WAVE STRUCTURE MANIFESTATION OF IONOSPHERIC DISTURBANCE DURING MAGNETIC STORM

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ABSTRACT

This work studies variations of HF characteristics and ionospheric parameters recorded over mid-latitude paths of Russian East-Siberian region during magnetic storm on May 15, 1997. The sharp wave-like changes of maximum observed frequencies (MOF) were recorded during the main phase of investigated storms. Assuming that such MOF variations can be produced by the ionospheric disturbances propagating from the northern to the southern latitudes simulation of HF propagation conditions for this paths was carried out.

INTRODUCTION

Ionospheric response to magnetic storm represents a complicated complex of phenomena determined by characteristics of the solar wind, magnetosphere, neutral atmosphere and depended on many factors: local time of a storm commencement, intensity and duration of a magnetic disturbance and others. Generation of large-scale traveling ionospheric disturbances (TID) is one of the significant effects of ionospheric storms. The TIDs are formed at the auroral zones and propagate equatorwards on large distances [1-3] causing considerable variations of critical frequencies and heights at the F2-region maximum at the same time. Such sharp gradients of electron density can lead to considerable changes of radio wave propagation parameters. This work studies variations of HF characteristics and ionospheric parameters recorded at mid-latitude paths of Russian East-Siberian region during magnetic storm on May 15, 1997.

EXPERIMENTAL DATA ANALYSIS

The magnetic storm was recorded at some stations of the southern and northern hemispheres about 02 UT on May 15, 1997 and continued more then 40 hours. The magnetic field was quiet before the storm. The D_{st} index reached a minimum value of -115 nT during the major negative storm phase while the K_p index reached its maximum value of 7^+ at that time. Figure 1a shows D_{st} variations changes.

Ionospheric response to the storm had been carried out using both EISCAT data [4] and vertical sounding data at the different longitude sectors of the northern hemisphere [5]. It was mentioned that the short-lived positive disturbances were recorded on some stations of the Siberian and the Far East longitudes during the major storm phase in the evening sector and maximum amplitudes of the positive variations were observed at the stations located on the 130-150▫ E longitudes [5]. The positive disturbances were changed by the negative ones 2-3 hours later.

Investigation of the radio wave propagation characteristics during the storm has been carried out for oblique-incidence and back-scattering sounding paths. The Magadan-Irkutsk oblique-incidence path is supplied with the Chirp Ionosondes. Transmitter is in Magadan, receiver is in Irkutsk, the interval between soundings is 15 minutes. The path azimuth is 55°, distance is approximately 3000 km. The back-scattering sounding paths are oriented to the south-east direction with the azimuth 121°, the transmitting and receiving points are in Irkutsk, the interval between soundings is 15 minutes. Figure 1(b-c) shows maximum observed frequencies variations (MOF) for the first (b) and second (c) hop modes of HF radio signals propagation recorded at the Magadan-Irkutsk path for the two successive days of May 14 and 15. It is obvious that before the magnetic storm under the quiet geomagnetic conditions on the May 14 MOF variations changed insignificantly with the exception of the night and early morning hours. During about 6 hours in the daytime

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we can see reflections from both F2-layer and F1- one but MOF1F2 and MOF1F1 distinguish insignificantly. The last fact points out development of a typical picture for the F-region of summer ionosphere. As the magnetic disturbance develops the differences between MOF1F2 and MOF1F1 becomes larger. In addition we can note wave-like character of MOF1F2 changes after 8 UT: from the beginning the values increased then they decreased sharply then MOF1F2 increased up to 25 MHz following which there was observed sharp decrease of the MOF1F2 values up to 14 MHz during 1 hour. The MOF1F2 reflections vanished after 13UT and appeared at the morning hours only. The same response character for the MOF2F2 was from 8.45UT to 13UT but the second hop mode registration was realized during the whole day on May 15 unlike the first hop mode (Fig.1c).

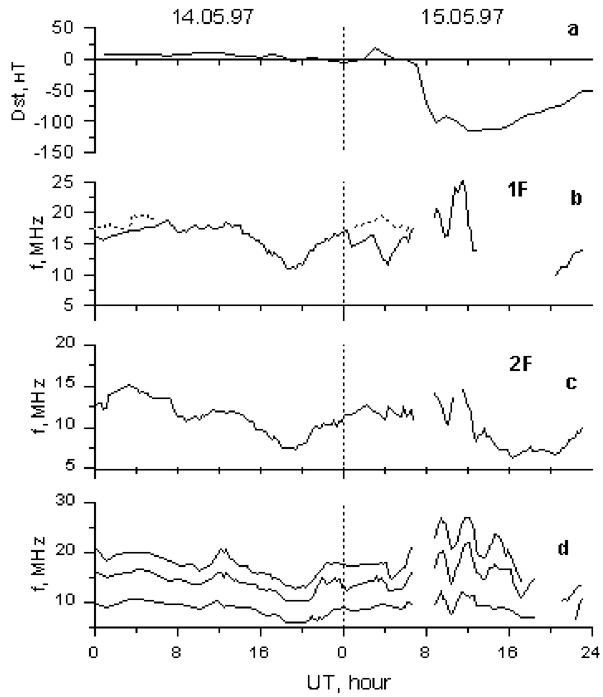

Figure 1. D_{st} (a) and MOF (b-c) variations at the Magadan-Irkutsk path and back-scattering sounding paths on the May 14-15, 1997

Figure 1d shows observed MOF variations at the back-scattering sounding paths for the distances of 1000, 2000 and 3000 km obtained a day before and during the magnetic storm. One can see under quiet conditions on May 14 MOF variations for the 2000 and 3000 km paths are similar, there are observed two MOF1F2 maximums at 04UT and 12UT (approximately 13-14LT and 20-21 LT) and minimum values are recorded near 20-22UT. The 1000 km path day and evening maximums develop insignificantly and minimum values are recorded at early morning hours too. During the magnetic storm disturbance MOF variations were changed considerably. One can note wave-like character of MOF variations for the 2000 and 3000 km paths with large amplitudes with maximums recorded near 9.30UT, 12UT and 15.15UT moreover MOF maximum values on the May 15 noticeably top MOF values for the quiet conditions.

Thus during the major phase of the magnetic storm on May 15, 1997, the sharp wave-like changes of MOF with large amplitudes and period of 2-3 hours were recorded at the investigated paths.

IONOSPHERIC RADIOCHANNEL SIMULATION

Under the assumption the ionospheric disturbance has a wave structure and propagates from the northern latitudes to the southern ones the simulation of HF radio wave propagation conditions for this paths was carried out. The calculation of ionospheric radio channel parameters has been performed using program complex developed on the base of normal wave method at the Institute of Solar-Terrestrial Physics SB RAS. Ionospheric parameters distribution was specified using IRI-95 model with the correction of the critical frequencies along the propagation path.

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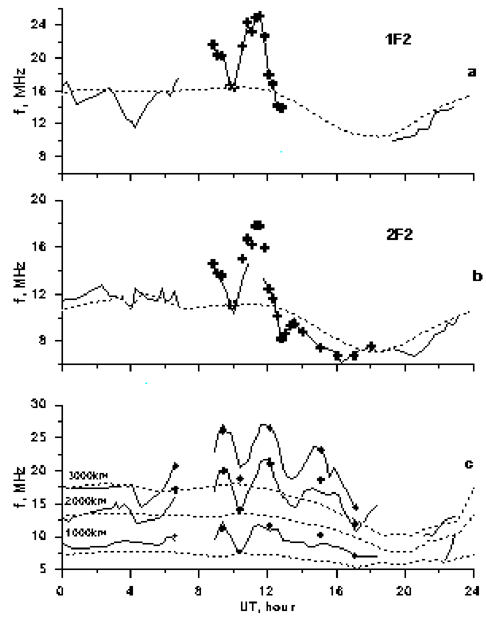

Figure 2. Diurnal variations of experimental MOF and calculated MUF for the investigated paths

The parameters of the wave disturbance were selected thus that the calculated magnitudes of maximum useful frequencies (MUF) of the first mode MUF1F2 coincides with observed MOF1F2. The criterion of calculation accuracy served coincidence of observed MOF and calculated MUF of the second hop mode and propagation time of the first hop propagation. Figure 2 shows experimental (solid line) and calculated MUF variations values. Dotted line shows computations executed without correction and symbols label calculated MUF for the first hop (2a) and the second hop (2b) modes of radio signals propagation using correction. The selected model of ionospheric disturbance allowed receiving good agreement between experiment and calculated HF channel characteristics. It was realized mathematical simulation of the evening and night situation then the radio wave propagation at the path was happened by the second hop mode only (after 13UT).

The bottom part of the Figure 2 (c) shows calculations obtained for the back-scattering sounding paths. Evidently MUF calculations carried out using IRI model without correction (dotted line) show large deviation with the experimental data while calculations carried out with the correction of the ionospheric parameters show good coincidence with the experimental data.

DISCUSSION AND CONCLUSIONS

During the major storm phase enhanced critical frequencies were recorded at the Magadan, Petropavlovsk and Khabarovsk vertical sounding stations which 2-3 hours later were decreased sharply. Such ionosphere response can be classified as the dusk effect manifestation appearing at the major storm phase in the evening sector at the subauroral and middle latitudes [6]. The incoherent scatter data analysis at Millstone Hill obtained during the magnetic storm on the May 26-27, 1990, during observation of the intense dusk effect and simulation results showed that such response of the electron density can be caused by different reasons: combined effect of the meridional winds and electrical fields, aeronomical processes including transmission of the atmospheric wave disturbances [7]. Carrying out mathematical simulation of the radio wave propagation conditions at the Magadan-Irkutsk path using the correction we obtained the projection of such wave disturbance shown at the Figure3.

According to the modeling calculations the period of the ionospheric disturbance was about 2-2,5 hours with a travel velocity of about 450-500 m/s that corresponds to estimations obtained using experimental data [1-2].

The selected model of ionospheric disturbance allowed receiving good agreement between experiment and calculated HF channel characteristics.

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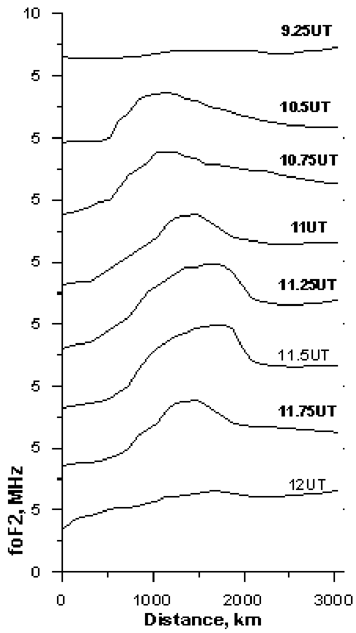

Figure 3. Calculated variations of critical frequencies for some time moments along Magadan-Irkutsk path

Accordingly the following conclusions can be made:

1) During the main phase of the magnetic storm wave-like changes of maximum observed frequencies of HF radio waves were recorded over the paths located in the regions of Siberia and the Far East;

2) The mathematical simulation of the HF radio signals parameters was carried out for the Magadan-Irkutsk oblique-incidence sounding path and back-scattering sounding ones. Wave disturbance parameters obtained as a result of the critical frequencies correction over the propagation path agrees with commonly accepted estimations for the velocity and time characteristics of wave ionospheric disturbances.

ACKNOWLEGMENTS

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