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INVESTIGATIONS OF THE RESPONSE OF MID-LATITUDE IONOSPHERIC D-REGION TO POWER ATMOSPHERIC FRONT PASSAGE

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It was experimentally found that almost in half of cases of atmospheric front (AF) passages quasi-periodic changes in height and time variations of amplitudes of the partially reflected (PR) signals and radio noise as well as electron concentration in the D-region took place for tens of minutes due to the passage of infrasonic waves unlike during the periods before and after the passage. It was also determined that in the lower part of the mid-latitude D-region (heights of $z < 80$ km) the values of electron concentration appeared to be underestimated by a factor of 1.2…2.2 times as compared to control days. The mechanism of such an drop in magnitude $N(z,t)$ can be explained by the effect of the tropospheric disturbance with the help of a complicated series performed both via the dynamic channel and via the channel of small components redistribution.

KEY WORDS: *atmospheric front, height and time variations of the amplitudes of partially reflected signals and radio noise, electron concentration, infrasonic waves, mid-latitude ionospheric D-region*

1. INTRODUCTION

Natural disturbances in the lower ionosphere caused, for instance, by powerful earthquakes, solar terminator, volcanic activity, strong rainstorms, powerful atmospheric events (atmospheric fronts passage, cyclones and anti-cyclones, typhoons), Sun eclipses etc., have not been studied thoroughly by now. Very often they exert an essential influence upon the atmosphere and ionosphere of the Earth and, thus, represent a substantial interest for understanding of the physics of ionosphere and solving of a number of applied problems in the radio communications, radio navigation etc. To investigate the events occurring in such cases in the lower ionosphere the partial reflections technique (PR technique) (see, for example [1–8]) has been applied often during the recent decades. It is stipulated by the acceptable accuracy of obtaining the information about height and time variations of basic parameters of the lower ionosphere and radio noise, the opportunity of performing continuous lasting (tens of hours - days) observations with temporal resolution of single seconds-tens of seconds-single minutes and the resolution upon the altitude of Δz = 1.5-3 km. The latter parameter is a very favorable advantage of the PR technique as compared to other methods of the lower ionosphere investigation, like, for instance, the rocket ones, which are episodic. It is known that natural disturbances possess quite a broad range of durations – from single seconds to tens of hours-days.

The results of the experimental study of the response of mid-latitude ionospheric D-region to passage of power atmospheric front are provided and considered in this work. The foundation of this paper is the database accumulated during the years 2000 to 2010 using the PR technique on the equipment owned by V. Karazin Kharkiv National University [9] near the city of Kharkiv,

2. BRIEF INFORMATION ABOUT THE EXPERIMENTS

Behavior of the electron concentration N at different altitudes z in the mid-latitude ionospheric D-region was considered in the periods before, during and after passage of the warm and the cold atmospheric fronts (AF) for different seasons. The cycles of continuous observations using the PR technique were 3-3.5 days. Their number was 8. Brief information about their results is provided in Table 1. Altitude and time variations of PR signals amplitudes $A_{so,x}(z,t)$ and the noise amplitudes $A_{no,x}(t)$ were recorded while performing the experiments. Height profiles of the electron concentration $N(z)$ were obtained after the time steps of 10 minutes with the error of < 30% using the technique described in [10].

TABLE 1: Information about the experimental conditions

Date	Time of measurements, (LT)	Time of AF passage, (LT)
10 – 12.04.2001	Continuously	11.04.2001: 11.20 a.m – 02.20p.m.
16 – 19.11.2001	Continuously	17.11.2001: 09.00 a.m – 02.00p.m.
27 – 30.10.2004	Continuously (several breaks for 1…3.5 hr)	29.10.2004: 11.00 a.m – 02.30p.m.
30.03–3.04.2004	Continuously	02.04.2004: 09.00 a.m – 02.00p.m.
02 – 03.02.2005	Continuously	02.02.2005: 10.30 a.m – 02.00p.m.
10 – 12.05.2006	Continuously	11.05.2006: 10.30 a.m – 02.00p.m.
07 – 09.02.2007	Continuously	08.02.2007: 08.00 a.m – 03.00p.m.
20 – 23.03.2007	Continuously	22.03.2007: 11.30 a.m – 02.30p.m.

We admit that the observations were performed under the quiet heliogeomagnetic conditions. The time of start and completion of the AF passage is determined with the accuracy of ~ 10-30 minutes. Time intervals of the start and the recession of the AF amounted to tens of minutes and more. AF temporal parameters were determined on the basis of meteorological data – variation of the atmospheric air temperature and pressure, wind direction and velocity – measured near the Earth's surface. The information about the heliogeomagnetic conditions and the AF parameters was obtained via Internet and at Kharkiv weather station (the airport ground control facility). During the experiment of 30.03–03.04.2004 the air temperature and the atmospheric pressure were measured with the time step of 0.5-2 hr at the observation point (no material discrepancies were revealed at their comparison with the data received from the weather station).

3. MAIN RESULTS

Figure 1 provides the time dependences of the electron concentration N at different altitude levels in the mid-latitude ionospheric D-region for the periods before, during and after passage of the warm (11.05.2006) and the cold (22.03.2007) atmospheric fronts in various seasons of the year (in relative units). For the purpose of comparison we used the ratio N/N_{AF} of the averaged for 30 minutes values of $N(z,t)$ obtained on control days N and on the days of the AF passage N_{AF}.

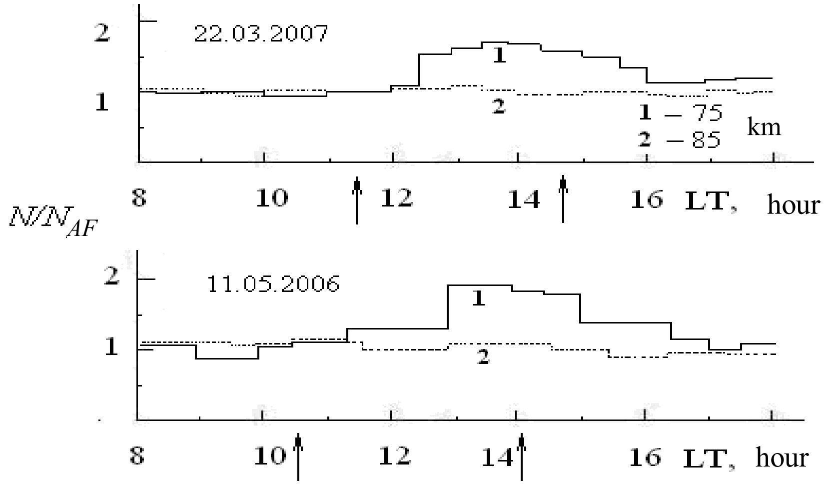

FIG. 1: Time dependences of the electron concentration at different altitude levels in the mid-latitude ionospheric D-region during the passages of the atmospheric fronts on 11.05.2006 and 22.03.2007 (the arrows indicate periods of the atmospheric fronts)

Analysis of the experimental results demonstrated that basic particularities of the height and time dependences $A_{so,x}(z,t)$, $A_{no.x}(t)$ and $N(z,t)$ during all of the experiments concerned can be summarized to the following:

1) during the AF passage and within 1-5 hours afterwards (sometimes even longer but the identification is aggravated by the influence of the solar terminator) the non-stationary mode of PR-signals and radio noise is significantly higher than during the periods before the passage of the fronts;

2) almost in half of the considered cases there were revealed certain changes in the behavior of $A_{so,x}(z,t)$ during the AF passage as compared to the periods before and after it. Quasi-periodic changes of $A_{so,x}(z,t)$ were observed during tens of minutes. In that case there also occurred the height shift of the above process. As it was demonstrated by the analysis of initial recordings of PR-signals, the estimated rate of the process shifting was of ~ 350–340 mps. Figure 2 shows an example of the height and time profiles of $<A_{so}^2>$, each of them was obtained during the experiment held on 22.03.2007 (01.10 p.m. LT) during the AF passage by averaging upon 50 realizations (within 5 seconds).

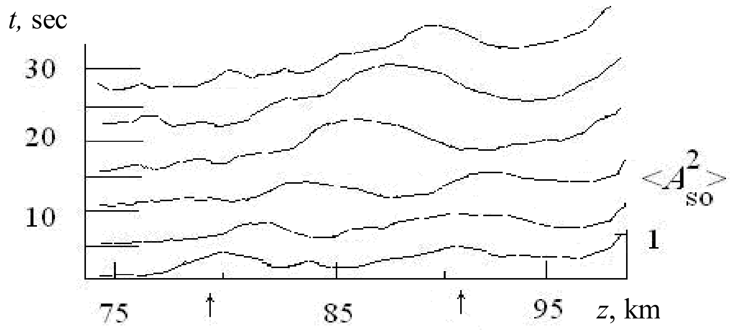

FIG. 2: An example of height and time profiles $< A_{so}^2 >$

There were determined the particularities, which had not been observed before the passage of AF. It is clearly seen that the height shift of the maximal value of $<A_{so}^2>$ with time (within 30 s) by 12…13 km. Similar effect occurs for $< A_{sx}^2(z,t) >$ as well. The estimated vertical velocity of the disturbance transfer is $V \approx 350$ mps. We note that similar changes were observed during severe rainstorms (see, e.g. [11]).

At spectral processing of the dependencies $A_{so,x}(z,t)$ (performed for the heights of z = 75-93 km, see for example Fig. 3) it was established an essential increase of the spectral component power at the frequency $f \approx 0.5$ Hz that corresponds to the infrasonic band. It should be noted that such variations were not observed during the background measurements on control days (same as during a number of experiments under the non-disturbed conditions);

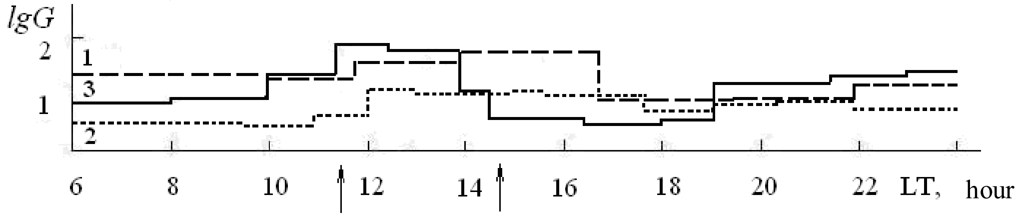

FIG. 3: Time dependences of the spectral density G for $A_{so,x}(z,t)$ obtained during the atmospheric front passage (marked by arrows) using the PR technique on 22.03.2007, curves: 1 – z = 75 km; 2 – z = 84 km; 3 – z = 93 km (f = 0.5 Hz)

3) as it is evident from Fig. 1 at the altitudes of the lower part of the D-region (z < 80 km) the values of N appeared underestimated one as compared to control days. The underestimation factor was 1.2-2.2. The authors explain the mechanism of the above underestimation N by the tropospheric disturbance effect through a complicated series of interactions executed both via the dynamic channel (with the help of horizontal and vertical transfers) and via the channel of redistribution of small components (e.g., O_3. It is known that with the increase of the ozone concentration the electron concentration decreases). The authors explain decreasing of the electron concentration in the lower part of the D-region by the increased concentration of negatively charged ions;

4) the remarkable changes in behavior of $N(z,t)$ were not determined in the upper part of the D-region.

4. DISCUSSION

The influence of the atmospheric disturbance upon the lower ionosphere exerted through the entire complicated series of interactions is executed comparatively fast (of the order of hundreds of minutes or maybe faster). Judging upon the results of ground based artificial acoustic-electromagnetic (comparatively low-power) disturbance of the ionosphere (practically an "instant" one) [12] we can admit that this possibility of a "fast" disturbance exists under the considered natural conditions as well. However, performance of the required detailed analysis with respect to determining of exact channels of influence of the above effect upon the lower ionosphere behavior is necessary.

It is known that the main role in dynamics and energetics of the atmosphere and ionosphere is played by atmospheric gravitational waves (AGW); acoustical waves (AW), the periods of which are less than 5 minutes and the wavelengths are less than 100 km, along with the internal gravity waves (IGW) having typical periods from 5 minutes to 3 hours and the wavelengths more than 100 km. Having attained the ionospheric altitudes AGW reveal their properties in the form of the travelling ionospheric disturbances (TID). Two types of TID are observed in the ionosphere [13]: 1) the medium-scale ones propagating at the velocity of 100-250 mps (less than the speed of sound in the lower ionosphere), their periods vary from 15 minutes to 1 hour, their horizontal lengths are ~ 10-100 km, vertical lengths do not exceed ten kilometers; 2) the large-scale ones propagating at the velocity of 400-1 000 mps (comparable with the speed of sound at such altitudes), their periods vary from 30 minutes to 3 hours, the horizontal wavelengths are more than 1 000 km.

The sources of the wave disturbances propagating from the bottom to the upper atmosphere and ionosphere may be represented by tropospheric cyclones, frontal systems, stream flows, polar and equatorial stream systems interrelated with magnetic storms, solar terminator, hurricanes, rainstorms, nuclear weapon tests, earthquakes, eruptions of volcanoes, rocket flights at supersonic velocities etc. The wave mechanism is one of the efficient mechanisms of interaction between the atmospheric layers and the effect exerted by the bottom layers of the atmosphere. Atmospheric disturbances excite a broad AW and IGW spatial-temporal spectrum. These waves propagate from the source of disturbance in various directions and at different velocities due to dispersion and they are filtered depending upon the extent of their distribution in the atmosphere. The experiments demonstrated that AW were observed above the point of disturbance, while IGW were observed primarily at large distances [14]. Therefore, in addition to control of the helio- and geomagnetic environment the meteorological conditions in the region under study must be also considered while analyzing the effects of wave disturbances in the parameters of ionosphere because passages of atmospheric fronts can also be sources of IGW that is witnessed by the experimental results provided in this chapter.

5. CONCLUSIONS

1. Main particularities of height and time variations of the amplitudes of PR-signals, radio noise and of the electron concentration in the ionospheric D-region have been experimentally studied during passages of atmospheric fronts. It was experimentally found that almost in half of cases of atmospheric front passages quasi-periodic changes of $A_{o,x}(z,t)$ take place during tens of minutes due to the passage of infrasonic waves as compared to the periods before and after the AF passage. This process changed its height at the rate of 350-340 mps.

2. It was also determined for the first time that in the lower part of the mid-latitude D-region ($z < 80$ km) the values of electron concentration appeared to be underestimated by a factor of 1.2-2.2 times as compared to control days. The mechanism of such an underestimation of $N(z,t)$ can be explained by the effect of the tropospheric disturbance with the help of a complicated series performed both via the dynamic channel and via the channel of small components redistribution.

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