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HF radio emissions as a tool of ionospheric plasma diagnostics

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Abstract
The electromagnetic emission in the topside ionosphere has been investigated since the first satellites were located on the orbits. HF measurements can be used to diagnose the different electron plasma waves as well as the typical ionospheric parameters like f_0F_2. This paper presents the examples of measurements of the ionospheric RF radio noises in 0.1-10.0 MHz frequency range, which have been observed on the boards of the Intercosmos-19, Intercosmos-24, APEX satellites in the period 1979-1992, and the current experiment CORONAS.

Key words *ionosphere – RF wave measurements – electron plasma waves*

1. Introduction

Electromagnetic radiation in the hecto and decametric range in the nearest space is a subject of its investigation as a constituent of the geophysical environment, as well as an element of physical processes in which ionospheric plasma particles and fields participate. Despite the long history of plasma wave investigations in the ionosphere, our understanding of ionospheric wave plasma property is still not sufficient. Lately research has progressed on such satellites as Active, Apex (Kłos, 1989; Rothkaehl, 1993), Freja and Exoc C and D. All these observations have yielded many important results concerning the physical processes in the ionosphere. The natural sources of radiation in the ionosphere in hecto and decametric range are:

1) cosmic noise understood as a galactic emission of the order of 10^{-21} Wm^{-1} Hz^{-1} (spectrogram background);

2) ionospheric plasma emission around characteristic plasma frequency with mean intensity of the order of 10^{-10} Wm^{-1} Hz^{-1};

3) solar radio emissions particularly related to solar flares types III and IV with intensity of 10^{-16} Wm^{-1} Hz^{-1}.

Parallel to sources mentioned above, the Earth's ionosphere undergoes various man-made disturbances. Only few are connected with controlled experiments in the ionosphere and are transient. A major part of them is related to industrial activity and increase in recent years. The most important power sources are broadcasting transmitters, power stations, power lines and heavy industry. In observations performed on the satellite board the contribution from the artificial sources is significant.

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2. Instrumentation

The presented measurements of RF radio noises were detected on board the following spacecraft:

– Intercosmos-19 which was active from March 1979 till March 1981 and its initial perigee was 500 km apogee 980 km, and inclination 74 degrees;

– Intercosmos-24 «Active», which was located on the orbit with perigee 500 km and apogee 2500 km, inclination 82.5 degrees;

– Intercosmos-25 «Apeks», which was launched in December 1991 with perigee 430 km and apogee 3100 km inclination 82.5 degrees, with small subsatellite Magion-3;

– CORONAS satellite launched 4.03.1994 on circular orbit at altitude *ca.* 500 km.

The observations were made using the hetorodyne radio receiver with double frequency conversion and sweeping frequency in the first experiment and the synthetyzer method of detection in the others. All radio receivers were constructed in the Space Research Center in Warsaw and were located on board spacecraft next to other plasma diagnostics. Generally, spacecraft have the same velocity (about 8 km/s), so the spatial resolution between two spectra depends on the sweeping time as well as the telemetry speed transmission. The radio receivers were operated with double electric dipole antenna 15 m long from tip to tip. Because of the small dimensions of subsatellite Magion-3 the board receiver was connected to the shorter antenna 3 m long from tip to tip. The frequency range available to examine was from 0.6-6.0 MHz on IK-19, 0.1-10.0 MHz band had an access on Active Apex and Magion spacecraft while 0.1-30.0 MHz on Coronas board. Except Magion-3 all satellites had an «on board» memory so that the plasma properties could be examined in all geographic sectors. The «on line telemetry system» on Magion-3 permits access to data only over the Europe area.

3. The observations data

The typical radio spectrum detected on current operated spacecraft, Coronas, in the frequency range 0.1-30.0 MHz is presented in fig. 1.

The «A» arrow manifests the cut-off ionospheric natural plasma radiation, but the «B»

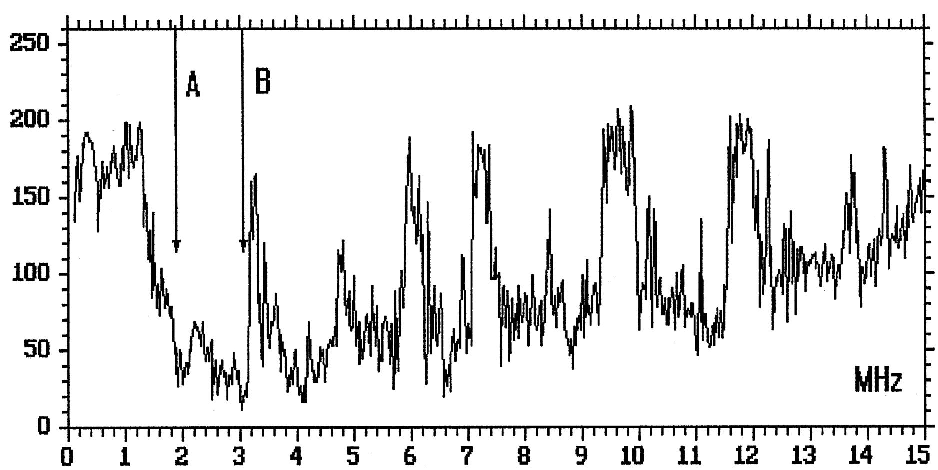

Fig. 1. The individual power spectrum detected on board the Coronas spacecraft on 27.04.1994. The intensity of the radio emission is plotted in telemetry units.

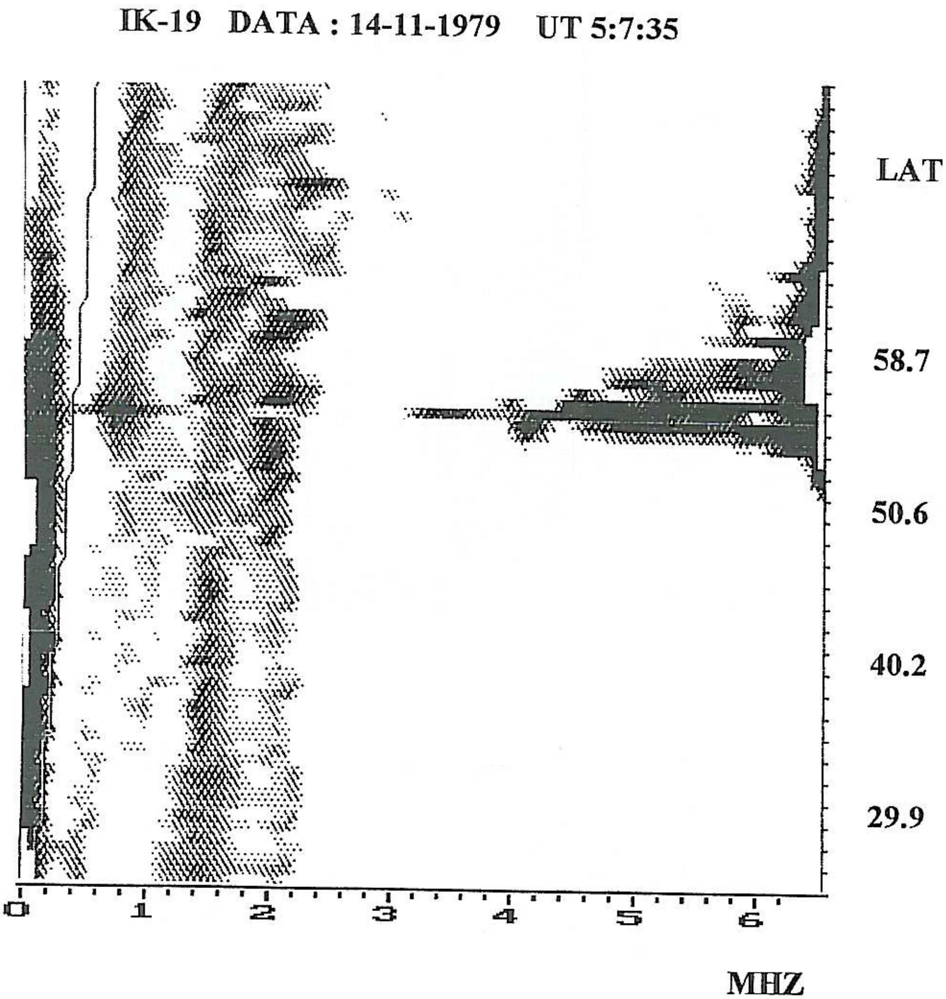

Fig. 2. The sequence of dynamic spectra observed along the orbit of satellite IK-19 over ionospheric trough. Emission intensity is marked from white at 0 dB/μV to black at 50 dB/μV with seven equidistant levels.

one shows the cut-off ground based broadcasting stations signals. At an altitude higher than f_0F_2 broadcasting transmitters can penetrate the ionosphere when the emitted frequency is greater than f_0F_2 value. The sharp cut-off broadcasting stations permit diagnosis of the f_0F_2 value, as well as an enhancement of background radiation level which can help to estimate the value of f_0F_2 with better accuracy. It is also informative to show some examples of data collected during IK-19 mission. Figure 2 presents the sequence of spectra detected over the main ionospheric trough. Emission intensities are marked from white 0 dB to black 50 dB. The sharp cut-off poleward of the ionospheric trough is well manifested. Unfortunately, because they are telemetry and electronic problems some data are lacking. Nevertheless a quite significant set of ionospheric parameters during disturbed ionospheric condition has been collected for the different ionospheric areas, like the ionospheric trough.

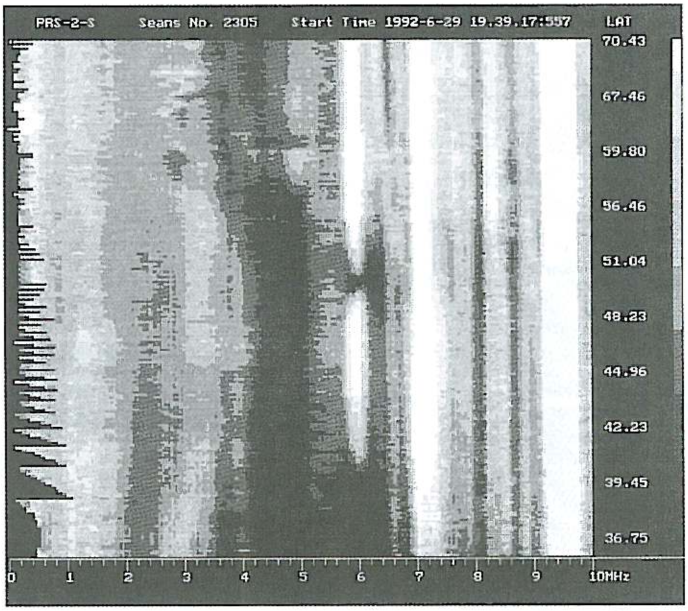

Fig. 3. The dynamic spectrum detected on 29.06.1992 along the orbit of Magion-3 satellite in northern hemisphere. The intensity of radio noises are marked from black at 0 dB/μV to white 30 dB/μV.

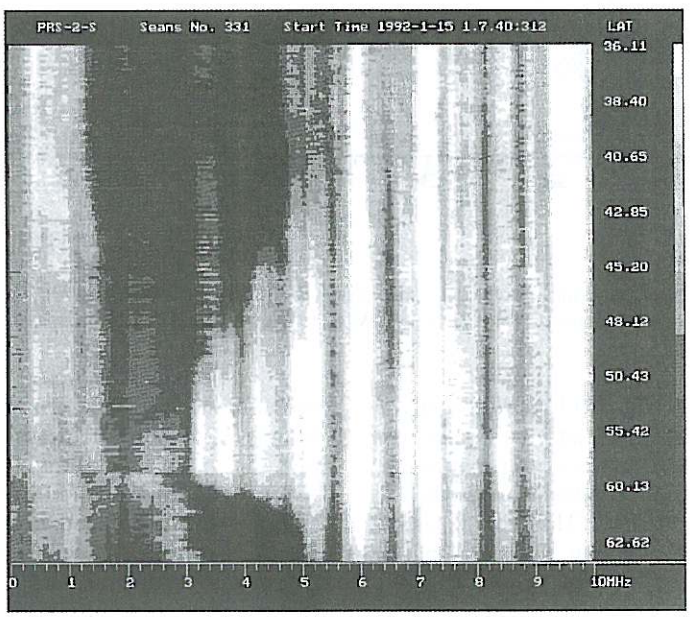

Fig. 4. The dynamic spectrum detected on 15.01.1992 along the orbit of Magion-3 satellite in northern hemisphere over the ionospheric trough. The intensity of radio noises are marked from black at 0 dB/μV to white 30 dB/μV.

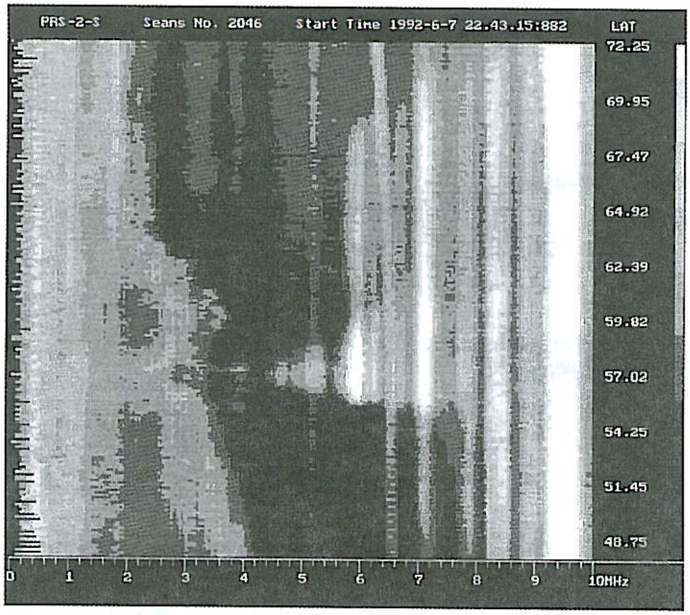

Fig. 5. The dynamic spectrum detected on 07.06.1992 along the orbit of Magion-3 satellite in the northern hemisphere over the ionospheric trough. The intensity of radio noises are marked from black at 0 dB/μV to white 30 dB/μV.

Practically, the same kind of data quality has been collected during the Active experiment.

The data which have been gathered on board the Apex-mother satellite and subsatellite Magion-3 permit more reasonable set to be built. It is very important to stress that at the same time we have two independent measurements from two remote spacecraft. Despite the short lifespan of the subsatellite Magion-3 (only 8 months), radiospectrometer measurements brought very significant and informative data.

The very fast sweeping time of the receiver on board Magion-3 satellite permitted investigation the small scale irregularities along the orbit in the upper ionosphere and reconstruct the dynamics of the ionosphere in more detail. The sequence of the dynamic spectra in fig. 3 displaces the disturbed ionosphere in the evening sector; the envelope of the f_0F_2 value detected along this orbit, is smooth.

The increase in HF emission over the trough with sharp poleward and equatorward boundary is well manifested in fig. 5. Usually the sharp structure of a poleward boundary is more often detected than the equatorward boundary (see fig. 4), and the shape and dynamics of the main ionospheric trough strongly depends on the phase of the magnetic storm; usually sharp equatorward boundaries exist in the descent sequence of the storm. The structure of the ionospheric trough deduced from data presented in fig. 5, indicates that the depletion at local plasma density on the satellite altitude are consistent with the minimum at the F_2 peak. Sometimes we observe an oblique configuration on the trough. The top-side RF wave diagnostics indicate that the trough position correlates well with independent Langmuir probe plasma density measurements (fig. 6). The comparison of our data and ground based ionosond measurements is also satisfactory.

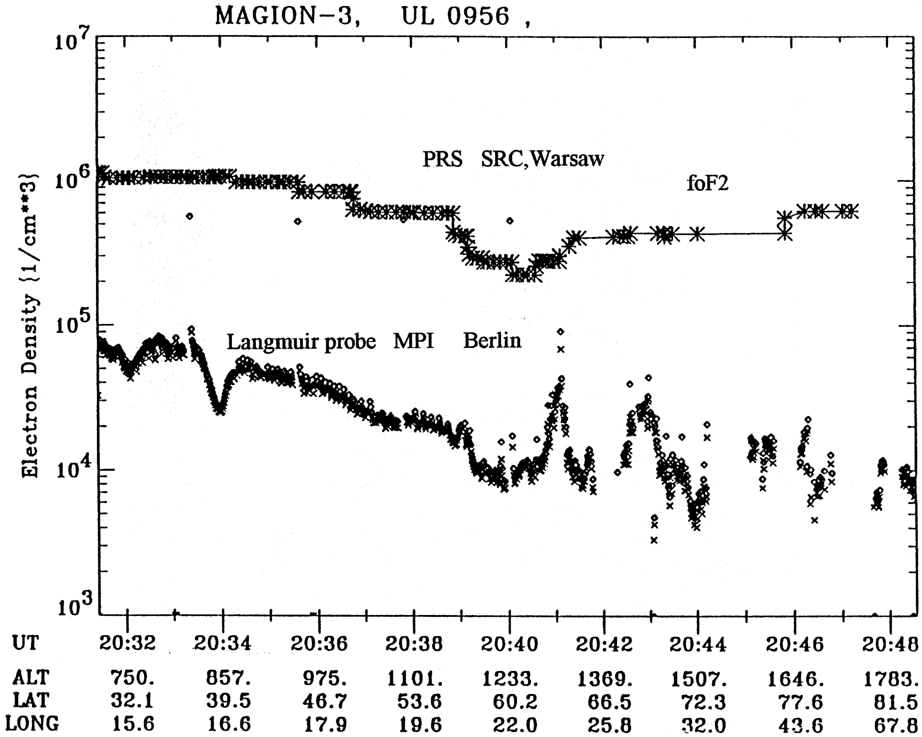

Fig. 6. The estimation of local electron density done by Langmuir probe at the altitude of satellite Magion-3 and the estimation of the f_0F_2 value obtained from wave measurements.

4. Conclusions

Summarising the set of radio wave data detected on board the satellites and stored in the PAS (Space Research Center) bring the unique base of ionospheric data which indicate that HF plasma wave measurement is a good tool to build the global picture of some ionospheric characteristics. The past, present and future (CESAR mission launching is planned for 1997) give us the possibility of widening our knowledge of the dynamics and evolution of the ionosphere. The set of f_0F_2 data, wave diagnostics origin, is significant complementary to the groundbase measurements.

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