Scientific Device for High-Energy Charged Particle Bursts Registration in the Earth’s Vicinity

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Abstract. An autonomous onboard satellite spectrometer for 3-30 MeV electron, 30-100 MeV proton and hydrogen, helium isotope bursts registration in millisecond time range is discussed. Spectrometer uses fast scintillator counters as a charged particle burst detectors and capable to accept a particle fluxes providing an event frequencies of more then 1 MHz. The spectrometer has some modification models were developed for different space missions. It is dramatically increase the validity of data due to parallel experiments. Some scientific results from these experiments were obtained and is presented and discussed also.

Keywords: Scintillation spectrometer, high-energy particles, atmospheric phenomenon.

I. INTRODUCTION

In last ten years a new class of atmospheric phenomenon in high-energy electron fluxes and streams in high-altitude electric discharge (HAED) volume is hardly studied and discussed. It was proposed, that an observation of different “nonstandard” atmospheric, ionospheric objects and objects in electric discharge volume (for example, Red Sprites, Blue Jets, Elves, gamma-rays and etc.) are connected with these [1], [2]. Such phenomenon result in an interaction between high-energy electron beams and residual Earth atmosphere. This electrons can be observed between a tops of charged clouds and lowest ionosphere [3]. For example, on base of RHESSI mission data [4], one can suppose the electron accelerations up to 20-40 MeV from about of 20 MeV gamma-ray registration in HAED. The principal possibility of special-purpose satellite experiment on direct observation of accelerated electron beams was analysed in [5]. The instruments for carrying out of such satellite experiment is proposed in this report. Main physical and technical characteristics of instrument are described below.

II. MAIN PHYSICAL TASKS

Spectrometer was developed at Moscow Engineering Physics Institute (MEPhI) in accordance to the joint MEPhI - Korolev’s RSC "Energia" scientific space project ALFA-ELECTRON for onboard International Space Station (ISS) mission. This project is devoted to intensive explorations of high-energy charge particle bursts and will directly to study a physical nature of charge particle fluxes variation phenomena in the upper atmosphere, search for the mechanism of foundation for high-energy electron beams in HAED. The studying for the processes of bursts trapping and time evolution in the Earth’s magnetosphere will plan also.

III. MAIN FEATURES

The spectrometer consists of two parts: one is the outer particle detector part and other is the inner part (placed in the ISS module). This is the host computer system needed for control and data treatment operations. The particle spectrometer will be installed at the outer surface of ISS and will be connected to the host onboard computer through local network on base of RS-485 standard interface. Maximum data transfer velocity of the order 2 Mbps is expected. Host computer is one of AMPRO single board computer (SBC), specially developed for extreme working conditions. The particle spectrometer consists of stack of plastic scintillation detectors (Fig. 1) and has the next main features:

- energy resolution ~ 10%;
- dynamic energy range - (0.1-10) MIP;
- angular resolution ~ 10°;
- geometric factor ~ 40 sm² × sr;
- possibility of particle imitation < 1%;
- time resolution (fast trigger) ≈ 50 ns;
- dimensions - 300×300×350 mm;
- weight < 10 kg;
- power consumption < 30 W.

IV. DETAIL SPECTROMETER DESCRIPTION

The detector part of the spectrometer is based on the ten multilayer scintillation counters (MSC). From physical scheme (Fig. 1, left) one can see that the charged particle, which passes in the "up-down" direction, first of all, must pass through the upper double scintillation counter (C1-C2) and the middle scintillation counter (C3) for registration in so-called triggering system (TS), that initiates the process of data handling. Then the particle must penetrate to the scintillation calorimeter volume for particle identification on base of energy loss in lowest counters (C4-C10). For exception of uncertainties, the particle must stop in the calorimeter. If not, there are no any identification is produced and the spectrometer can define a part of particle energy and fact of particle registration only. For exception of particles with the direction "down-up" spectrometer is equipped by anticoincidence counter C10, which reset the TS.

The composition of the spectrometer is presented in
(Fig. 1, right). Spectrometer is surrounded by aluminum container and installed on the surface of the force plane. Spectrometer includes of some housekeeping units also - power unit (PU), front-end electronics system (FEE), unit of the amplitude analysis (UAA), triggering system unit (TSU) and data processing unit (DPU). FEE is needed for MCS counter signals adaptation and amplification. PU accepts onboard current supply and produces a low voltage supply. TSU produces both the main trigger signal (MTS = C1 × C2 × C3 × anti C10) for incoming data format registration and some technological triggers. UAA includes multichannel peak detectors, pulse stretchers, fast ADCs and FIFO registers. Pulse stretchers and peak detectors give the needed amplitude stability for 12 bit ADCs, it outputs connected to a fast FIFO registers. Using of fast FIFO is needed for decreasing of DPU dead time, then DPU microcontroller can not accept new data format from ADC outputs. According to the data handling algorithm, DPU capable to collect the data formats in real time for incoming data frequencies up to 106 Hz, moreover, DPU microcontroller can translate these data to host SBC through the internal links. SBC can be switched to the local ISS network also for data damping and control operations from the Earth through the telemetry system. SBC operates under control of supervisor on base of robust QNX operation system.

The instrument energy resolution is shown in (Fig. 2) It is not exceed the level of 18% for electrons and 7% for protons in the mentioned above energy range.

V. CONCLUSIONS

The satellite onboard ISS high-energy charged particle spectrometer was presented. Main scientific tasks of the instrument include both an investigation of physical process in HAED and monitoring of charged particle
bursts in the Earth’s vicinity. The instrument detector structure was realized on base of stack scintillation detector architecture are presented. Technical arrangement of the spectrometer was described also.

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REFERENCES