Precipitating Energetic Electrons at high Latitude: PEEL data from HotPay-2 mission.

J. Baláž, K. Kudela, T. Sarris, I. Strhárský

Abstract: **Data recorded by PEEL instrument during the flight of the HotPay-2 sounding rocket launched from Andoya Rocket Range (*Lat. 69°.18'N, Long. 16°.01'E*) on 31-JAN-2008 at 19:14:00 UT are discussed. After the brief description of the instrument, its possibilities and limitations to measure energetic electron flux in the upper atmosphere, the profile of counting rate obtained by the three detectors in four energy channels is presented. During the epoch of solar activity minima and relatively low geomagnetic activity, the detectors with given geometrical factor provide relatively low counting rate.**

1. INTRODUCTION

The energetic electrons precipitating into the atmosphere are subject of study for long time (e.g. [1-6] among others). The fine structure of the electron fluxes at high latitudes within the local loss cone were observed e.g. in papers [7,8]. HotPay-2 provides a possibility to observe the energetic electrons at high latitudes below the altitude accessible from satellites.

After short description of the PEEL instrument we present the first results of the measurements during that rocket mission and discuss the results obtained.

2. THE ELECTRON SENSOR

The PEEL electron sensor is based on a solid state surface-barrier silicon detector with active area of 25 mm^2 and the depleted layer thickness of 300 μm. There is a mylar foil with thickness of 3 μm installed in the detector entrance window that suppress entering of the ions to the detector. The electron flux is collimated with conical collimator with serrated and blackened surface. The collimator provides a conical field of view of 38° (fwhm), the overall sensor geometry provides the geometrical factor of 0.077 cm^2.sr. The detector works in fully depleted mode under the bias voltage of 70 V. The signal of the detector is processed with charge sensitive electronics.

J. Balaz, K. Kudela* and I. Strharsky were with Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, SK-04001 Kosice, Slovakia (*corresponding author, phone: +421-55-6224554; fax: +421-55-6336292; e-mail: kkudela@upjs.sk).

T. Sarris was with Democritus University of Thrace, Xanthi, Greece

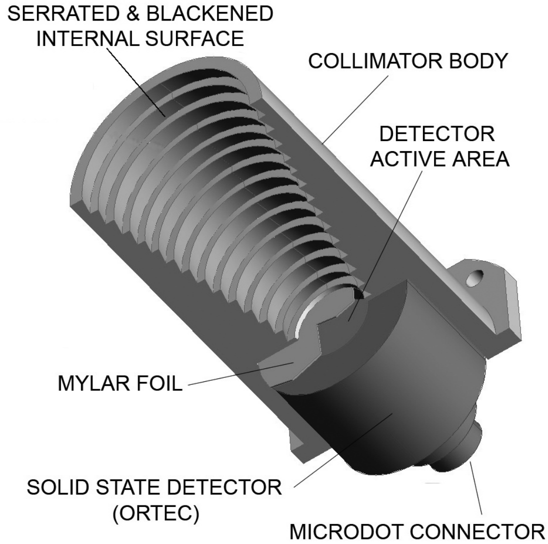

Fig. 1. Construction of the electron sensor

3. RECORDING OF THE ANGULAR DISTRIBUTION

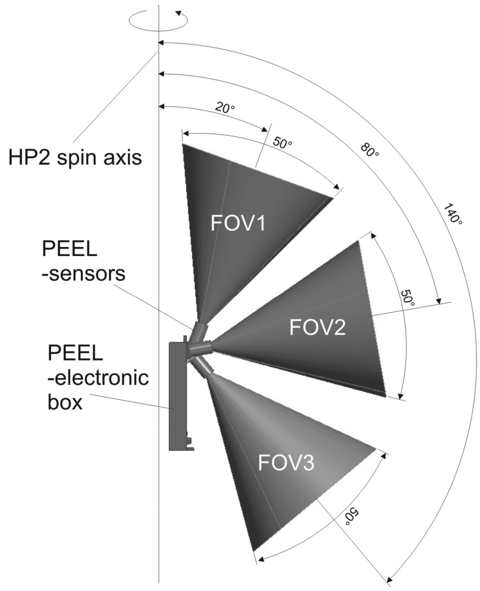

Fig. 2. Field of view of individual sensors related to the rocket spin axis.

The recording of the angular distribution of the electron flux is provided by using of 3 identical electron sensors mounted at the angles θ_1=20°, θ_2= 80° and θ_3= 140° to the spin axis respectively. The relatively fast rocket spinning (4 s^{-1}) and fast temporal sampling of the PEEL device (62.62 samples s^{-1}) provides division of the azimuth plane to 15 sectors. Thus, the total angular coverage is 160° × 360° divided to 3 × 15 = 45 sectors.

4. RECORDING OF THE ENERGY DISTRIBUTION

Figure 3 describes electrical design of the PEEL instrument. The signal from each semiconductor detector is preprocessed by a low noise charge sensitive preamplifier, a pulse amplifier and a shaping amplifier (τ = 1 μs). The stack of four discriminators provides discrimination to corresponding energy levels 30 keV, 60 keV, 120 keV and 240keV respectively. The physical calibration was provided by using of ^{109}Cd radioisotope (a source of conversion electrons with energy 62 keV and 84 keV). A simple hardware circuitry provides triggering and sampling of the individual events for the microcontroller. The microcontroller provides collection of the event data, formatting of the data frames and communication with the rocket telemetry. The telemetry signals are galvanically separated with fast optocouplers, the powering of the device is provided with galvanically separated DC-DC converter.

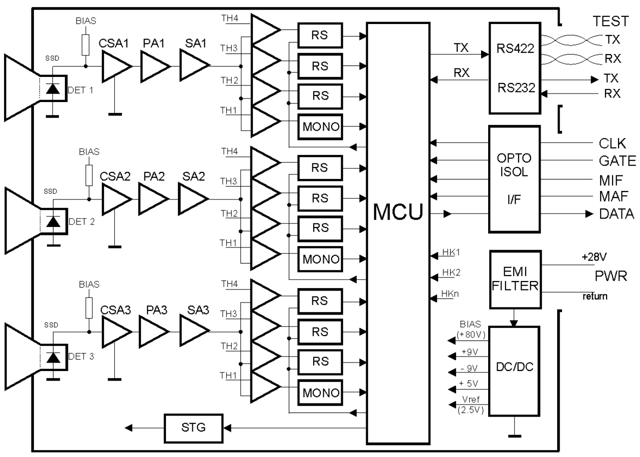

Fig. 3. Electrical design of the PEEL instrument

5. MECHANICAL DESIGN

The PEEL is designed as a compact unit with all the electronic subsystems located on a single printed circuit board. The placing of the low-noise charge sensitive circuitry together with high-level digital and powering electronics required careful design and shielding policy. The unit consists of a flat metallic box with three external cylindrical sensors that are mounted to the box with wedge-shape adapters to provide required angular orientation. The PEEL unit was installed in the nosecone part of the rocket to provide required free field of view for all sensors. The nosecone aerodynamic shield has been jettisoned after 60 seconds of flight at the altitude of 71 km.

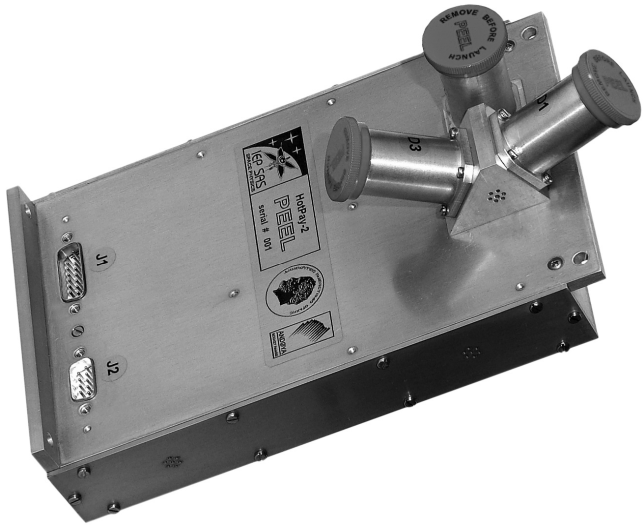

Fig. 4. Mechanical design of the PEEL instrument

6. PEEL BASIC SPECIFICATION

Weight	0.96 kg
Dimensions	226mm × 124mm × 77mm
Power	2.1 W (75mA / 28V)
Sampling frequency	62.62 Hz
Temporal resolution	15.97 ms
Angular coverage	160° × 360° (3 × 15 sectors)
Sensor field of view	38°(fwhm) / 50° (max), conical
Geometrical factor	0.077 cm^2sr
SS-Detector thickness	300 μm
Mylar foil thickness	3 μm (+ 150 nm aluminium)
Energy channels	30 – 60 keV
	60 – 120 keV
	120 – 240 keV
	240 keV - ~ 350 keV
Dynamic range	2.6×10^6 $(cm^2.s.sr)^{-1}$
Telemetry rate	32051 bps

7. MEASUREMENT

Figure 5 presents the plot of 1 sec sums of counting rate of detector 1 in channels 1-4 during the flight. Figure 6 is a plot of the flight trajectory. In addition, L parameter is added.

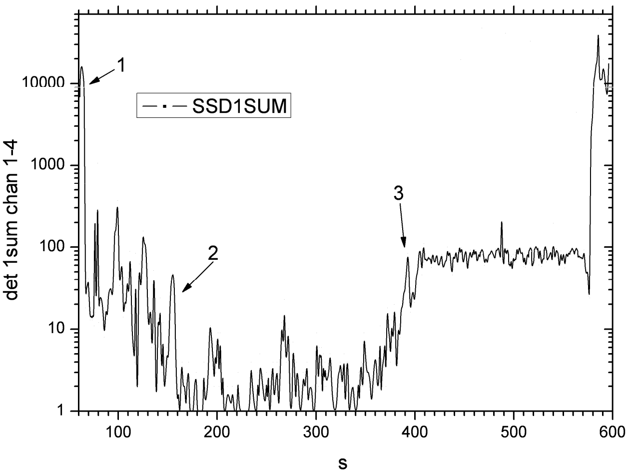

Fig. 5. The temporal profile of the sum of 4 energy channels of the detector 1 during the flight. The x-axis is in seconds after the launch at 19.14.00 UT on January 31, 2008. The 1 sec data were produced from 10 ms measurements available.

Relatively low flux of energetic electrons was observed during the flight and thus the angular distribution is not established from the existing data in the presentation here. The observations of precipitating electrons and X rays observed at the same site in a pulsating aurora indicate the isotropic flux of electrons in the energy range 10.8 – 250 keV above 10^7 $(cm^2.s.sr)^{-1}$ (Fig. 11 of paper 6]. Using the geometrical factor 0.077 cm^2.sr of the PEEL and assuming the e-folding energy of the order of 10 keV and higher energy threshold of PEEL with respect to the detector described in [5], the highest pulse (event 1 in Fig.5) gives the value of >10.8 keV electrons of the order of 2.10^6 which is by factor ~10 lower than what was observed during the strong geomagnetic activity [5].

The launch of HotPay2 was at different geomagnetic conditions, so we can just report the estimates of the fluxes of electrons during different phases of the flight in relatively quiet conditions. The values presented in Fig. 5 should be multiplied just by factor 13 to obtain the estimates of flux in units $(cm^2.s.sr)^{-1}$.

The maximum flux of > 30 keV electrons is observed during the event 1 (~2.10^5 $(cm^2.s.sr)^{-1}$) at about 80-100 km. Its averaged value is decreasing with the altitude to the level ~10 – 20 and it is again increasing with the decrease of altitude.

The three increases marked in Figure 5 have the following energy spectra composition and downward to upward ratio at the low energies as shown in Fig. 7, 8 and 9.

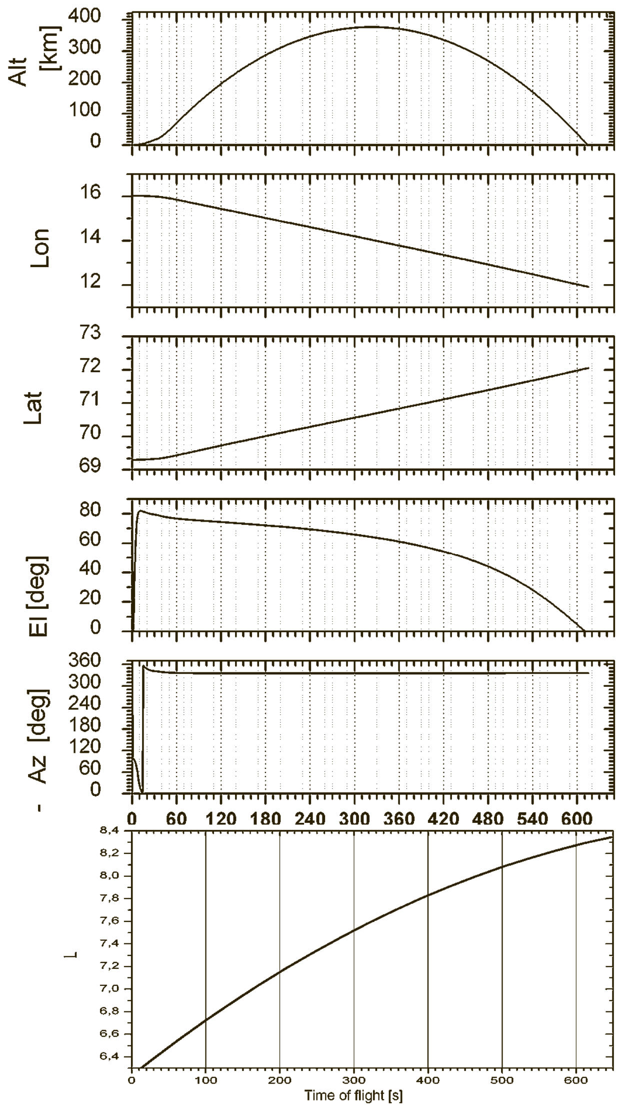

Fig. 6. The HotPay-2 flight trajectory and L - parameters

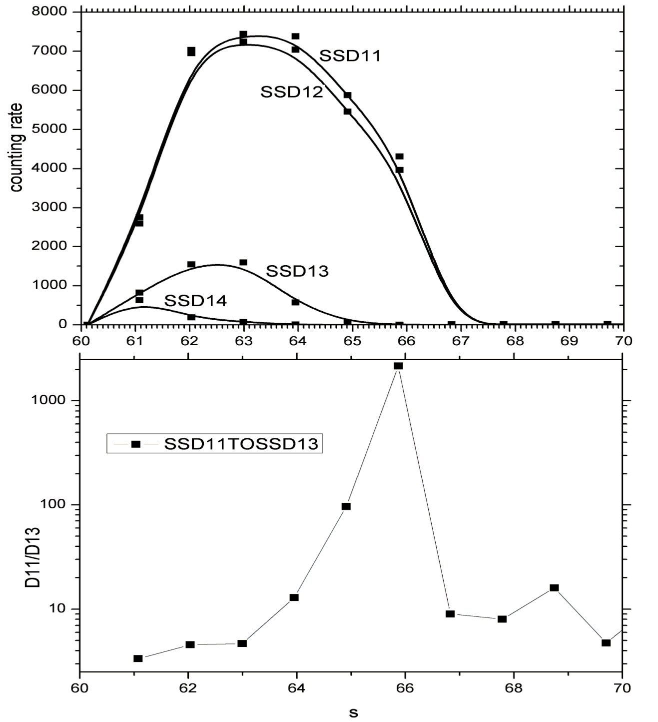

Fig. 7. The profiles of electron flux on detector 1 at 4 different energies for the event 1 marked in Fig. 5. The change of energy spectra shape is seen from lower panel (ratio of channel 1 to 3 is varying by more than 2 orders during the event.

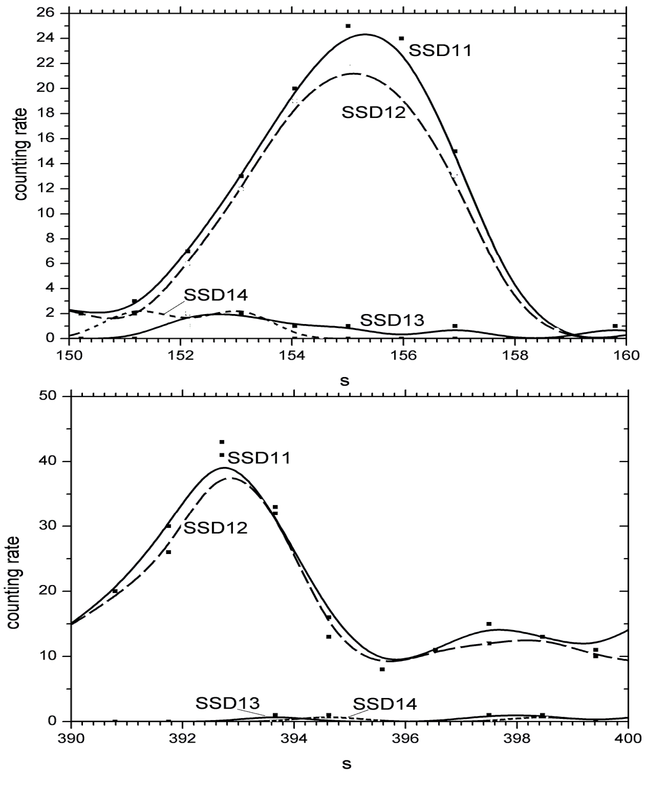

Fig. 8. The profiles of counting rate at different energies of detector 1 during the events 2 and 3

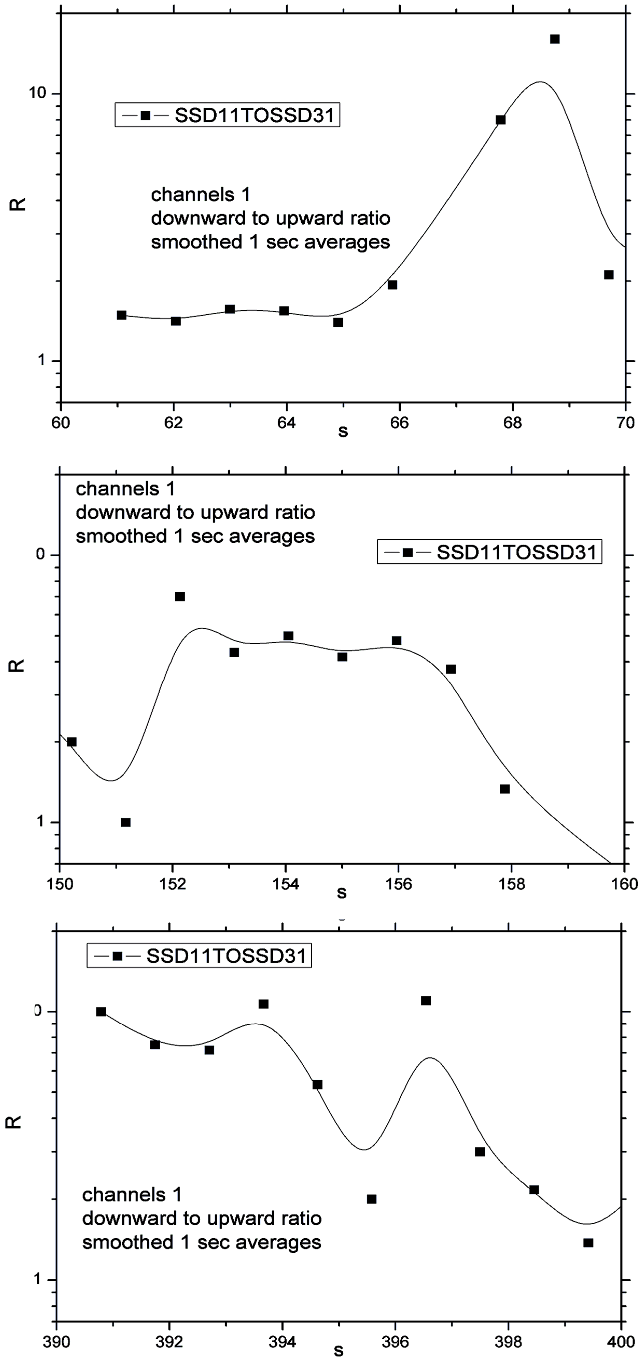

Fig. 9. The ratio of counting rates of the lowest energies in detector 1 and 3 indicating the estimate of downward to upward electron flux ratio.

8. CONCLUSION

The first results obtained from PEEL measurements during the HotPay-2 campaign indicates:

1. Low level of energetic electron fluxes > 30 keV during the whole flight in comparison with more active periods is observed. The variability is ~ 10 – 2. 10^5 during the flight.

2. Short spikes have rather variable energy spectra. Comparison with optical emission measurements may be important for understanding possible relations similar to those discussed e.g. in paper [9]. Also data from electron density measurements profile and/or model (e.g. in [10]), especially for spikes of energetic electrons observed, are important in physical analysis.

3. The ratio of upward to downward flux (precipitating to backscattered particles is generally above unity and its variability is also remarkable. It is consistent with observations [6].

ACKNOWLEDGMENTS

The PEEL project was supported by Slovak Research and Development Agency under contract APVV-51-053805; Democritus University of Thrace, Xanthi, Greece and ALOMAR eARI project, Andoya Rocket Range, Norway, Contract No.: RITA-CT-2003-506208

REFERENCES

[1] Yamagishi, H. et al, Energy spectra and pitch angle distributions of auroral electrons observed in active and quiet auroras, J. Geomagn. Geoelectr., 40, 7, 871-886, 1988

[2] Weber, E.J., et al, Rocket measurements within a polar cap arc – plasma, particle, and electric-circuit parameters, J. Geophys. Res., 94, A6, 6692, 1989

[3] Goldberg, R.A. et al., Energy deposition and middle atmosphere electrodynamic response to a highly relativistic electron precipitation event, J. Geophys. Res., 99, D10, 21071-21081, 1994

[4] Williams, D.J., et al, Parallel electric fields inferred during a pulsating aurora, Ann. Geophys., 24, 7, 1829-1837, 2006

[5] Ostgaard, N. et al., Simultaneous measurements of X rays and electrons during a pulsating aurora, Ann. Geophys., 16, 148-160, 1998

[6] Ogasawara, K. et al., Rocket observations of energetic electrons in the low altitude auroral ionosphere during the DELTA campaign, Earth, Planets and Space, 581155-1163, 2006

[7] Forster, M. et al, Simultaneous measurements from Millstone Hill radar and the Active satellite during SAID/SAR arc event of the March 1990 CEDAR storm, Ann. Geophys., 17, 3, 389-404, 1999

[8] Kudela, K. et al., Strong fluctuations of energetic electrons at low altitudes, Advances in Space Research, Volume 20, Issue 3, 499-503, 1997

[9] Lanchester, B.S. et al, Large fluxes of auroral electrons in filaments of 100 m width, J. Geophys. Res., 102, A5, 9741-9748, 1997

[10] M. Friedrich, M. Fankhauser, A steady-state model for the *D*- to *F*-region of the polar cap, Advances in Space Research, Available online 5 March 2008