Radiophysical observations of ionosphere disturbances generated by heavy class launch vehicle start.

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Abstract. Space vehicles launched at the near-earth orbits are able to cause the disturbances of the near-earth space areas. For purposes of such ionosphere disturbances detection the method of the estimation generalized parameter of ionosphere - the relative scattering cross section was developed. It is considered the heavy rocket launch from launch site Baikonur of 25 December 2006. Presented results on investigation of the ionosphere responses to the start of this heavy class launch vehicle with the Kharkiv IS radar observations. Measured dependences of ionosphere plasma scattering cross section and statistical processing results during this event were adduced.

Anthropogenic actions related with the human influence into the weather, climate and near-earth space have become comparable with influence of natural processes. Space vehicles launched at the near-earth orbits are also able to cause the disturbances of the near-earth space areas. The artificial disturbances are usually originated due to the energy entry by the rocket propellant combustion at the time of rocket launches and space vehicle orbit corrections, due to the emissions of different matters during space vehicles operation at the orbits and their displacement in the space [1]. The aim of this paper is the account of the results on investigation of the ionosphere responses to the launches of heavy rocket with the Kharkiv IS radar observations.

The ionosphere parameters measurements in height region 100-1500 km the most exact and information incoherent scatter method allows to obtain the most fully data about space weather: electron and ion temperature, drift velocity, molecular composition, electron density [2]. In the process of the ionosphere sounding the power spectrum (or autocorrelation function) is directly measured by incoherent scattering facility. To measure the electron density and temperature with error no more than 10-20% it is necessary to accumulate the signal during 10-15 min depending on conditions. Such temporal resolution in the most of cases is unfit for registration of the anthropogenic ionosphere disturbances.

For purposes of anthropogenic ionosphere disturbances detection the method of the estimation generalized parameter of ionosphere - the relative scattering cross section was developed. For a homogeneous ionosphere this parameter is determined by expression

$$\sigma_0(h) = \frac{kN_e(h)}{1 + \dfrac{T_e(h)}{T_i(h)}}, \tag{1}$$

where $N_e(h)$, $T_e(h)$, $T_i(h)$ – altitude dependences electron density, electron and ion temperatures in ionosphere, k – scale coefficient. For no homogeneous ionosphere relative scattering cross section depend of sounding wavelength, parameters and spatial plasma structure. In special case of backscatter and equality of electronic and ionic temperatures an equation for the scattering cross section is looked like as:

$$\sigma = r_e^2 \left\{ \frac{0.5 + \left(4\pi\lambda / \lambda_D\right)^2}{1 + \left(4\pi\lambda / \lambda_D\right)^2} N_e + \frac{8\pi l^3 \overline{\left(\Delta N_e\right)_T^2}}{\left[1 + \left(4\pi l / \lambda_D\right)^2\right]^2} \right\}. \tag{2}$$

Here r_e – classic electron radius, λ – scattered wavelength, λ_D – Debye shielding length, l – intrinsic scale of plasma irregularities (turbulences) with electron density root-mean-square deviation $\overline{\left(\Delta N_e\right)_T^2}$. Consequently, the ionosphere plasma scattering cross section is determined by its e electron density (first element) and presence in her of electron density irregularities (second element).

Equation (1) subject to (2) at T_e=T_i it is possible to produce in simplified form

$$\sigma_0(h) = k_1 \frac{P_c(h)}{P_ш} h^2 = q(h) \cdot h^2. \tag{3}$$

Thus for relative scattering cross section σ_0 estimation quite enough to measure the ratio of scattered signal power to power of noise and know scattered altitude *h*. The estimation σ_0 relative error in 2 times more than error of power estimation. At accumulation scattered signal during 1 min the error of relative scattering cross section do not exceed 5%.

Time - altitude scattering cross section dependences take possibilities to determine such anthropogenic ionosphere plasma disturbances:

- Disturbances time of delay and velocity, if is known time their arising and distance to this point;
- Altitude range of disturbances propagation (within the bounds of IS method sensitivity);
- Disturbances obtaining duration in a view point taking into account the time estimation error, caused discreteness of data from temporal accumulation
- Spatial - time shape of ionosphere disturbances;
- Relative intensity, which is relative variations ionosphere plasma scattering cross-section during disturbances lifetime as compared to a background value.

The presented radar observations ionosphere plasma response on launches of rockets were carried out in December 2006 with Institute of Ionosphere UHF incoherent scatter radar. Is situated near Kharkiv, Ukraine. Its geodetic coordinates are 49.7 N and 36.3 E. Geomagnetic coordinates are 45.3 N and 117.7 E. Radar facilities characteristics during experiment is: operation frequency – 158 MHz, zenith 100 m diameter parabolic Cassegrainian antenna with effective aperture about - 3700 m^2, provides power gain coefficient of about 10^4, the beam width of directional pattern of ~ 1^0, Pulse Transmitter power – 2 MW. Pulse duration of compound sounding signal element, that define altitude resolution are 130 and 660 mks, Pulse repetition frequency – 24.4 Hz. Polarization - circular. Is used tree signal processing system - double channel programmed correlators. Signal sampling period by time and delay is 30 mks.

In the given paper it is considered the rocket launch from lanch site Baikonur of 25 December 2006. At 23:18 o'clock 25.12.2006 per Moscow time (22:18 per local time) was carried out launching of "GLONASS" system satellites by launch vehicle “Proton-K” with upper stage.The launch was successful. The distance from the rocket launch site and the site of observations done is 2500 km.

Heavy class launch vehicle characteristics is:

Liftoff Mass – 698000 kg; overall length - 57,64 m; maximum diameter - 7,4m; stage number - 4; initial traction ~ $9x10^6$ N. The first stage parting passed at 20 second of flight.

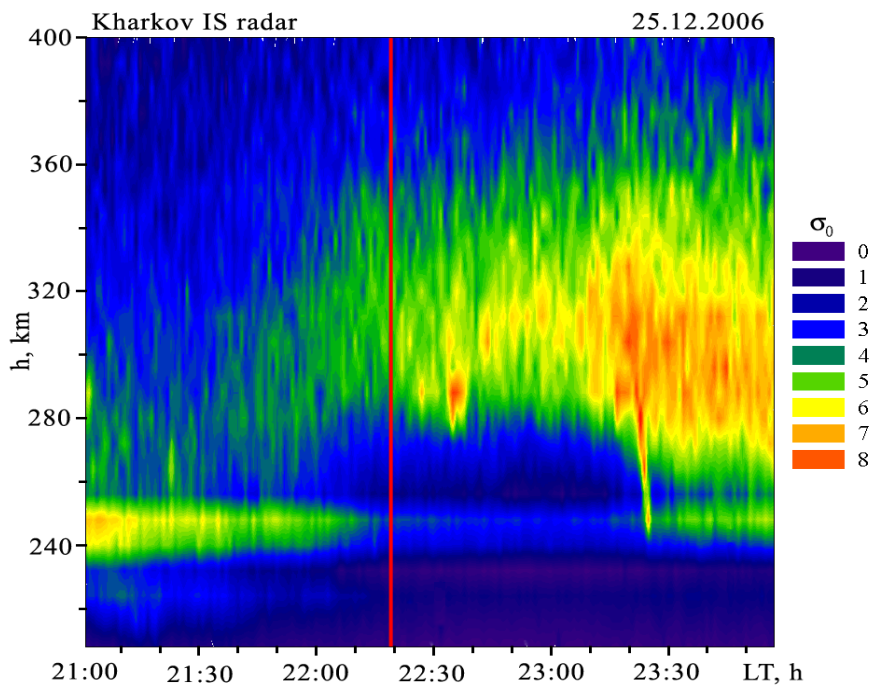

Fig.1. Time- altitude dependences relative scattering cross section σ_0 during launch vehicle “Proton-K” start 25.12.2006.

For analysis are used data obtained in double frequency measurement channel with spatial resolution ~ 19,5 km. It is to take possibilities more accurately is localize disturbances at altitude. The data storage time in one initial measuring session is 1 min (1460 sounding cycle). Sequentially was calculated IS signal power, normalized to power of noise (q) and cross section of unit plasma volume (σ). Measurement results of cross section were presented on figures 1 in the form of 3D time series $\sigma_0(h)$ - profile. The startmoment is showed by red line. Further is calculated moving average dispersion at 10 points in altitude range 280-500 km and is determined characteristic times. The result can see on fig.2. The start time is showed by arrow.

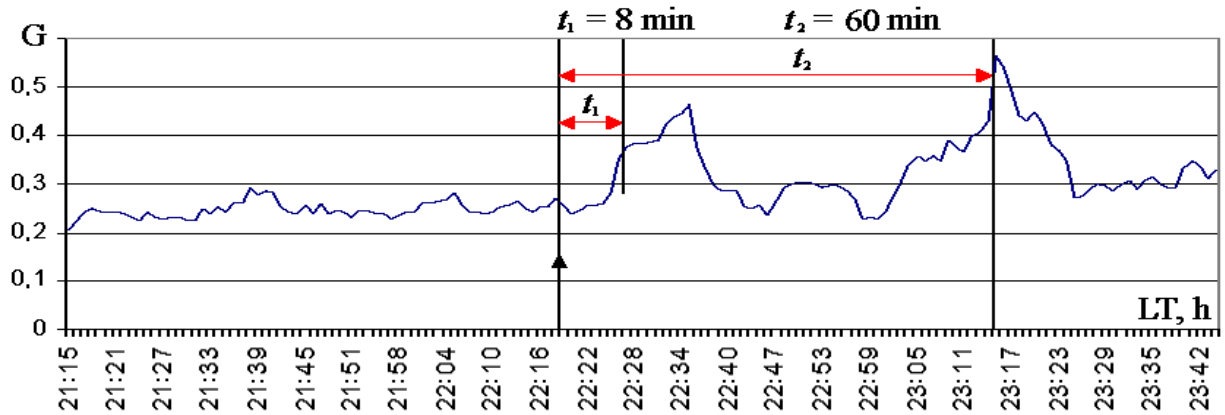

Fig.2. The moving average dispersion at 10 points on altitudes 280-500 km.

It is clearly seen there are two disturbed areas. The first disturbance was observed 8 min after rocket start. The calculated apparent velocity of disturbance propagation reached the value of 5.2 km/s. This velocity is typical for slow magneto-hydro-dynamic waves in the ionosphere [3]. They cause 1-1.5 periods of significant changing of the ionosphere plasma cross section with total duration of 10-20 min at all heights of the ionosphere F region. The relative amplitude of these disturbances is practically invariable with height and is equal of several tens of percents relative to the background conditions. The apparent velocity of disturbance propagation is no less than 4-6 km/s.

The second disturbance was observed 60 min after start. The calculated apparent velocity of disturbance propagation was about 700 m/s. The internal gravity waves propagate with similar velocities at the heights of the ionosphere F layer [4]. In character of the influence into the ionosphere they are similar to the well known traveling ionosphere disturbances. The slow disturbances become apparent in quasiperiodic change of the ionosphere plasma cross section, whose period are within the bounds from 30 min up to 2 h. The relative amplitude (σ_0 deviation from the background condition) in average reaches the value of 30-50%, but in individual cases this value can reach 70-80%. The slow disturbances are mostly observed at the heights of lower part of the ionosphere F region.

There is the great interest in research into the comparison of anthropogenic and natural disturbances in their characteristic temporal scales and maximal amplitude of the ionosphere plasma cross-section variations.

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).

2. Burmaka V.P., V.N. Lysenko, Chernogor L.F., Tcherniak Y. V. Geomagnetism and Aeronomy, 2006, 46, 783-800. (in Russian).

3.Sorokin V.M. Fedorovich G.V. Physics of slow magneto-hydro-dynamic waves in ionosphere plasma M.: Energoizdat. 1982. p. 136. (in Russian).

4. Gossard, E.E., Hooke, W.H., 1975. Waves in the Atmosphere, Section 24. Elsevier, Amsterdam. ISBN 0-444-41196-8, 456 pp.