COMPARISON OF IONOSPHERIC RADIOSOUNDING FROM THE MIR MANNED SPACE STATION WITH DATA FROM GROUND-BASED IONOSONDES

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1. Introduction

The ionosonde on the MIR Manned Space Station (MMSS), which orbited at altitudes of about 350 km, provided a new opportunity for ionospheric sounding from satellites. The orbits of previous topside ionosondes were considerably higher. The Alouette 1, ISS, Cosmos 1809 and ISIS 2 satellites flew in polar (or close to polar) circular orbits with heights of ~1000 km, 900 km and 1400 km, respectively. The orbits of Alouette 2, ISIS 1, and Intercosmos 19 (at the end of its life) were elliptical at altitudes of 500-3000 km, 570-3550 km, and 500-1000 km, respectively. The average orbital height of MMSS corresponded to the height of the electron concentration maximum in the ionosphere. However, the ionosphere is a very changeable medium both in time and space, so during the measurements, MMSS was located both above the main electron concentration maximum and below it. It is worth mentioning that, when MMSS flew in the near-equatorial region, the ionosonde was rather often below the ionospheric maximum.

The concept fro deployment of an ionosonde within the region of the ionospheric ionization maximum occurred after conducting experiments on transionospheric sounding [1]. From these experiments it became clear that one could determine the principal ionospheric parameters (critical frequency, peak ionization height, and half-width of the F region) at any position of the ionosonde relative the ionospheric maximum. When the satellite was located below the peak sounding provided new possibilities for calculation of the Nh-profiles in the bottom side ionosphere. These possibilities appeared due to a combination of the solutions based on the methods using radio wave reflection from the ionosphere and methods used in transionospheric radio wave propagation. The methods developed are based on using in the calculations at least one point on the Nh-profile, the position of which is determined from highly accurate navigation satellite data for Nh-profile calculation accuracy. The latter means that the entire profile is also derived with much higher accuracy.

2. Peculiarities of ionograms recorded at low-orbiting satellites

Depending on where (below or above the F-region maximum) the satellite is orbiting, significantly different details appear in the ionograms. The examples of such ionograms registered on one orbit when MMSS was crossing the ionospheric maximum downward are shown in Figure 1. Ionograms 1 and 2 were obtained when MMSS was situated above the electron concentration maximum. They resemble usual topside ionograms with distinct ordinary and extraordinary components reflected from the F2 layer.

Ionogram 3 corresponds to a rare occasion when MMSS crosses the F2-layer maximum. The reflection trace from the maximum became almost vertical (the plasma frequency of the ordinary component varies from 15.05 MHz to 15.1 MHz, the latter value being foF2, and the plasma frequency of the extraordinary component varies from 15.65 MHz to 15.7 MHz, the latter value being fxF2). The traces of the ordinary and extraordinary components are marked in Figure 1 by "o" and "x" respectively.

Fragments 4 and 5 provide typical examples of ionograms recorded onboard the satellite when situated below the F2-layer maximum. The principal feature is the non coincidence of the lower frequency of the sounding wave reflected from the ground with the critical frequencies of the F region: foF2 and fxF2. The coincidence of the above-mentioned parameters, vice versa, is the most typical feature of the topside sounding, that is, the sounding during which the ionosonde is situated higher (as a rule, considerably higher) than the electron concentration maximum in the ionosphere, and of vertical radio wave propagation. When the satellite is situated below the ionospheric maximum, the lower frequency of the reflection from the ground determines the plasma frequency of the ionosphere in the satellite location point. The trace of the reflection from the ground (unusual for topside sounding) is seen in Ionograms 4 and 5. This trace makes a smooth turn at the lower sounding frequency related to the plasma frequency at the MMSS location and is continued in the direction of increasing frequency (denoted by L) when the virtual distances are significantly higher those determined

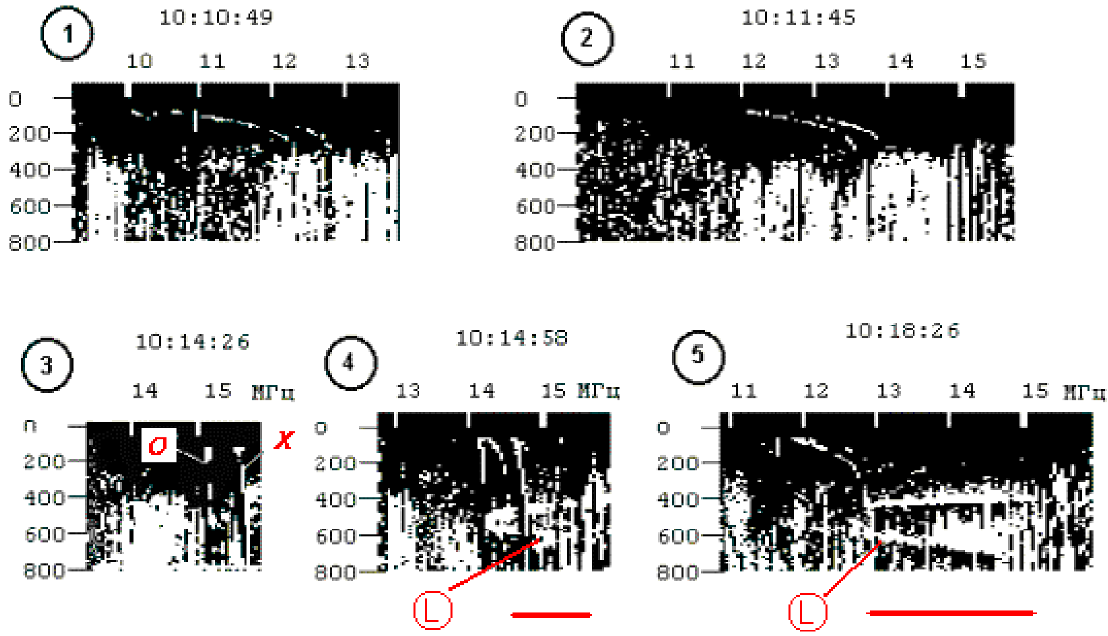

Fig. 1.

for a routine reflection from the ground. Such a trace is a characteristic feature of a large-scale isolated irregularity in the ionosphere situated at distances of 50-150 km from the MMSS position. The frequency range, in which the irregularity parameters are "ciphered" is shown by red horizontal lines at the bottom of Figure 1.

3. Nh-profile calculation

The calculation for ionograms 1 and 2 (Figure 1) was performed from the real height of MMSS to the F2-layer maximum height directly using the traces of o- and x-components reflected directly from the ionosphere. The results of these calculations are shown in Figure 2 by curve 1. It is worth explaining that in this figure the shifts of the concentration axes are proportional to the time between the corresponding experiments. The time interval for the first two ionograms was about 1 minute.

To compare the satellite radiosounding results with the data from ground-based ionospheric stations, Figure 2 shows the Nh-profile of the bottomside and topside ionosphere marked by {*} and published in [2]. This Nh-profile is a result of calculation based on two ionograms. One was recorded in an analog regime by a ground-based receiving station on a telemetry channel at 137 MHz. The other ionogram was recorded by a ground-based ionosonde at the time when MMSS was situated nearest to the point over the ground-based station.

Calculations show that, by combining various methods of Nh-profile calculations, one is always able to derive the electron concentration profile in the vicinity of the F-layer maximum. Thus, at least part of the profile is obtained more accurately than in standard methods of Nh-profile derivation from below or from above (when the satellite is at an altitude of ~1000 km).

4. Comparison

Further comparison of the results of the N(h) profile calculations from the MMSS data with the profiles based on the data of ground-based vertical radiosounding was performed using the data from the vertical sounding station at Chilton, UK.

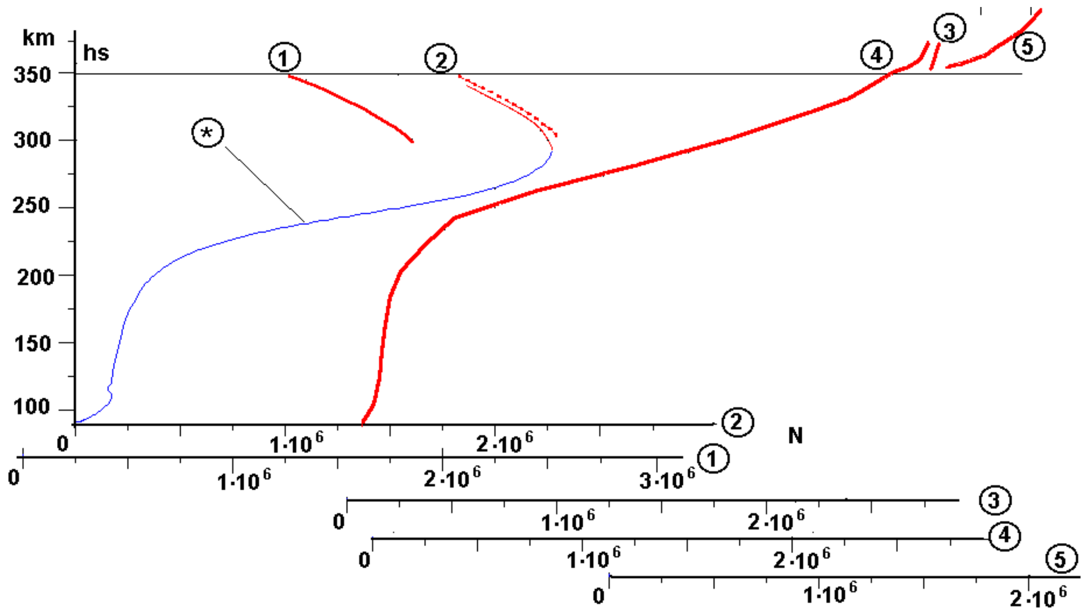

Fig. 2.

The periods have been chosen when MMSS flew within a small distance of a ground-based ionosonde and when there were no sharp changes in the ionosphere. The comparisons were performed for various times of day, for various conditions in the ionosphere and for various distances of MMSS from the F2-layer maximum. To completely exclude methodical errors, the cases have been chosen when MMSS was located directly within the F2-layer maximum. It is worth remembering that, when MMSS is directly within the F2-layer maximum, only the plasma resonances and/or cut off frequencies of this maximum, as well as traces of the reflection from the ground, are registered in ionograms. The height of plasma resonance, i. e. the F2-layer maximum height, was then determined from the MMSS location which is well known from navigation data thereby ensuring unusually high accuracy.

The comparison of the main parameters of N(h) profiles determined from MMSS station and from the Chilton vertical sounding station shows complete agreement when there is no E layer. However, the comparison of night-time ionograms showed that, though the critical frequency is determined with the same accuracy as in the daytime, the F2-layer maximum height is determined with much lower accuracy. Table 1 shows the data, which illustrate these differences.

Table 1. Comparison MMSS data with data of night-time ionograms

The sounding station.	**UT**	**The critical frequency (MHz)**	**The F2-layer maximum height (km)**
Chilton (London) 07.05.1999	04-00	5.35	326
MMSS, 07.05.1999 N 51.83 W 0.26	03-55-32	5.34	358.3
Chilton (London) 07.05.1999	02-00 02-30	5.9 5.7	368 373
MMSS, 07.05.1999 N 49.15 E 0.04	02-19-59	5.84	357.5

5. Conclusion

It has been demonstrated that an ionosonde installed onboard a satellite situated in the vicinity of the F2-layer maximum can be used to determine the principal ionospheric parameters. This confirms what has been shown earlier in a model experiment.

Combining the transionospheric methods (calculation of the N(h)profile on the basis of the reflection from the ground) with standard methods of N(h) calculation, one is able to derive N(h) profiles of the inner ionosphere with an accuracy comparable to the accuracy of the N(h) determination from ground-based ionosondes (and even exceeding it in some parts of the vertical profile).

It is shown that the ground-based ionospheric stations do not determine the height of the ionospheric maximum at night correctly. If ionograms from a manned space station (for example, International Space Station) were transmitted to a corresponding ground-based ionospheric station within the same geographical region, it could considerably improve the accuracy of F2-layer maximum height determination at night.

References

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