Radio Signal Reflections in the 7-11 MHz Band on the Interkosmos-19 Ionograms

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***Abstract* — We consider the scattered reflections and multiple traces observed on the topside sounding ionograms recorded onboard the Interkosmos-19 satellite in the frequency band of 7-11 MHz. The reflected radio signals in this band appear both above and below the critical frequency of the F2 layer. They are regularly observed at high latitudes (>60° ILAT) and less frequently at the equatorial latitudes, at all altitudes of the outer ionosphere. The scattered traces indicate the presence of small-scale irregularities, and the multiple traces is the result of total internal reflection from the large-scale irregularities. The ray tracing shows that the size of large-scale irregularities is the hundreds of kilometers in height and tens of kilometers in latitude.**

Key words* — *ionosphere; topside sounding; Interkosmos-19; plasma irregularities

I. INTRODUCTION

Specific ionograms of the Intercosmos-19 satellite, characterized by the scattered reflections (noise) in the frequency band of 7-11 MHz are discussed. Besides, in the same frequency range the structured multiple traces associated with total internal reflection from the large-scale irregularities are sometimes observed. Therefore, the aim of this work is to study the characteristics of the scattered reflections and multiple traces in the radio frequency range of 7-11 MHz and modeling of irregularities which cause these reflections on ionograms reconstructed using the ray tracing.

II. SCATTERED REFLECTIONS OF THE RADIO SIGNAL

Fig.1 shows the typical ionogram with the scattered reflections received on April 26, 1979 in the day-time high-latitude ionosphere of the Northern hemisphere. The scattered reflections are quite clearly structured: the narrow band of a noise in a range of 8-9 MHz is located as at a pedestal at the wider noise domed area in the range of 7-10 MHz. The digital Interkosmos-19 ionograms have specific feature: only 3 strongest reflections of the radio signal at each frequency are recorded. Therefore, in the presence of multiple reflections on the ionogram only the upper part of the scattered cloud is recorded. In the case discussed the cloud of the scattered reflections is above the critical frequency F2-layer.

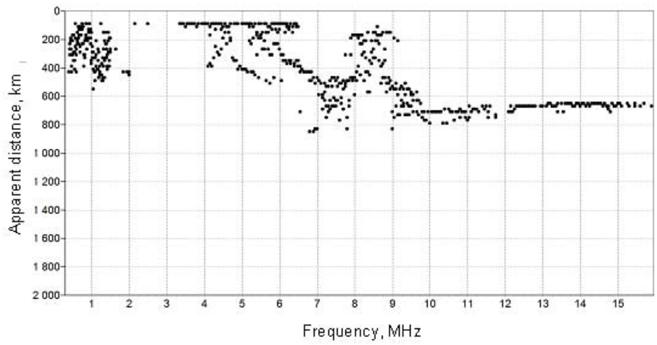

Fig.1. Ionogram recorded on April 26, 1979 at 23:04 UT, 16:25 LT at longitude of 260° E, latitude 68.8° N and altitude 620 km.

III. MULTIPLE TRACES OF THE REFLECTIONS

Fig.2 shows the ionogram with the diffuse cloud in the same frequency band of 7-10.5 MHz, the upper edge of which is formed as a separate trace. In this case the scattered cloud is again above the critical frequency F2-layer. The appearance of a clear trace means the total internal reflections from the irregularity with the size much greater than the length of the sounding radio wave. Since there are both structured and diffuse reflections, it means that a large-scale irregularity is filled with the small-scale irregularities. Since this is a region of high latitudes, most of all, we are dealing with a bundle of the irregularities along the magnetic field lines.

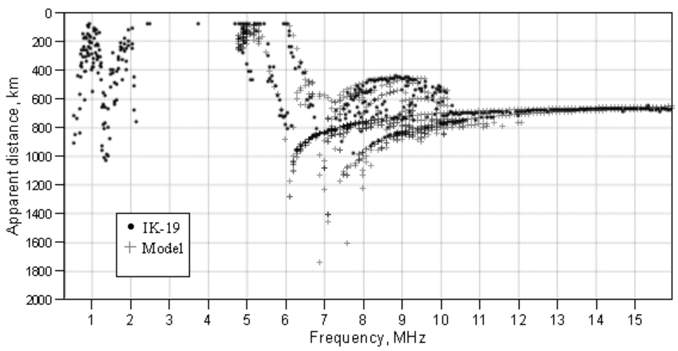

Fig.2. Ionogram received on November 13, 1979 at 21:36 UT, 12:00 LT, at longitude of 216° E, latitude 72.2° S and altitude 637 km. Points represent experimental ionogram, crosses – model ionogram (see text below).

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IV. Ray Tracing

The features of the ionospheric plasma irregularities were determined using the ray tracing. The ray tracing method described in [1,2]. The calculations were carried out in three stages: 1) a creation of the background ionosphere model according to the Interkosmos-19 data, 2) a formation of the inhomogeneous structure of the ionosphere, 3) the actual ray tracing based on the characteristics of the ionosphere model, and the formation of a model ionogram. Fig.3 shows the ionosphere model developed according to the principles described above, and in Fig.2 the model ionogram reconstructed on its basis is superimposed on the experimental ionogram for comparison (bright crosses). The main plasma irregularity forms the upper boundary of the diffuse structure in the range of 7-10.5 MHz frequencies. Its size is a few hundred kilometers. It is filled with small-scale irregularities.

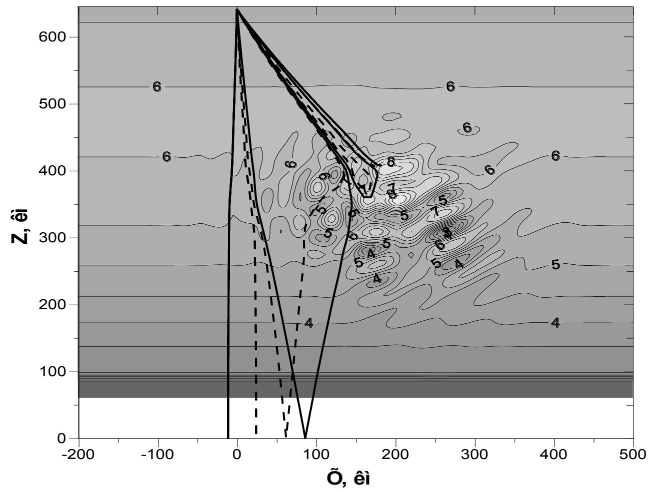

Fig.3. Ionosphere model for the event on November 13, 1979. The curves are a few examples of the ray paths at a frequency of 8 MHz, forming model ionogram. The solid curves represent the *O*-component and the dashed curves show the *X*-component of the radio signal.

V. Statistical Features of the Fenomenon

Fig.4 shows all cases of observation of the scattered reflections and multiple traces for an entire period of the satellite operation. They are presented in terms of longitude-invariant latitude in the upper panel and the local time-invariant latitude in the bottom panel. From Fig.4 it is evident that the phenomenon investigated occurs mainly at high latitudes, rarely in the equatorial ionosphere and very rarely at mid-latitudes. (High-latitude boundaries in the upper panel in both hemispheres are determined by Interkosmos-19 orbital inclination of ±74°). The occurrence probability of the high-latitude phenomenon does not depend on local time. In contrast to the high-latitude the equatorial phenomenon is observed mainly at night from 20 LT to 08 LT.

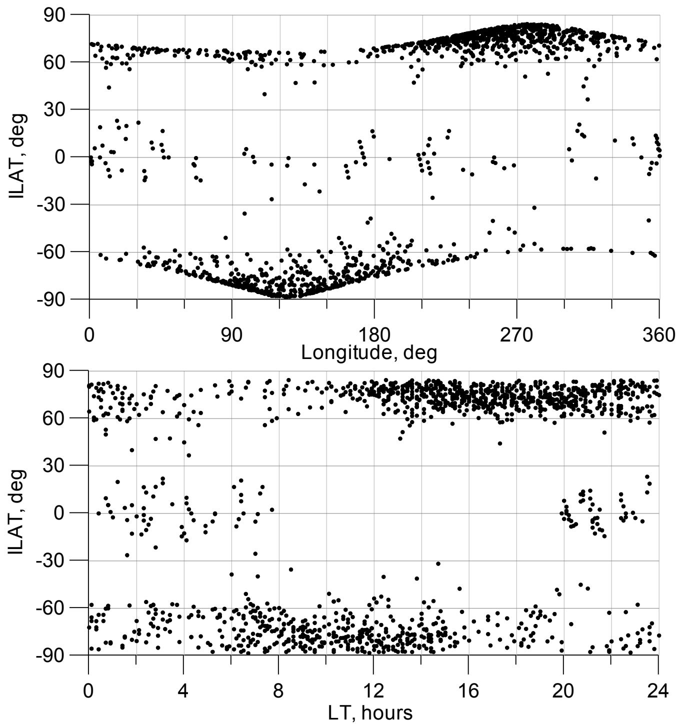

Fig.4. Top: the distribution of the events in terms of invariant latitude - longitude. Bottom: the same in terms of invariant latitude - local time.

VI. Discussion and Conclusion

An analysis of the Interkosmos-19 data shows that we are dealing with the irregularities of different scales, which due to the specifics of the topside sounding onboard the Interkosmos-19 appear in the frequency range of 7-11 MHz. The scattered traces clearly observed in the restricted area (in frequency, height and latitude) which indicates that they are formed in the large-scale irregularities filled with small-scale irregularities. The statistical analysis shows that phenomena are divided, as usual, into two classes: high latitudinal and equatorial. The high latitudinal phenomena are observed at latitudes greater 60° ILAT. This region corresponds approximately to the minimum and polar wall of the ionospheric trough. The irregularities considered are observed in the whole topside ionosphere from hmF2 to satellite altitude of 1000 km. Thus, the experiment onboard the Interkosmos-19 satellite makes a significant contribution to the diagnosis of the ionospheric plasma irregularities, adding other observations, both satellite and ground-based.

References

[1] Yu.A. Kravzov and Yu.I. Orlov, "Geometrical Optics of Inhomogeneous Media". M.: Nauka. 1980. 304 pp.

[2] A.T. Karpachev, G.A. Zhbankov, and V.A. Telegin, "Detection of Large-Scale Irregularity in the Region of the Main Ionospheric Trough According to Topside Sounding Data Onboard the Intercosmos-19 satellite," Geomagnetism and Aeromomy, vol. 52. 2012, pp. 204−210.