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MEASUREMENTS OF ELECTROMAGNETIC ULF FIELD ONBOARD THE MAGION-4 SATELLITE: THE ULF EXPERIMENT

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Abstract

The ULF instrument is a part of the research complex of the Magion-4 satellite. This experiment is designed for measuring 4 electromagnetic field components (3 magnetic and 1 electric) in a frequency range from 0.1 to 30 Hz. Preliminary results on ULF emissions and associated phenomena are presented. Peculiarities of ULF emissions in the magnetosphere are discussed.

Introduction

The ULF instrument provides the ability to solve independent tasks jointly with the KEM-3 and SAS instruments on board of the satellite Magion-4 (Agafonov et al., 1996, Galeev et al., 1996, and Perraut et al., 1998), as well as complex tasks jointly with the instrument IESP-2M, which is placed on board of the main satellite INTERBALL-2. The orbital parameters of the satellite Magion-4, launched on August 3, 1995, are apogee 192,000 km, perigee 750 km and inclination 63°.

The complex of instruments ULF-IESP represents a very convenient apparatus for the solutions of the following tasks:

- Research of global processes taking place within the magnetosphere and ionosphere of the Earth,

- Local processes during mutual influence of waves and particles within the active magnetosphere regions,
- Fine structures of electric currents and particle flows within the aurora zone and within the tail of magnetosphere,
- Evolution and dynamics of nonlinear electromagnetic and electrostatic structures like the spirals of the Alfvenic type, impact waves, double layers etc.
- Various mechanisms of particle acceleration by non-linear wave structures within the ionosphere and magnetosphere plasma,
- Mechanisms of generation and propagation of different types of geomagnetic micro-pulsations.

Technical description

The ULF instrument is designed for acquisition of three magnetic field components and one electric field component in the range of 0.1 to 30 Hz. This instrument performs filtration of analog signals and their conversion into digital form, convenient for the on-board block of data acquisition STS (Small Telemetry System)

The ULF-DIGITAL unit provides an interface between the ULF-ANALOG unit and the STS. It accepts four channels (Bx, By, Bz, E) of ULF signals in the range of +/-5V relative to the analog ground. The ULF experiment is supported only in the following TM speed - TM structure combinations:

- Telemetry rate of 40 and 20 Kbits/sec - all four measured components are transmitted, sampling speed is about 280 samples per sec.
- Telemetry rate of 5 Kbits/sec - one component is transmitted at sampling rate ~70 samples/sec.
- Telemetry rate of 1.2 Kbits/sec - one component (f_{max} = 10 Hz) is transmitted at sampling rate ~ 25 samples/sec.

The electric antenna comprises a dipole consisting of two spherical graphite sensors with diameter of 8 cm. Inside the balls, there is a low-noise preamplifier, with +1 amplification, which transforms the high impedance of the spherical sensor into the low impedance of the satellite's cable wiring. The spherical sensors, designated EDA and EDB are placed on the 1.7 m long satellite deployable booms (see Fig.1).

The sensors MSUX, MSUY and MSUZ of the "search coil" type for the three-component measurement within the ULF range are attached to the deployable booms (Fig.1) together with the low-noise preamplifiers. The

sensors are operated by the feedback by means of magnetic field, which rejects the own resonance of the working circuit, thus compensating the frequency characteristics of the sensor.

Sensitivity: component E 5.10^{-8} V Hz^{-1}
component B 1.10^{-4}nT Hz^{-1}

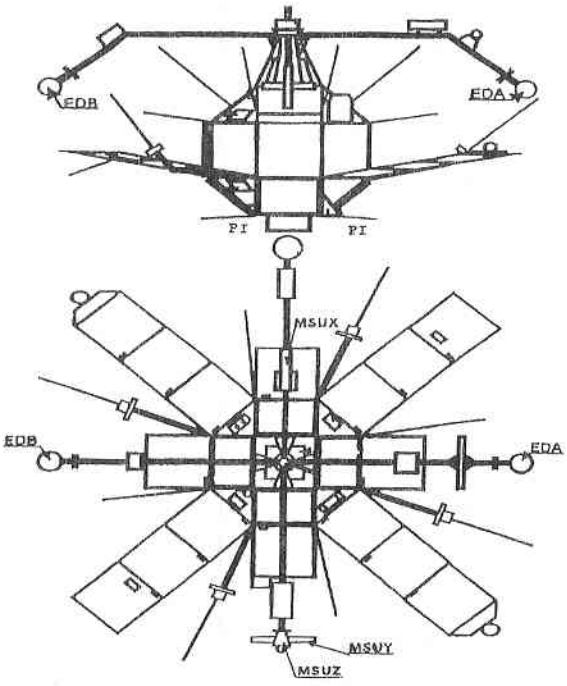

Fig. 1. General overview of the subsatellite Magion-4 in the flight configuration.

To the inputs of all the sensors (electric and magnetic), a calibration signal may be fed through the preamplifier relay contact. Thus, the test calibration cycle is effected with each switching on of the instrument, or by a command from the ground station.

Upon amplification, the signals from the electric and magnetic sensors are tied to the high-pass filter (0.1Hz). Then, they are digitized.

Upon being added in the differential amplifier, the output signals of the electric preamplifiers, the dipole EDA and EDB, are then processed in the instruments KEM, KEMVLS and SAS.

Measurement results

A lot of experimental data is collected using the ULF instrument. We have got data from 160 orbits and at this moment their analyses and interpretation is still going on. To analyze the data from the multi-component measurements of the electromagnetic field in the ULF band we have developed an universal software in DOS environment. It is user-friendly and provides for quick and flexible data analysis, applying numerous standard data processing algorithms and dedicated programs for wave process analyses.

Below, the results obtained from measurements on two orbits are presented in order to illustrate the applications of both the instrument and the software. Although the instrument has three different operation modes, due to the lack of space only two examples are shown. Records from various orbits are also discussed.

Orbit 58/27.02.1996

The first and the second panels in Fig.2 present data characterizing the magnetosphere region, which is crossed by the satellite. The results were obtained by two instruments:

- MPS (electrostatic analyzer for measurements of electrons and ions from 200 eV-20 keV along the axis ± Z in 16 different energetic levels) and
- VDP (Faraday Cup 120°, for electrons and ions with energy >170eV).

The third panel presents the By component in frequency-time space, i.e. in the form of a spectrogram.

At 23:34UT, the ULF experiment recorded a monochromatic wave packet with frequency of 1.5Hz.

At 00:14UT, the ULF experiment recorded an increase of broad band noise plus an intensification of ion flux, which corresponded to the crossing of the magnetopause and the time of its leaving. The ULF data is in accordance with the data registered by MPS on the M-4 satellite.

The increase of fluctuation corresponds to the zone of magneto-sheath. It should be emphasized that, at that moment, the ULF instrument measured only the By component. The ULF measurements were compared

to the By component recorded by the ASPI/MIF-M instrument launched on INTERBALL-1 satellite. The comparison revealed:

- ❖ Coincidence of the enhanced intensity at magnetopause and magneto-sheath crossing recorded by several instruments.
- ❖ Crossing of the magnetopause at 00:14 UT.

Of course we render an account of the fact that Magion-4 and INTERBALL-1 crossed the magnetopause at different moments of one and the same orbit. Magion-4 was outdistanced to INTERBALL-1 by almost 40 minutes. In other words, such simultaneous measurements by two different satellites provides the possibility to study the dynamics and movement of the magnetopause. The required condition is to know the satellite's ballistics (Rezeau et al., 1989, Styazhkin et al., 1999).

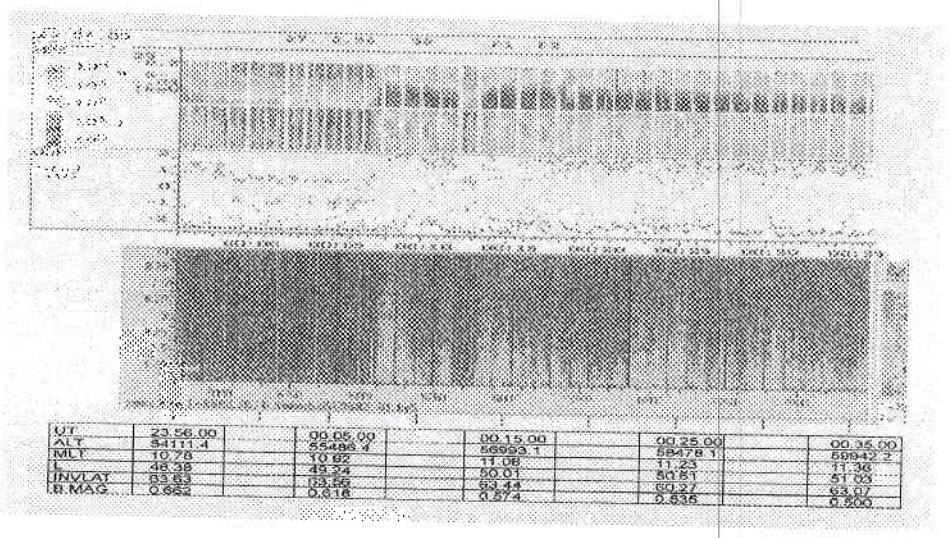

Fig. 2. Frequency-time spectrograms of the By magnetic component and spectrograms of electrons and ions measured by the MPS and VDP instruments on Magion-4, orbit 58 from February 27, 1996. By component is perpendicular to the spin axis.

Orbit 38/7.02.1997

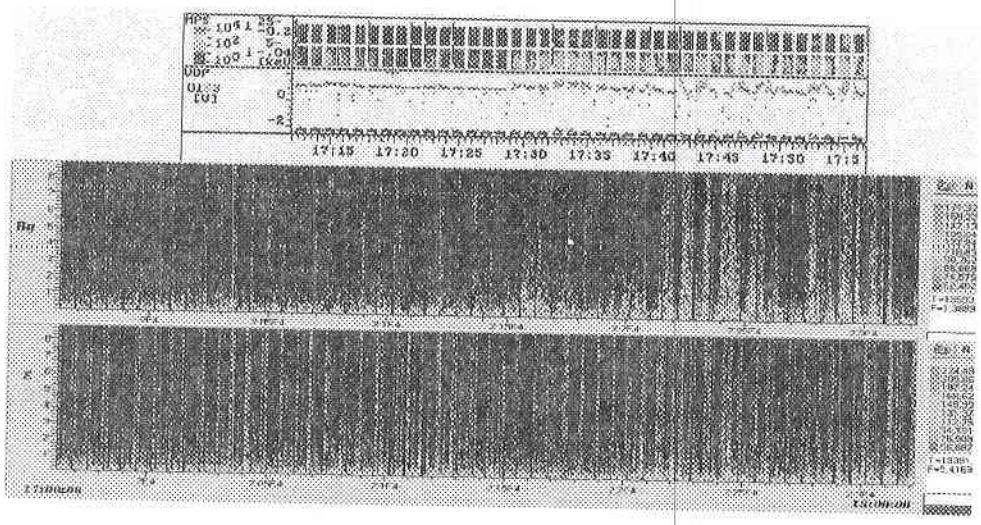

Fig. 3. Frequency-time spectrograms of the magnetic component By, electric component E, and spectrograms of electrons and ions measured by the MPS and VDP instruments on Magion-4, orbit 38 from February 7, 1997 at 17:00 UT to 18:00 UT. By end E are perpendicular to the spin axis.

The data shown in Fig. 3 illustrates the strong correlation between ion and electron fluxes and ULF noises in the frequency range from 0,1 Hz to 9 Hz. The magnetic component has a maximum at 1,5 Hz and the electric component at 0,5 Hz. This example corresponds again to the Magion-4 satellite movement from the magnetopause into the magneto-sheath.

Conclusion

The ULF instrument is a part of a larger scientific instrument KEM-3 dedicated to the VLF range. Identical magnetic and electrical detectors are used for recording of both the ULF and the VLF bands.

The presented results show that the instrument operated well and with sufficient sensitivity. The technical arrangement and especially the overlapping of the frequencies up to 30 Hz allows us to:

- Compare the recorded data,
- Complement the data sets for calculation of the E/B ratio. This ratio allows to judge the wave type and to interpret the mechanisms and the place of their origin.

The knowledge of wave processes in the boundary layers of the magnetosphere is of enormous importance for estimation of the transmission

mechanism of solar wind energy into the magnetosphere (De Keyzer et al., 1999, and Tsurutani et al., 1989 and 1998).

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ИЗМЕРВАНЕ НА ЕЛЕКТРОМАГНИТНОТО СНЧ ПОЛЕ НА БОРДА НА СПЪТНИКА МАГИОН-4: СНЧ ЕКСПЕРИМЕНТ

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Резюме

СНЧ уредът е част от научния комплекс на спътника Магион-4. Експериментът има за цел да измери 4 компоненти на електромагнитното поле (3 магнитни и 1 електрическа) в честотния диапазон от 0.1 до 30 Hz. Показани са предварителни резултат за СНЧ емисиите и свързаните с тях явления. Обсъдени са особеностите на СНЧ емисиите в магнитосферата.