FIRST RESULTS OF THE SOVIET-POLISH SPACE EXPERIMENT 'INTERCOSMOS-KOPERNIK 500'

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Abstract. The report contains a short description of the first Soviet-Polish space experiment, which has been accomplished aboard the 'Intercosmos-Kopernik 500' satellite, launched to commemorate the 500 anniversary of Copernicus birth. The purpose of the experiment is to observe sporadic radio emissions generated in the coronal and interplanetary medium at hectometric wave-length range and to measure parameters of the ionospheric plasma by means of the low- and high-frequency impedance probes. The idea of the experiments is presented together with the brief description of the measuring equipment and data recorded. First results of the space observations are shown. The correlation between electron density of the ambient plasma, ion-sheath capacitance of the aerial, and the upper hybrid frequency can be seen.

1. Introduction

The Soviet-Polish satellite, called 'Intercosmos-Kopernik 500' to commemorate 500th anniversary of Copernicus birth, was launched on the 19th of April 1973 from the territory of the Soviet Union to the orbit of 1551 km at apogee, 202 km at perigee, inclination of 48°43′ and period of revolution 102.2 min.

The programme of experiments has been divided into 3 parts:

(1) Polish experiments which are aimed to investigate low-frequency radio-bursts travelling out through the corona and interplanetary space, and to measure the ionospheric resonances, both the experiments being made with the aid of the 4-channel radio-spectrograph, swept over the frequency range of 0.6 to 6.0 MHz with the period of repetition of 12 s and frequency resolution of 30 kHz; (Astrophysical Laboratory in Toruń of the Institute of Astronomy, Polish Acad. of Sci.);

(2) A Soviet experiment aimed to determine the characteristics of the ion-sheath of the aerial immersed in the ionospheric plasma and to determine the parameters like electron density and temperature in the ionosphere, the experiment being carried out with the aid of the low-frequency impedance probe (Institute of Radio Engineering and Electronics, Moscow);

(3) A Soviet experiment aimed to measure the electron density and electron density irregularities in the ionosphere with the aid of the high-frequency impedance probe (Research Institute of Radiophysics, Gorky).

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2. Aerial System and Telemetry

The radiospectrograph uses a crossed electric 15-m dipole system, and the l.-f. and h.-f. impedance probes use 5-m and 70-cm cylindrical aerials, respectively. It should be mentioned that the measurements made with the h.-f. and l.-f. impedance probes enable the continuous calibration of the radiospectrograph aerial system.

Tape-recorded data over a whole revolution and resolution of 12 readouts per second are available for 7 to 8 hours daily. For the fast transmission of the radiospectrograph operational data to the ground station at the Ondrejov Observatory near Prague the special telemetry transmitter developped in Czechoslovakia is working aboard.

3. Bursts of Solar Radio Emission

During the first few months of the flight a great variety of results has been obtained, which at the moment are in course of reduction. Therefore only preliminary results can be presented here. The revue of satellite observations of solar radio bursts is given by Fainberg and Stone (1973).

The sample of radio-spectrograph data contains good examples of fast drifting type III bursts, of which one is shown in Figure 1. As it can be seen from this figure these bursts are characterized by their drift from upper to lower frequencies and by sudden rise and exponential decay. The burst shown in the figure had been observed while the satellite was deep in the ionosphere, and the ionospheric cut-off frequency limited the useful data in this case to the frequency range between 3 and 6 MHz. Coinciding type III bursts were observed at higher frequency range of 45 to 90 MHz by the ground station at IZMIRAN near Moscow (Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of the Acad. of Sci. USSR). These bursts are commonly believed to be excited by fast electrons that travel along open-field lines out through the corona into interplanetary space (Hartz, 1964; Fainberg and Stone, 1970; Alvarez *et al.*, 1972; Lin *et al.*, 1973; Frank and Gurnett, 1972).

4. Aerial Capacitance Measurement

The low-frequency impedance probe makes it possible to measure reactive and active components of the impedance of an electric aerial immersed in the ionosphere at frequency of 50 kHz. At this frequency the aerial impedance for the ionospheric plasma is practically capacitive (Hugill, 1965; Gurnett *et al.*, 1969). Its value is determined by an ion-sheath which developes in the aerial vicinity (Aksenov *et al.*, 1970; Aksenov *et al.*, 1971). For the cylindrical aerial the capacitance of the ion-sheath is given by

$$C = \frac{2\pi\varepsilon_0 l}{\ln\frac{a+s}{a}}, \tag{1}$$

where ε_0 is the free-space permittivity, l – length of the aerial, a – its radius, s – the

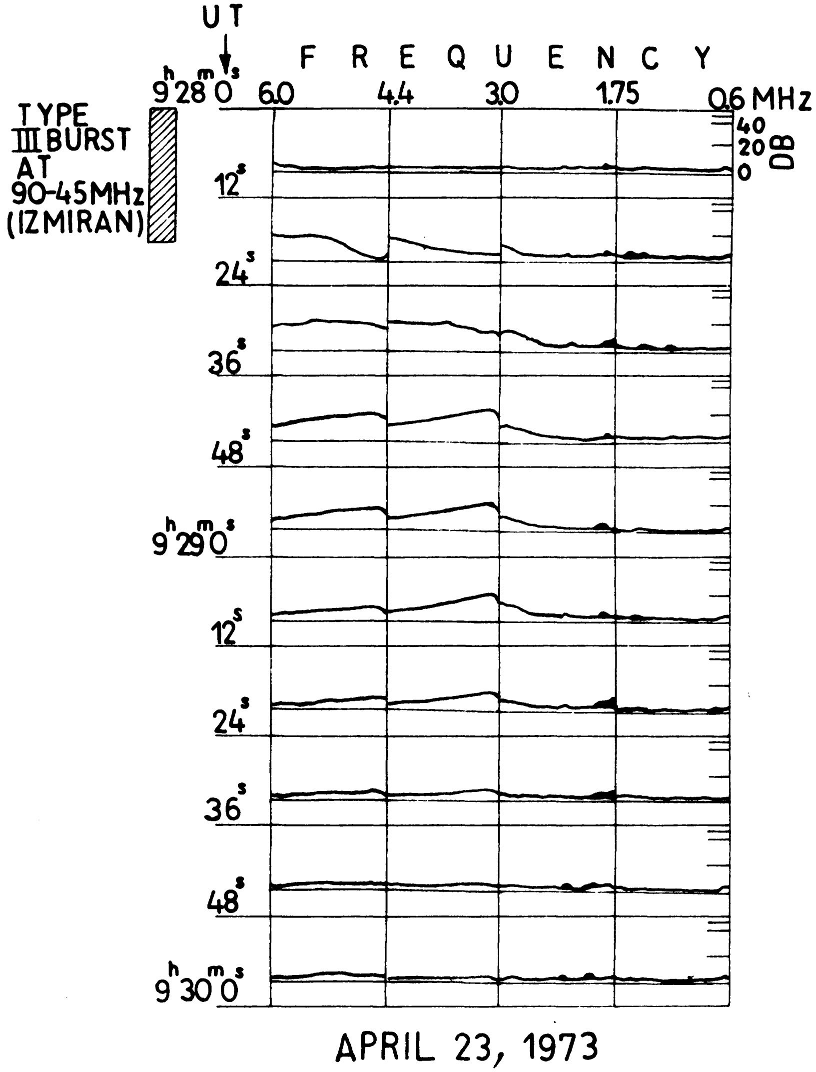

Fig. 1. An example of the dynamic spectrum of the type III burst as recorded with the radio-spectrograph installed aboard 'Intercosmos-Kopernik 500' on April 23, 1973 at 9^h28^m UT. The amplitude is in decibel scale. The shaded area shows the duration of the coinciding burst, which was also recorded at IZMIRAN, at 45 to 90 MHz frequency range.

sheath thickness. The value of the sheath thickness is near to the Debye's radius (Gurnett *et al.*, 1969):

$$s = 6.9(T/N)^{1/2}, \tag{2}$$

where T – is the temperature of the charged particles, N – electron density.

Figure 2 shows an example of the results for the aerial capacitance measurement for the revolution No. 53. It can be seen that the altitude dependance of the capacitance corresponds to the electron density distribution in the ionosphere.

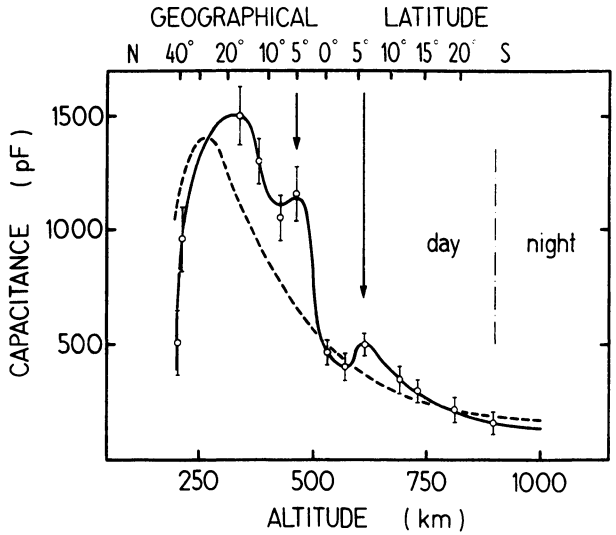

Fig. 2. Variations of the aerial capacitance in the ionosphere as measured with the low-frequency impedance probe during the 53rd revolution of 'Intercosmos-Kopernik 500' (April 23, 1973). Full line – experimental data, dashed line – results of calculation.

Additional maxima at the experimental curve (to north and south of the equator) are due to the latitudinal anomalies of the electron density in the ionosphere. For comparison this figure shows also the results of calculation for the ion-sheath capacitance with assumption that the sheath thickness is equal to one Debye's radius. Calculation has been carried out for the model of the ionosphere at the minimum solar activity. (The latitudinal anomalies have not been taken into account in the theoretical model). Satisfactory agreement between experimental and theoretical results proves that the l.-f. impedance probe can be used for the determination of the ionospheric plasma characteristics.

5. Electron Density Determinations

The determinations of electron density and its irregularities for the ambient ionospheric plasma, by means of the high-frequency impedance probe, are based on the measurements of the capacitance of the electrically short aerial (70 cm) at two frequencies 3.1 and 15 MHz, which is purely capacitive (13 pF in free space). The aerial capacitance for the collisionless ionosphere without magnetic field is proportional to the dielectric permittivity of the ambient plasma, which is equal to:

$$\varepsilon = 1 - \frac{4\pi e^2 N}{m\omega^2}, \tag{3}$$

where e – electron charge, N – electron density, m – mass of the electron, $\omega = 2\pi f$ – frequency of observation.

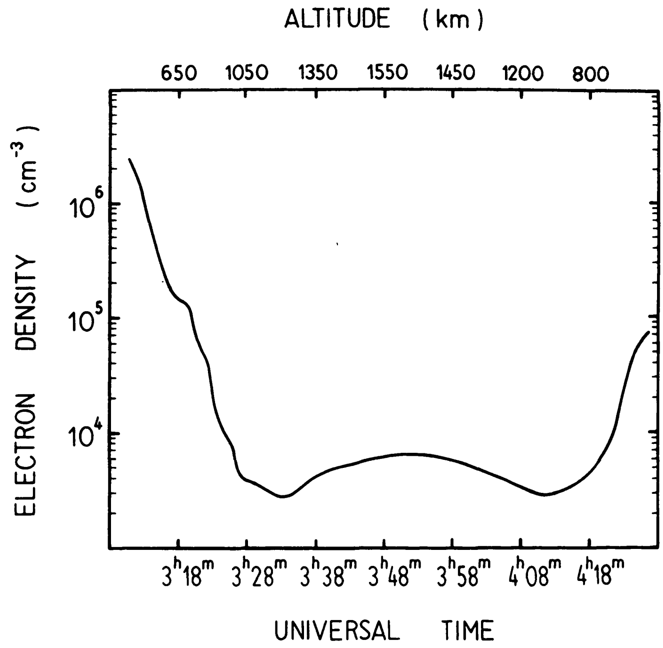

Fig. 3. Variations of the electron density in the ionosphere as determined with the high-frequency impedance probe during the 53rd revolution of 'Intercosmos-Kopernik 500' (April 23, 1973).

Variations of the aerial capacitance in the ionospheric plasma cause proportional frequency variations of the input oscillatory circuit, which after discrimination give proportional fluctuation of the telemetred d.c. voltage. To measure electron density irregularities a 0.05 to 20 Hz band-pass filter is applied to select slow variations of the d.c. output voltage. In this way the determinations of the electron density in the range of 10^3 to 1.6×10^6 electrons per cubic cm, and electron density irregularities of the size of 0.5 to 100 km and amplitude greater than 100 electrons per cubic cm are possible.

Finally, electron density of the ionosphere determined from the formula (3) can be corrected for the Earth magnetic field and the ion-sheath around the aerial and the satellite. The result of the electron density determination for the 53rd revolution is shown in Figure 3.

6. Radio-Noise at Upper Hybrid Frequency

Some data on the ionospheric plasma have also been obtained by means of the radio-spectrograph aboard. Bands of radio-noise at the frequency of upper hybrid resonance:

$$f_{uh}^2 = f_p^2 + f_H^2 , \tag{4}$$

where f_p and f_H are plasma- and gyro-frequencies of the ambient plasma, have been recorded.

The main characteristics of this resonance, which have been concluded from the first inspection of the recordings are:

(1) a correlation of the resonance frequency with the electron density of the ambient plasma as measured by means of the h.-f. impedance probe, and with the capacitance of the ion-sheath of the aerial as measured by means of the l.-f. impedance probe, which can be seen in Figure 4;

(2) modulation of the amplitude of the resonance by the satellite rotation in the Earth magnetic field, which can be seen in Figure 5;

(3) variations of the band-width of the resonance, which is usually wider than 100 kHz;

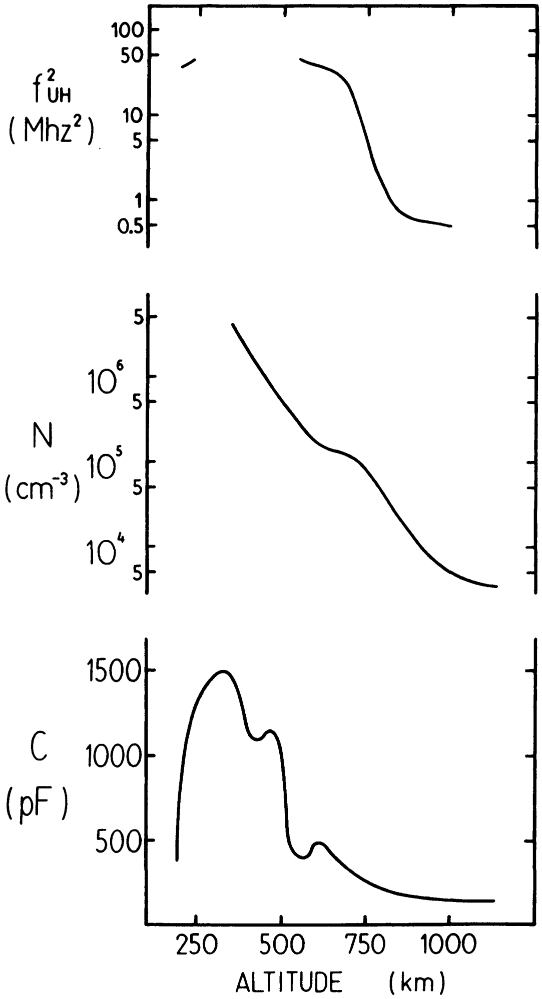

Fig. 4. Comparison of the capacitance of the aerial (C), electron density obtained with the high-frequency probe (N), and upper hybrid frequency (f_{uh}), as measured during the 53rd revolution aboard 'Intercosmos-Kopernik 500' (April 23, 1973).

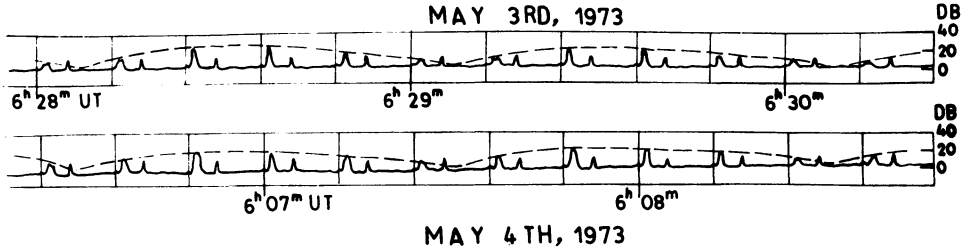

Fig. 5. Modulation of the amplitude of the upper hybrid frequency resonance in the ionosphere due to the satellite rotation as recorded with the radio-spectrograph aboard 'Intercosmos-Kopernik 500'.

(4) variable asymmetry of the frequency profile.

The results presented here do not comprise all the data obtained during the flight. The 'Intercosmos-Kopernik 500' satellite is still orbiting and the experiments aboard are continued.

The experiment reported here is a part of the 'Intercosmos' international space research programme.

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DISCUSSION

Fox: Where and when will the data on your 0.6–6 MHz radio emission experiment be published?

Hanasz: This is the first report on the experiment as the satellite is still orbiting, and these data have not been published as yet.

Smith: Is the 'Intercosmos-Copernicus' low-frequency receiver sensitive enough to receive Jupiter radio noise, and if so have you detected it?

Hanasz: The sensivity of the receiver is just enough to receive galactic radiation. However, we have not distinguished until now any signals which we could suspect originate from Jupiter.

Barrow: In reply to Dr Smith's question; Jupiter activity goes in an 11-yr cycle and has only recently passed the minimum. Perhaps for this reason there has been little opportunity for you to observe Jupiter so far.