THE VARIATION OF SPACECRAFT POTENTIAL ON HIGH ELLIPTICAL ORBIT. THE RESULT OF INTERBALL PROJECT (1995-2000)

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Abstract

Both ALPHA-3 instruments and ASPI complex carried onboard the Interball-1 (Interball-Tail) spacecraft (SC) performed successful measurements during near five years of the INTERBALL Project. An important aspect of experimental space technology addressed from these comprehensive measurements is the study of characteristics of the Langmuir sheath around the SC and its influence on the onboard low-energy plasma measurements.

1.INTRODUCTION

Field and wave data gathered with those experiments allow to obtain a plenty of scientific results related to the physical phenomena occurring in the solar wind, at the Earth's bow shock, in the magnetosheath, at the magnetopause and terrestrial magnetotail. In particular, new results on the energy and momentum transport at the high-latitude magnetopause are discovered mostly due to the high-resolution magnetic field measurements.

During the period of every year, the Interball-1 (Interball-Tail) satellite movement around the Earth changed with regard to the magnetosphere and to the Sun position (after launch apogee – 180 000 km, perigee – 500 km). Thus the perigee shifted from the evening sector of the magnetosphere, 18:00 MLT at the launch of the satellite, to the same sector one year later and in between the perigee magnetic local time was, for example, at 12:00 MLT, 06:00 MLT, and 00:00 MLT on November 13th, 1995, on February 12th, 1996, and May 2nd, 1997, respectively. The perigee after launch was localized in the Southern hemisphere and slowly shifted to the Northern hemisphere.

All time of measurements are distribute approximate:

- magnetosphere, magnetotail – 50%;
- magnetosheath – 15%;
- solar wind – 25%;
- plasmasheath – 5%.

2.MEASUREMENTS

Plasma density variations in the outer plasmasphere and near the plasmapause, as well as variations in its location were studied from the ALPHA-3 modulation ion analyzer during more than two years from the Interball-1 and Interball-2. Displacements of the plasmapause (Figure 1) in the course of storms were studied, and short-term motions

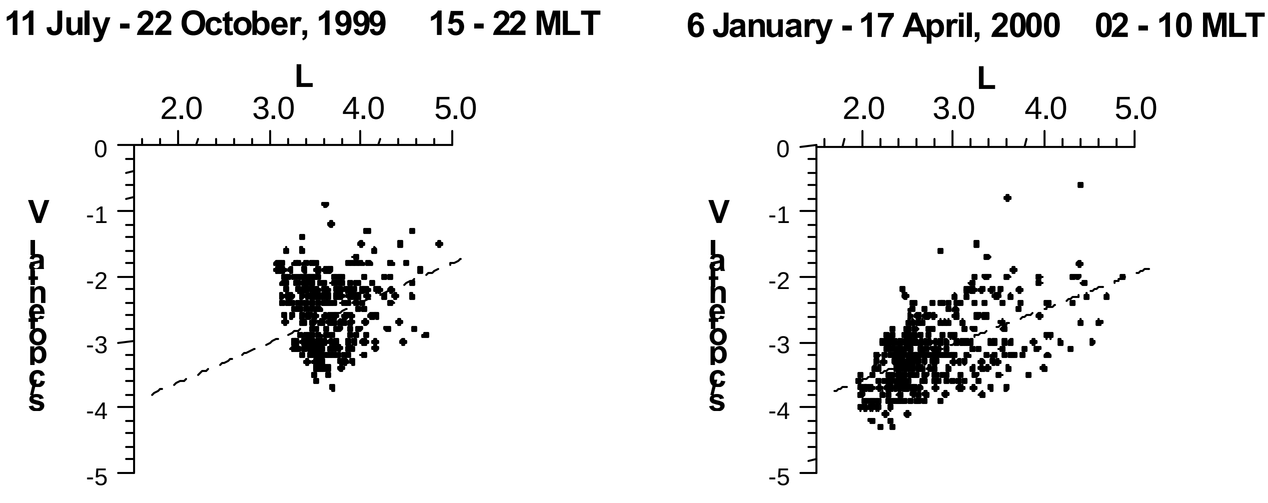


Figure 1. Spacecraft potential in the plasmasphere reduced from the ion spectra measurements, as functions of L-shells. Despite the scatter of the points, s/c potential fitting curves coincide very well for the dusk and dawn measurements.

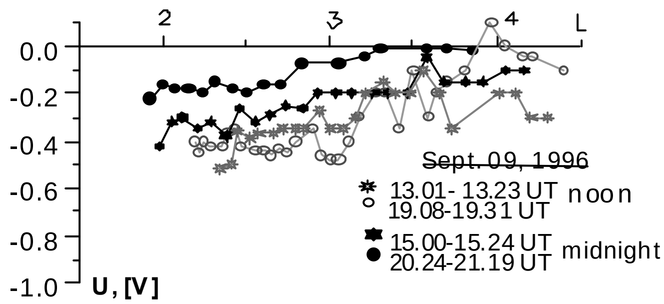
were analyzed. At last, the ALPHA-3 [1] modulation ion trap device, similar on both Interball-1 and -2, provides continuous data on the plasmasphere, plasmapause location and shape, which allow to compare the differential measurements of particle spectrometers with the total ion density data at and near the plasmapause. While the inter-comparisons of the data from different onboard instruments are ongoing, the main output from this work – the spacecraft potential inside the plasmasphere is close to –1,5 V and near plasmapause less that –0,1V.

The ALPHA-3 experiment (Figure 5) for cold ion flux measurements including retarding plasma analyzer (RPA) is continuously functioning on Interball-1. Due to highly eccentric spacecraft orbit as a rule the instrument provides data on plasmasphere cold ions once per four days. Cold ion spectra were measured during 2 s once per ~ 2 minutes. The data collected from 19 orbits of Interball-1 in July – October 1999 when the plasmasphere was crossed in the outer dusk sector (15 – 22 MLT) between L 3 and L 5 and from 21 orbits in January – April 2000 across the outer dawn side plasmasphere ($2 \le L \le 5$, 02 – 10 MLT) were analyzed.

The parameters of plasmasphere cold ions: density n and temperature T_i, as well as the value of the spacecraft potential Φ were obtained via fitting the experimental spectra by the calculated spectra assuming the convected maxwellian distribution of ions distorted due to non-zero potential of the spacecraft.

It is seen (Figure 1) that the spacecraft potential is negative inside the plasmasphere and its value is increasing while approaching to the plasmapause. The dashed line drawn in the top plot is a best-fit linear function. The same line is shown in the bottom plot and its location evidences that the spacecraft potential is the same on average in the dawn and dusk plasmasphere.

Figure 2 presents the potential of the Interball-2 spacecraft during 2 passes through the plasmasphere deduced from the cold ion spectra measurements by the wide-angle plane modulating analyzer (MPA). Inside the observed part of the plasmasphere at $1.8 < L < 5$ on the night and day sides the potential is negative, except one point (1 measured spectrum) of 0.1 V. Minimum potentials are varied between -0.55 and -0.2 V and increase with the spacecraft distance from the Earth.



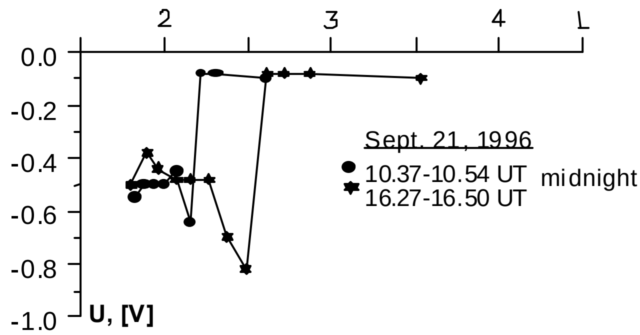


Figure 2 (above). The potential of the Interball-2 SC in the night (full circles and asterisk) and noon (open circles and asterisk) plasmasphere on September.

Figure 3 (below). The potential of the Interball-2 SC during eclipse (L<2.6) and in sunlight region.

Figure 3 shows variations of the Interball-2 potential in the Earth's shadow and after the exit from the shadow. It is seen that when the spacecraft left the shadow the potential.

The plasma-wave experiment ASPI onboard the Interball-1 is a combined wave diagnostic experiment. It performs measurements of the DC and AC magnetic field vector by flux-gate and search coil sensors, the DC and AC electric field vector by Lamgmuir double probes, and the plasma current fluctuation by Langmuir split probe. Data analysis shows the low noise level of the sensors connected with special orientation of the SC type Prognoz-M2 [2] and low SC potential, which we see from ALPHA-3 measurements.

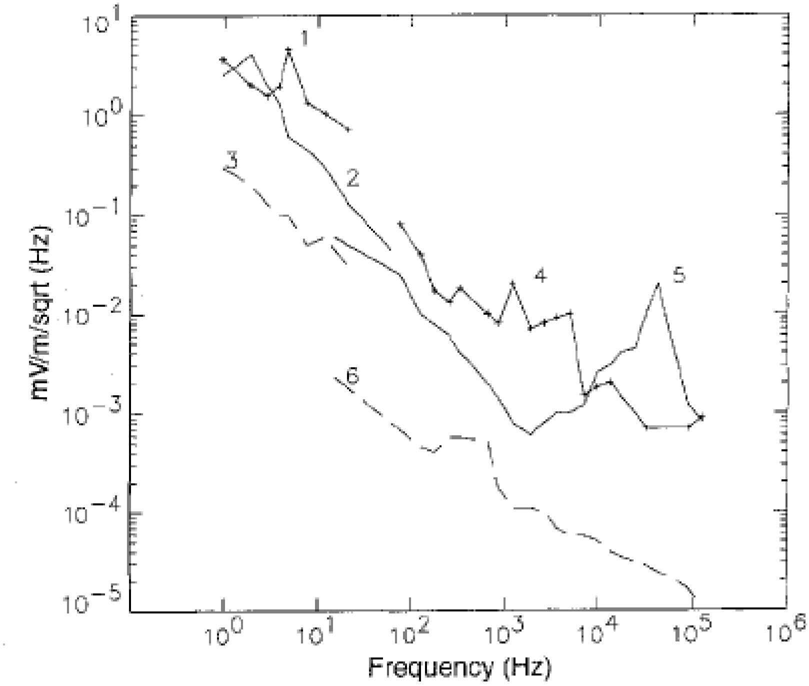


Figure 4. INTERBALL-1 electric field measurements

In Figure 4 we present the noise levels and characteristic signals of the electric field measurements. Curve 3 and 6 correspond to the background electric field spectra measured in solar wind. Curve 6 represents the filtered-bank spectrum of the signal from the dipole 22 m. Curve 3 represents on-board FFT spectrum summed over three components. Comparing these two curves, one should take into account the less sensitive quantization level of FFT and a possible overestimate of the electric field by the shorter lengths dipoles, spectra of which are summed in the FFT output. Curve 1 shows the on-board FFT spectrum detected at the quasi-perpendicular bow shock on Interball-1 with comparison Prognoz-8 (Curve 2). The filter-bank spectrum at the same shock is shown as curve 4. It is interfered with by one of SC transmitters at 40-60 kHz

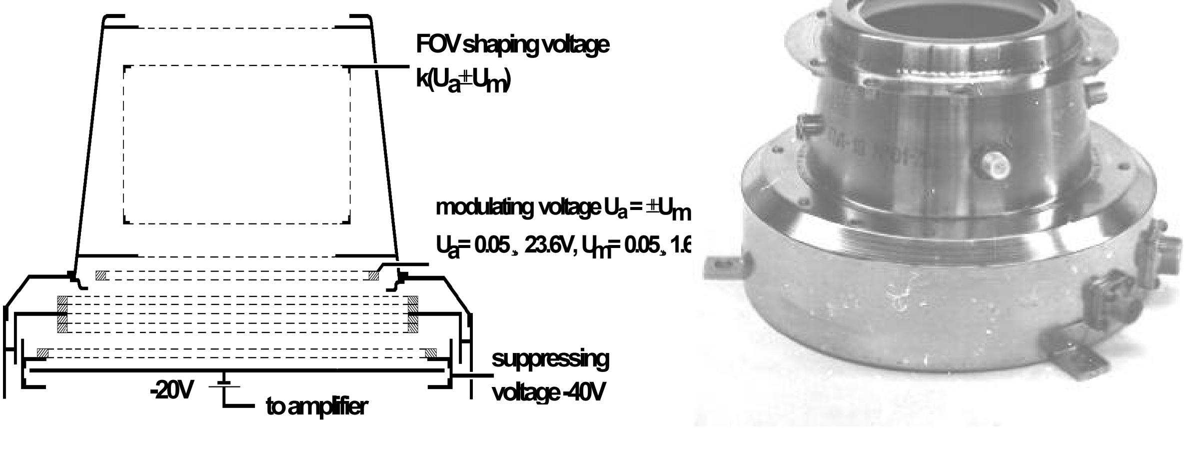


Figure 5. The analyzer PL-19 – the sensor unit of the ALPHA-3 instrument was installed on the dark side of the SC in the anti-solar direction (-X, Figure 6).

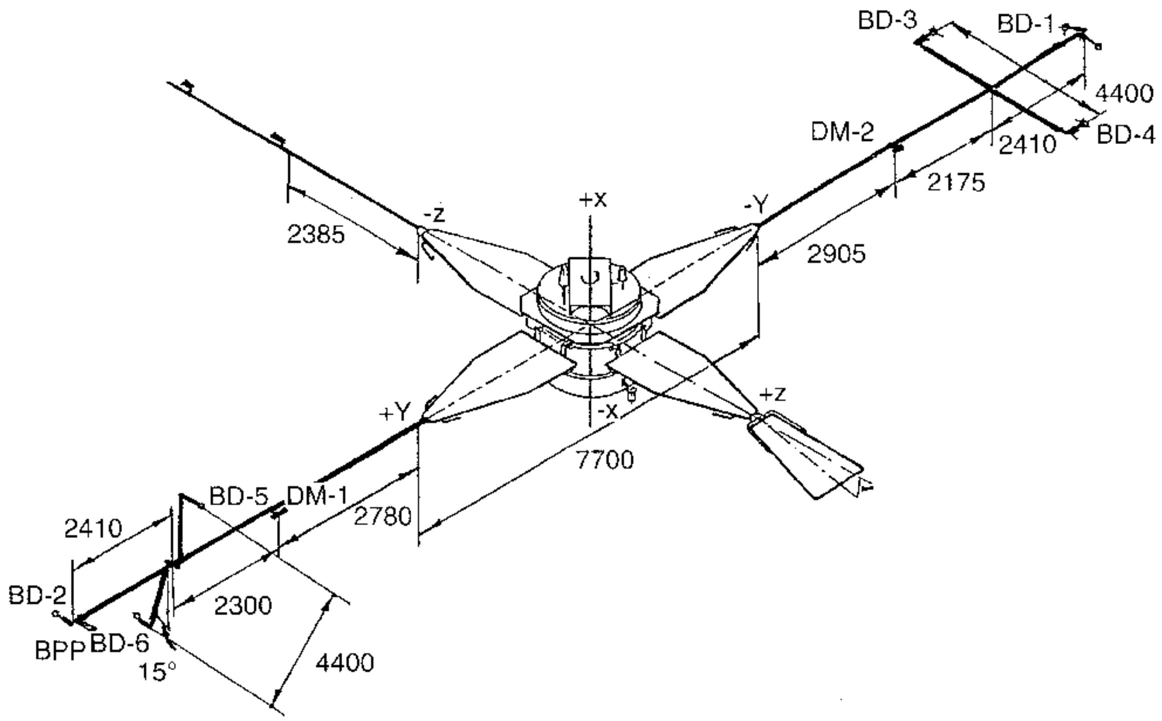


Figure 6. Sketch of the Interball-1 spacecraft: +X direction is pointing to the Sun; dimensions are in mm. The field and wave experiment ASPI sensors on the booms are shown: BPP – three-component flux-gate sensor of magnetic field MIF-M instrument; DM-1 – three-component flux-gate sensor of magnetic field FGM-1 instrument; DM-2 – search coil sensor of magnetic field MIF-M instrument; double probe sensors of electric field OPERA instrument BD-1 – BD-2 (Y axis 22 m), BD-3 – BD-4 (Z axis 4.4 m), BD-5 – BD-6 (X axis 4.4 m),

An example of the upstream electric field spectra from the 22 m dipole (Curve 5) exhibits a well-defined peak at the Langmuir frequencies. Such peaks are often registered in the electron forechock of quasi-perpendicular shocks. Its amplitude (0.02 mV m^{-1} $Hz^{-1/2}$) is much stronger than the average one, measured by ISEE-1 and IMP-6 longer antennas, but is close to the typical short-dipole measurements on Phobos –1, -2. Taking into account typical wavelengths of Lamgmuir waves (of order of the Debye length), we believe that the 22-m-long dipole antenna on Interball-1 is more appropriate for studies of high-frequency electrostatic waves.

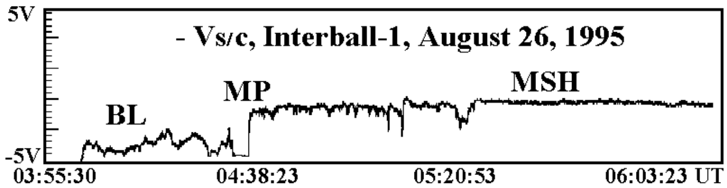


Figure 7. Interball-1 DC potential.

In Figure 7 we present an example of the spacecraft potential measurements aboard Interball-1 spacecraft during outbound from the tail magnetosphere on August 26, 1995. Note, that the shown value is -V_{SC} (i.e. negative spacecraft potential). In the empty high latitude magnetospheric lobes (left side) the spacecraft potential is higher than 5 V (that corresponds to the negative saturation in Figure 7). Later on Interball-1 encountered the mantle boundary layer (BL) with the density of the MSH-origin plasma of about 1 cm^{-3}. That corresponds to V_{SC} ~ 4.5 V. After MP at about 04:28:33 UT the dense MSH plasma (of ~ 7 cm^{-3}) kept the spacecraft potential at ~ 1 V. Till 05:21 UT one can see the potential disturbances, that corresponds to the density fluctuations in the turbulent boundary layer just outside MP (see details [2]). Thus, the 22-meter Interball-1 booms happen to be appropriate for the electric field measurements in most regions of magnetosphere excluding empty tail lobes. The particle measurements aboard the spacecraft without active potential control are satisfactory reliable in the same regions.

CONCLUSION

The spacecraft Prognoz-M2 is a modification of a Prognoz type satellite [3] which is good correcpond to electromagnetic field measurements. First of all this connected with constant orientation of axis X to the Sun and slow (one rev./2 min) rotation around axis X.

The main points on which SC was performed may be summarized as follows:

- Solar panels of a new type are used. They are electromagneticaly clean both in electric and magnetic noise components to high standards. Besides that these new panels have long time of operation, which allows to prolong SC lifetime considerably.
- The thermal coating (EVTI) of SC, which serves to support the spacecraft thermal balance, have conductive outer surface. Thus most part of SC outer surface is equipotential. The spacecraft potential inside the plasmasphere is near –1,5 V and near plasmapause less that –0,1V.
- The Prognoz-M2 overall electromagnetic cleanliness due to modernization of electrical circuits on board SC is considerably increased. Thus lower noise levels are expected in orbit for the plasma and wave experiments

ACKNOWLEDGMENTS

We wish to thank E.Amata (IFSI) and D.Klinge (ESTEC) for their help in OPERA instrument design and data interpretation. The ASPI team is grateful to J.-P.Catani and R.Marrama for their participation in realisation of EMC tests. This work was partly supported by the contract ¹ 101-10(00)-P / Veter.

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