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

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1. Introduction

The installation of an ionosonde on board the MIR Manned Space Station (MMSS), which orbited at altitudes of about 350 km meant a new qualitative step in ionospheric sounding from satellites. The orbits of all the previous satellites with ionosondes were considerably higher. The Alouette 1, ISS, Cosmos 1809 and ISIS 2 flied along polar (or close to polar) circular orbits with the height of about 1000 km, 900 km and 1400 km, respectively. The orbits of Alouette 2, ISIS 1, and Intercosmos 19 (in the end of its functioning) were elliptical: 500-3000 km, 570-3550 km, and 500-1000 km, respectively. Installation of an ionosonde directly within the region of the ionization maximum in the atmosphere became possible after conducting experiments on transionospheric sounding [1]. In the results of these experiments it became clear that one can obtain the main practically important ionospheric parameters (the critical frequency, peak ionization height, and half-width of the F region) under any position of the ionosonde relative the ionospheric maximum. It is worth mentioning that, when MMSS flied in the near-equatorial region, the ionosonde rather often was below the ionospheric maximum.

The orbiting height of MMSS on the average 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 either above the main electron concentration maximum or below it.

Registration of ionograms of the satellite sounding for the position of the ionosonde below the F-region maximum provided new possibilities for calculation of the Nh-profiles in the botomside 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 a possibility to use in the calculations at least one point at the Nh-profile the position of which is determined from navigation satellite data with rarely high 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 at one orbit when MMSS was crossing the ionospheric maximum downward are shown in Figure 1.

The first and second ionograms were obtained when MMSS was situated above the electron concentration maximum. They resemble usual topside ionograms with a distinctly seen traces of the 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 vary from 15.05 MHz to 15.1 MHz, the latter value being foF2, and the plasma frequency of the extraordinary component vary 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 a typical example of ionograms registered on board a satellite situated below the F2-layer maximum. Their principal feature is the noncoincidence 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

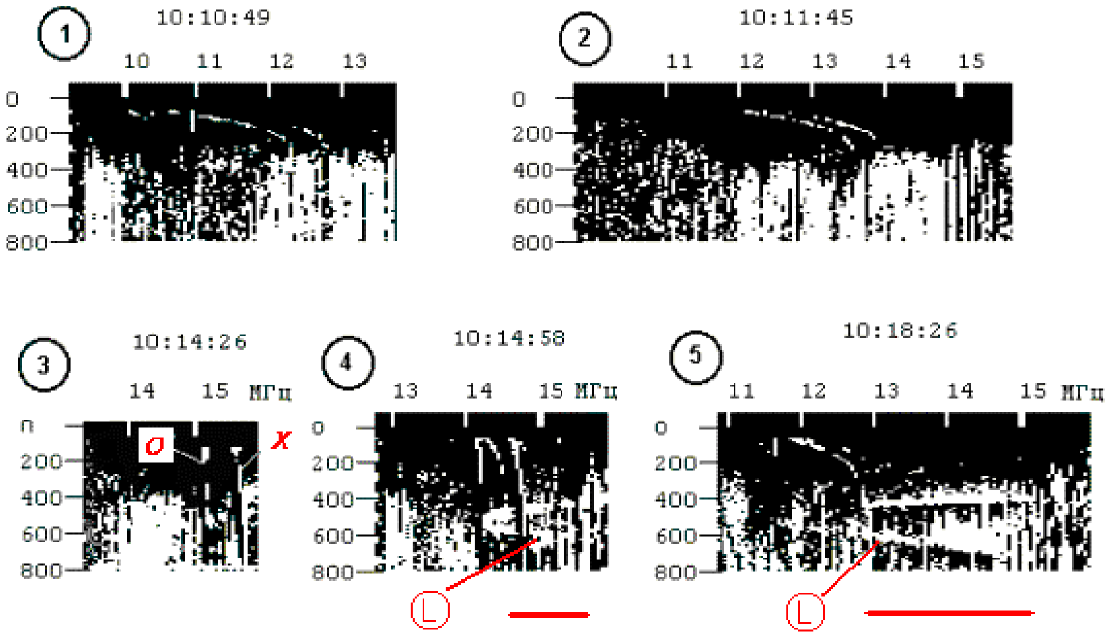

Fig. 1.

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 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 min.

To compare the satellite radiosounding results with the data of 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 in the telemetry channel at 137 MHz. The other ionogram was recorded by a ground-based ionosonde in the moment when MMSS was situated most close to the point over the ground-based station.

Calculations show that, combining various methods of Nh-profile calculations described, one is always able to derive the electron concentration profile in the vicinity of the F-layer maximum. Herewith at least part of the profile parameters will be obtained closer to the reality than in standard methods of Nh-profile calculations from below or from above but from the altitude of about 1000 km.

4. Comparison

Further comparison of the results of the Nh-profile calculations from the MMSS data with the profiles based on the data of ground-based vertical radiosounding was performed using the data of the most accurate (from the point of view of the authors of this paper) vertical sounding station on the planet located (after it was mover from Slough) in Chilton near London. This station publishes vertical sounding ionograms and corresponding Nh-profiles in the Internet.

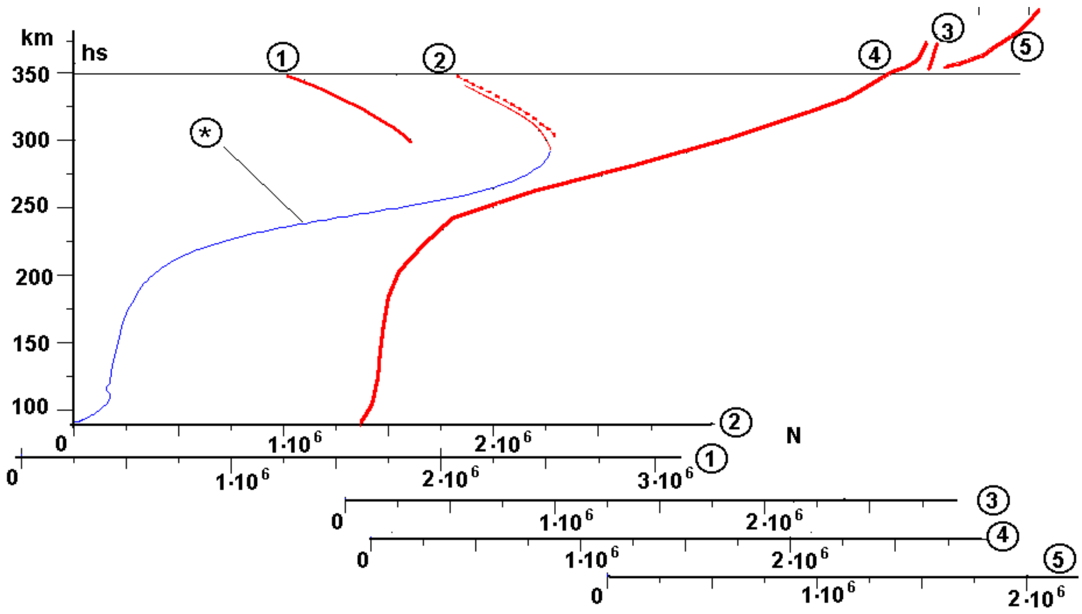

Fig. 2.

The sessions have been chosen when MMSS flied at a small distance over the ground-based ionosonde and there was no sharp changes in the ionosphere. The comparisons were performed for various time of day for various conditions in the ionosphere and various distance 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 reminding 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 appearance, i. e. the F2-layer maximum height, was determined in this case on the basis of the MMSS location which is known from the navigation data with unusual for N(h)-calculations accuracy.

The comparison of the main parameters of Nh-profiles determined from MMSS station and from the Chilton vertical sounding station demonstrates their complete coincidence for the cases when there is no E layer in the ionosphere. 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. Comparison MMSS data with data of night-time ionograms

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

Table 1 shows the data which illustrate these differences.

5. Conclusion

It is demonstrated experimentally that an ionosonde installed on board a satellite situated in the vicinity of the F2-layer maximum really makes it possible to determine the principal ionospheric parameters as it has been shown earlier in the model experiment.

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

It is shown that the height of the ionospheric maximum at night is not determined correctly enough by the ground-based ionospheric stations. One may assume that, if ionograms from manned space station (for example, international space station) were transmitted to a corresponding ground-based ionospheric station in the zone of the satellite visibility, that would have considerably improved the accuracy of F2-layer maximum height determination at night at all stations of the global ionospheric network.

References

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