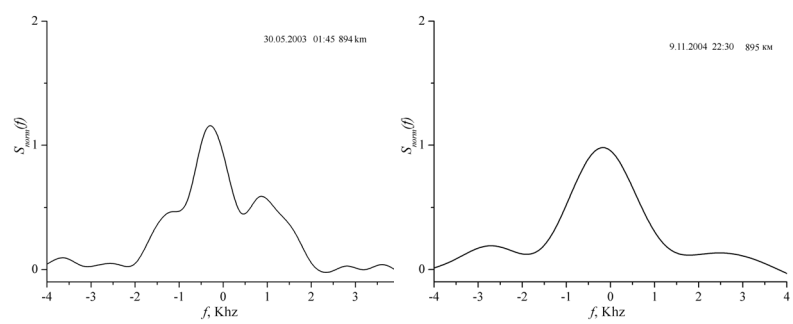


Fig. 2. Incoherent signal with coherent backscatter spectrums.

Since 23h. 22 min. UT on distances 900 - 1300 km, where before the signal/noise ratio did not exceed 0.03-0.05, has appeared a more high-power, unstable signal with a narrow-band spectrum (fig. 2). From 23h 35 min to 0h 05 a min. stable quasi-coherent a signal was observed. This signal on the correlation, spectral and temporary characteristics are different both from incoherent scatter signal, and from signals reflected from space vehicles. (fig. 3) At that the maximum value of imaginary component correlation function of a signal was increased at 5-10 and more time. That indicated to a large phase velocity of process. On fig 3. the estimations of thermal fluctuations electronic densities spectrum obtained during strong geomagnetic storm May 30, 2003 are presented.

The maximum intensity the signal had in a range of distances 990 - 1150 km. In an interval 23:52 min - 23:54 mines the signal strength has dropped on 8 - 10 db (fig. 4). The data's, are adduced on fig. 4, correspond to

integration time 2 min. They were obtained by summation of the by 1 min duration measured sessions. From the analysis of spectra (fig. 2, 3, 5a) it is visible, that further 800 km the signal consists of two component - incoherent and quasi-coherent. The quasi-coherent component is frequency shifted. The Doppler velocity, is calculated by a correlation method equal to 250 -500 m/s, depend from distance.

On night time was observed increasing of electronic temperature up to 2500 K. Usually at this time temperature of ions is equal to temperature of electrons.

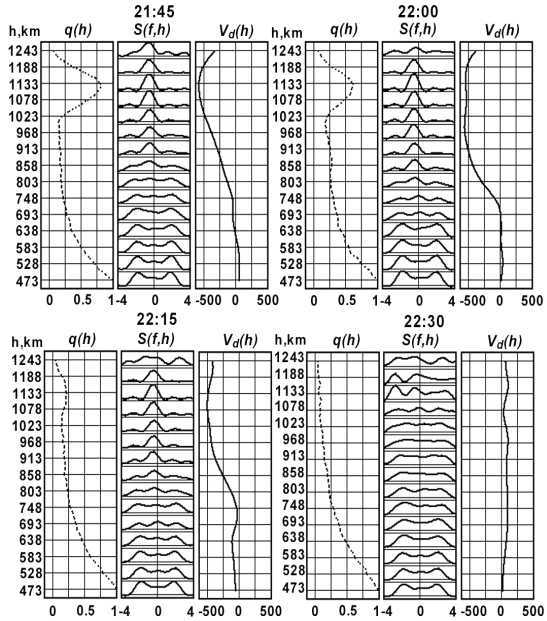


Fig. 3. The altitude structure of a signal/noise ratio, of electronic density thermal fluctuations spectra, drift velocity, is measured 30 May 2003.

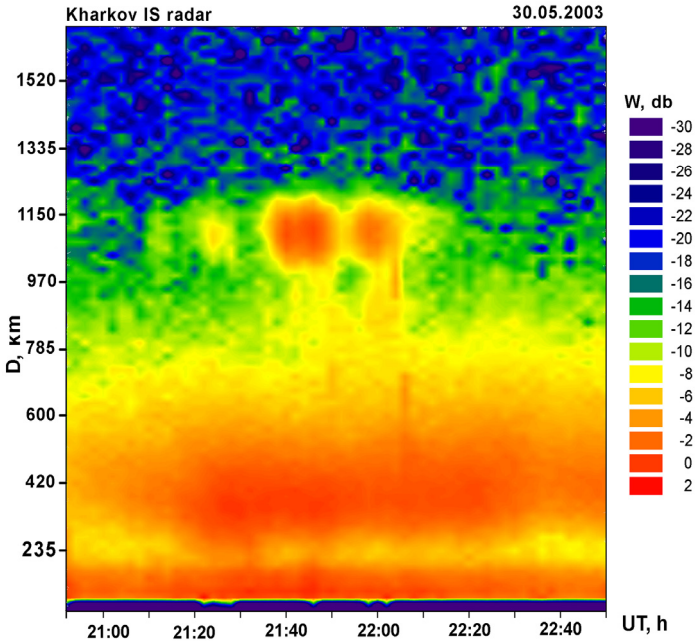
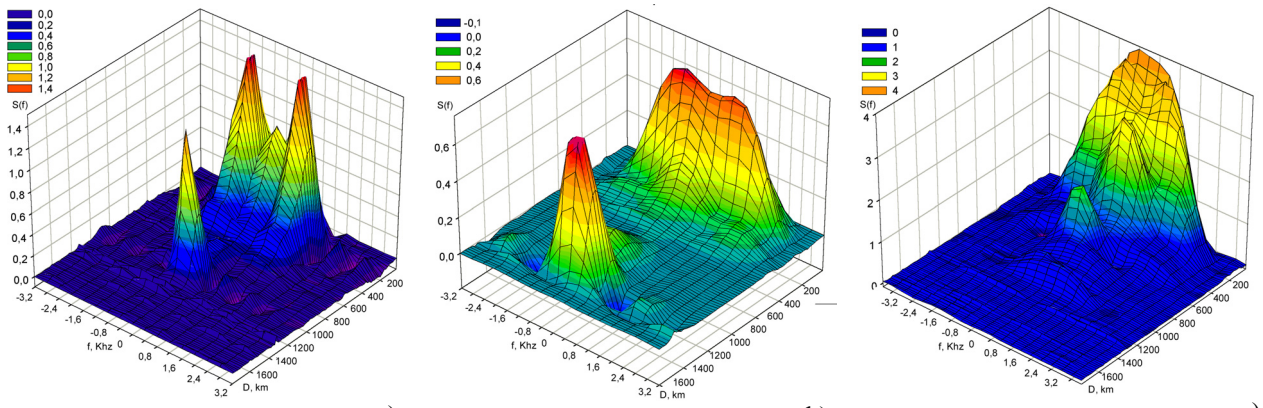


Fig. 4. Distribution of a signal power of return scattering, fixed during geomagnetic storm 30 May 2003

During strong geomagnetic storm on November 8-12, 2004 in night time 9.11.2004 and day time 10.11.2004 anomal signals - coherent backscatter were observed. In night time this signal from 19 h 52 min to 20 h 00 min, from 20 hours 18 min for 20 hours 26 min, from 22 hours 25 min for 22 hours 50 min UT in an interval of distances 1000 - 1190 km (fig. 6, 7) was registered. At this distances before incoherent scatter signal was not fixed because of the signal/noise ratio less than 0.5 %. The appeared well differentiable quasicoherent signal with narrow-band spectrum shifted in positive frequencies area. The estimations of thermal fluctuations electronic densities spectrum obtained on this period are presented on fig. 6.

30.05.2003 09.11.2004 09.11.2004



a) b) c)

Fig. 5 Spectrum signal altitude dependences

Between these intervals the same signal with a level on 10 - 15 db less was observed. About from 20 h 25 min for 20 h 50 min the signal strength varied on 15 - 20 db. During same period the signal on lower distances was observed also overall (superposition of incoherent and coherent component) signal above than 500 km with a maximum approximately on 700 - 800 km. At distances more than 1000 km the Doppler velocity reached 500 м/сек. During 20 h 10 min-20 h 30 min in a distances interval of 650 - 850 km the velocity with opposite direction and maximum value 270 m/s was observed.

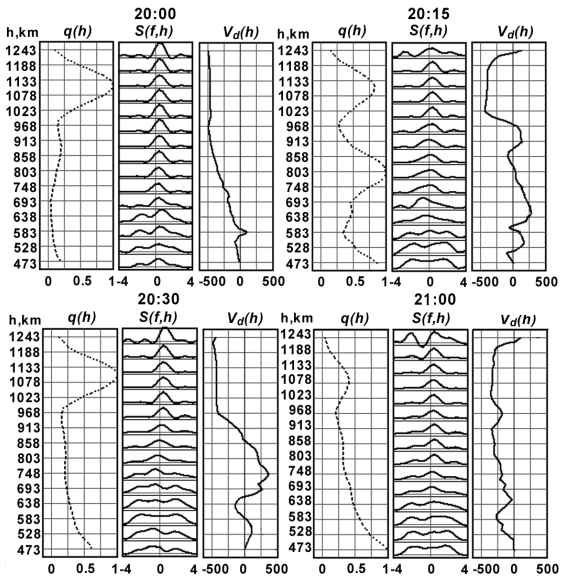


Fig. 6. The altitude structure of a signal/noise ratio, electronic density thermal fluctuations spectra, drift velocity, are measured November 9, 2004.

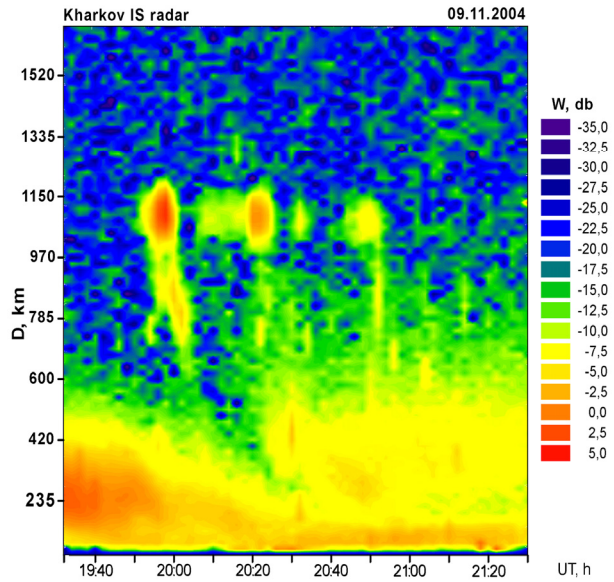


Fig. 7. Distribution of a signal power of return scattering, fixed during geomagnetic storm November 9, 2004.

At daytime anomalous received signal power amplification on slant ranges 350 - 1100 km was registered during ~ 20 min from 10 h 00 min to 11 h 20 min. The maximum magnitude at 11 h 10 min of UT in a range slant distances 400 - 450 and 650-730 km (fig. 8) was observed.

It is interesting fact, that on altitude-frequency characteristics that obtained by ionosonde in same point of observation, at 11:15 UT on November 10, 2004, during observation of signals coherent backscatters, diffuse reflections, that more typifying for high-latitude ionosphere (fig. 9) were fixed. The signal diffusion a could be stipulated by scattering of radiowaves on intense small-scale irregularities, oriented along a geomagnetic fields. These irregularities are generated near to the southern boundary aurora of the ovals during strong geomagnetic storm and have large space scale (from hundred to thousand of kilometres). It is important, that these day time events (coherent backscatters and diffuse trace on ionogramm) is occurred at minimum value Dst = -289 nTl.

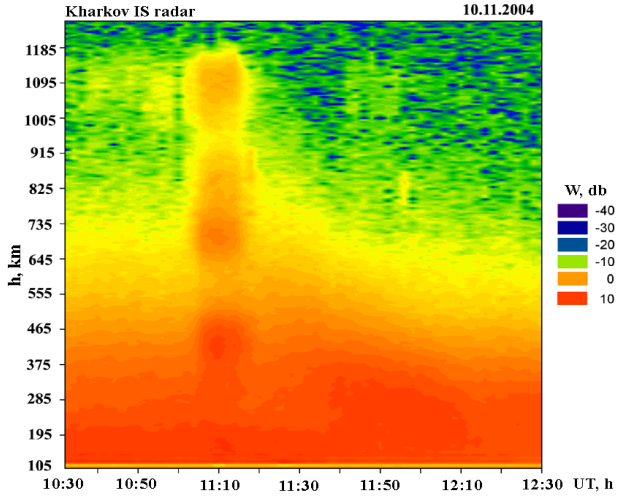


Fig. 8. Distribution of a signal power, obtained during geomagnetic storm November 9, 2004.

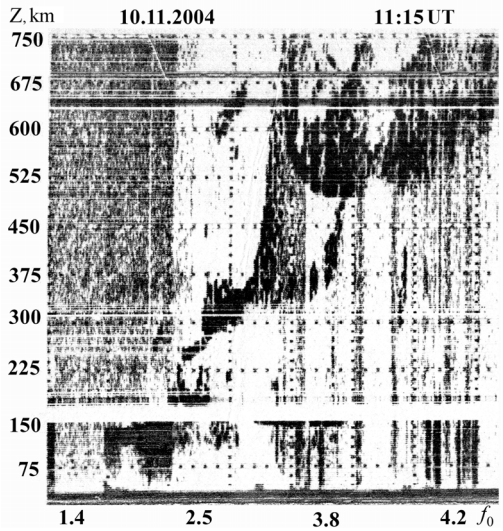


Fig. 9. Ionogramm.

Temporary variations of Dst index, obtained from World Data Centre (fig. 10, 12) and electron density in maximum F2 layer (fig. 11, 13), measured on Kharkiv incoherent scatter radar are presented on fig. It is seen, that the coherent backscatter was observed during a sharp decreasing of Dst index from approximately -40 up to -130 nTl for May 2003 and from approximately -120 up to -240 nTl for 9 November and from -160 up to -290 nTl 10 November 2004. During both event electron density in maximum F2 is inc The signal/noise ratio, that is registered at distances more1100 km on the degree more, than for usual IS signal.

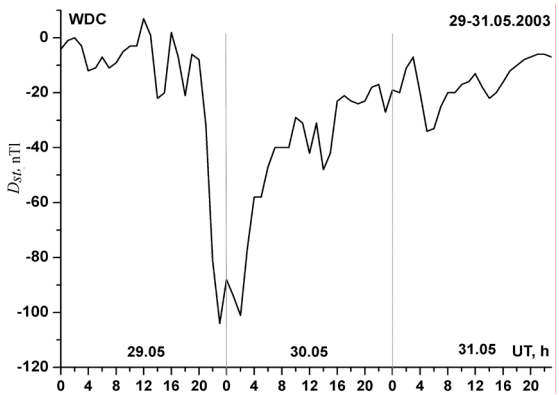


Fig. 10 Dst index 29-31 May 2003

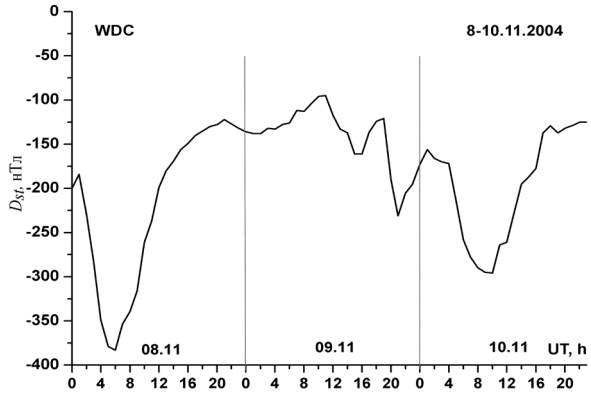


Fig. 12 Dst index 8-10 November 2004

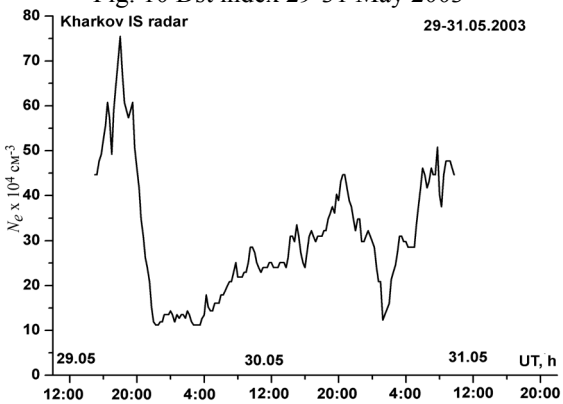


Fig. 11 Electron density on F2 max 29-31 May 2003

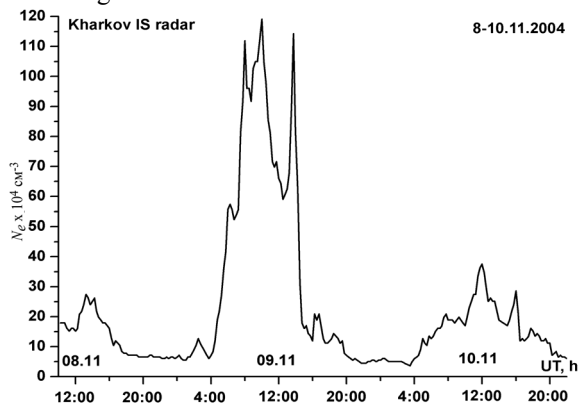


Fig. 13 Electron density on F2 max 8-10 November 2004

Under such space weather the displacement to equator of a main ionospheric trough is possible, the southern boundary auroral oval can extend up to geogeomagnetic latitude 51 - 45. In paper [2] is shown, that during strong geomagnetic storm there are conditions for formation of electron density irregularities stretched along a geogeomagnetic field and located in the E- layer at height about 110 km is appeared. In this case is possible this signal receiving by zenith antenna side lobes. The low-frequency spectrum, measured by us, most corresponds to typical of lower ionosphere. Similar characteristics midlatitude coherent backscatters were observed at Millstone Hill [3], twice registered on Irkutsk IS radar in 1998 and in 2000 [2]. On EISCAT radars is observed so-called naturally enhanced ion-acoustic lines (NEIAL) with similar spectra and amplitude-temporal characteristics [4].

1. V. I. Taran, “The Investigations of Ionosphere in Naturally and Artificially Perturbed States by Incoherent Scatter Method”, Geomagnetism and Aeronomy, vol. 41, no. 5, pp. 659–666, 2001 (in Russian).

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