

# Data collecting and treatment control system in the «Alpha-Electron» space experiment on board the International Space Station

**A M Galper, A G Batischev, P P Naumov and P Yu Naumov**

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe highway 31, Moscow, 115409, Russia

E-mail: pynaumov@mephi.ru

**Abstract.** The fast multilayer scintillation detector of the new telescope-spectrometer for the ALFA-ELECTRON space experiment is in ground testing mode now. Modules of data control system for spectrometer are discussed. The structure of the main data format and functional blocks for data treatment are presented. The device will planned to install on the outer surface of the Russian Segment (RS) of the International Space Station (ISS) in 2018.

## 1. Introduction

In the last 10-15 years a new class of atmospheric phenomena - high-altitude electrical discharges (HED) formed above thunderclouds is intensively studied. It is believed that a variety of observations for atmospheric, ionospheric and magnetosphere facilities such as so-called “red sprites», “blue jets”, “elves” and other similar effects are exists [1]. The results, obtained by numerical simulation, allowed to evaluate the probability of detecting beams of electrons accelerated in the upper atmosphere in experiments on spacecraft [2]. The new aboard scientific equipment is presented and it has the necessary speed (the dead time of 0.5 ms) to register a short variations of fluxes of electrons in the energy range from 2 to 20 MeV, the burst duration of 1 ms and higher, and has no analogues in Russia and abroad. The MSD is a standalone device with the mass of ~ 15 kg and power of ~ 40 W, the designated resource of at least 5 years working on the outer surface of the spacecraft [3]. It is planned to install the new MSD as part of the scientific equipment "ALFA-ELECTRON" on board the Russian Segment of the ISS in 2018.

## 2. Physical arrangement

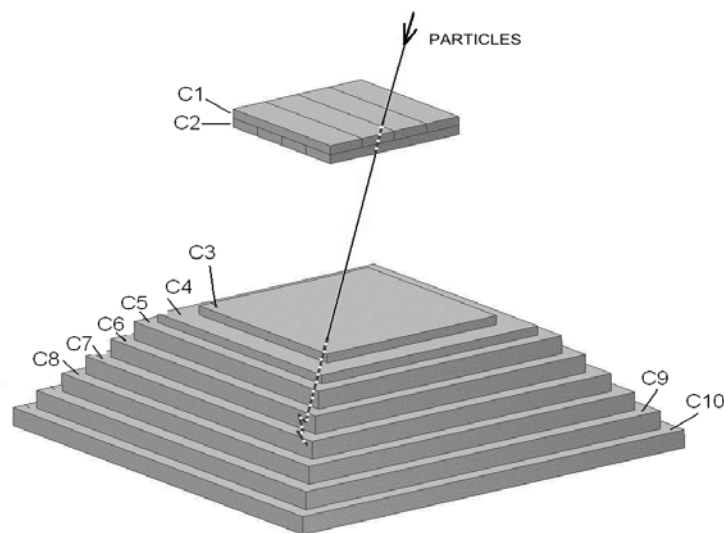
The physical arrangement of the detector system is shown in figure 1. The MSD consists of a set of scintillation detectors C1 - C10 and is an improved modification of the MSD, previously developed by NRNU MEPhI and formed on the basis of polystyrene [3]. This scintillator has a high transparency and a minimum excitation time. It has been proposed for the MSD to use the best (in terms of time, amplitude characteristics, dimensions, mass and energy) photomultipliers R5611-01A manufactured by Hamamatsu as photodetectors. This type of photomultiplier is recommended for use in scintillation detectors. PMT R5611-01A passed the qualification tests for resistance to vibration and impact.

Structurally, the MSD is composed of the upper detector (UD) and scintillation calorimeter (SC). UD includes ‘thin’ counter detectors C1 and C2, which consists of four identical strips. The C1 detector strip band is perpendicular to C2 detector one. Each band is viewed separately by different



PMT. Compound of strips detectors C1 and C2 with photomultipliers is arranged via optical fibers. SC located at the distance of 100 mm from UD and consists of C3 - C10 detectors, each of which can be viewed by two separate PMT. Controller unit together with the pulse amplitude analysis unit (see below) carries out the separation of particles (electrons and protons) by analyzing the energy in scintillation detectors when particles penetrate in a matter of MSD (so called  $\Delta E \times E$  technique). Detectors of the SC (C3 - C10) are used as total absorption detectors (as calorimeter) where the particle loses all its remaining energy. Particle energy left in the detectors C1, C2 and SC can reliably allocate electrons.

The energy of the electron is determined by the total energy of the particle detectors in the SC. The SC can further determine the energy of the particles by means of the number of particles passed by the detectors until it will stop. For operation in the intensive particle flux and in order to protect equipment from overload, the possibility of reducing the MSD aperture ratio approximately one order of magnitude by turning off portions of the strips in the detectors C1, C2 to control command from the ground.



**Figure 1.** The physical scheme of the MSD.

### 3. Main features

The ALFA-ELECTRON is a new space device for magnetosphere charged particle registration. The previous MSD type spectrometers ARINA and VSPLESK were launched in 2006-2007 respectively and their main characteristics are presented in figure 2.

The logical formula of the main trigger signal MST is as follows:

a) the case of charged particles (electrons, protons or helium nuclei)

$$\text{MSTC} = \text{PST} \times (\text{no C10}),$$

where preliminary signal trigger is

$$\text{PST} = (\text{C1-1 and C1-2 and C1-3 and C1-4}) \times (\text{C2-1 and C2-2 and C2-3 and C2-4}) \times \text{C3}.$$

In special "Hard trigger" mode PST is produced under the condition of coincidence signals from any of three C1 - C5 detector group, except combinations C3×C4×C5 and C2×C4×C5 involved in the implementation "Soft Trigger" mode.

b) the case of neutral particles (gamma rays and neutrons):

$$\text{MSTN} = \text{PST} \times (\text{no C10}),$$

where the signal PST is produced under the condition:

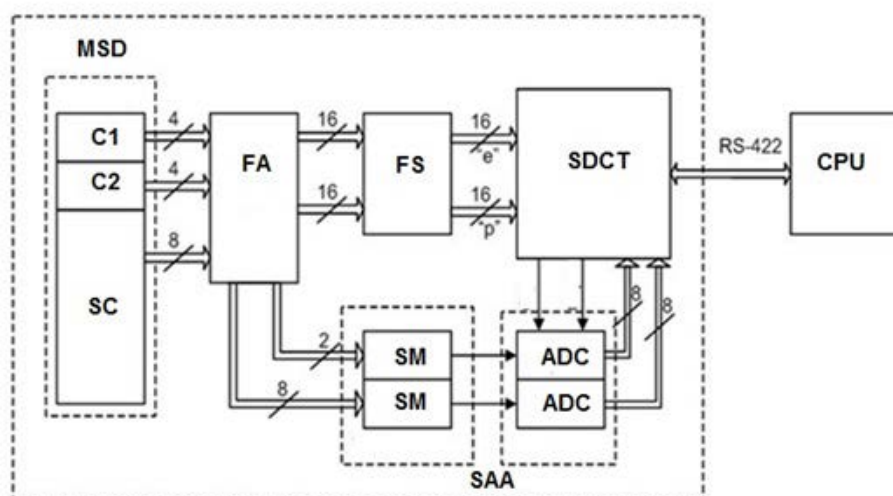
$$(\text{no C1}) \times (\text{C2-1 and C2-2 and C2-3 and C2-4}) \times \text{C3} \times \text{C4}.$$

Features	«ARINA» 2006	«VSPLESK» 2007	«ALFA-ELECTRON»
Particles type	electrons (3-30 MeV) protons (30-100 MeV)		electrons (3-30 МэВ), protons & light nuclei (30-100 MeV/nucI)
Geometric factor	10 cm <sup>2</sup> ×sr	10 cm <sup>2</sup> ×sr	60 cm <sup>2</sup> ×sr
Power	13,5 W	15 W	55 W
Dead time	1 msec	1 msec	0,5 microsec
Work in vacuum	NO	YES	YES
Memory	8 MB	8 MB	128 MB
Interface	HVRL	BITS 2-12, CAN	BITS 2-12, RS-422, ETHERNET
Given resource	3 years	3 years	more than 4 years
Method	<b>dE/dx</b>		<b>dE/dx-E</b>

**Figure 2.** Comparison of the MSD type spectrometers.

#### 4. MSD functional description

The MSD and front-end electronic functional block diagram is shown in figure 3. The MSD detectors include: the Fast Amplifiers (FA) of signal pulses from photomultipliers and the Fast Shapers (FS) of logical pulses that have thresholds for discrimination for the electrons and protons from electronics noise, the System of Data Collection and Transmission (SDCT), made on the basis of radiation-resistant FPGA manufactured by the Actel, and the System of Amplitude Analysis (SAA), based on high-speed ADC AD9058 with a sampling frequency of 50 MHz with parallel two-channel amplitude pulses digitizing from the upper detectors C1-C2 and calorimeter detectors C3-C10. The basis of the SDCT is the Event Selection Unit (ESU), implemented on the logic array (LA) and the microcontroller (MC), that combined local data highway from the buffer memory for temporary storage of the events and RS-422 data protocol for connecting with Control and Processor Unit (CPU). The ESU receives the outputs of 16 shapers and LA forms the main and private trigger signals which strobing ADC.



**Figure 3.** The MSD functional block-scheme.

Based on the table of the trigger logic STDC develops trigger signals in ESU, as well as the data formats read by MC on the local data line from the dual port buffer memory to RS-422 CPU interface. SAA also has an intermediate buffer memory for temporary storage of data digitized by ADC.

Despite of the high speed ADC in the event of a complete lack of buffering in registration long bursts of particles can be observed delay in reading data from SAA connected on the local bus to the CPU. With the accumulation of a certain amount of information (main format) SCDT begins output to the CPU via RS-422 with the transmission rate of the order of 1 Mbit/s.

At this time, the controller of the RS-422 performs procedure service for dual-port buffer memory, and MC begins input from the ADC. So, STDC has a minimal dead time with the using of implemented buffering registration system.

The structure of the main data format is shown in figure 4. The data file consists of some flags and status bytes, time and coordinates information bytes, two event (master) counter bytes (for charge and neutral particles) and signal amplitude codes of two fast ADC. The ADC codes are needed in direct and inverse forms for good reliability as well as the control sum too.

Byte number	Content
1	Format-flag (FF1)
2	Format-flag (FF2)
3	AT1 – aboard time (LSB)
4	AT2 – aboard time
5	AT3 – aboard time (MSB)
6	SELCMD (command status)
7	C1 и C2 (coordinates – C11p C11e C12p C12e C21p C21e C22p C22e; e – electron, p – proton)
8	C3, C4, C5 и C6 (coordinates – C3p C3e C4p C4e C5p C5e C6p C6e)
9	C7, C8, C9 и C10 (coordinates – C7p C7e C8p C8e C9p C9e C10p C10e)
10	RGSTAT (counter status)
11	Nm1 – master counter-1
12	Nm2 – master counter-2
13	NC1
14	NC2
15	NC3
16	NC10
17	ADC1 direct
18	ADC1 inverse
19	ADC2 direct
20	ADC2 inverse
21	Control sum (1-20 bytes)

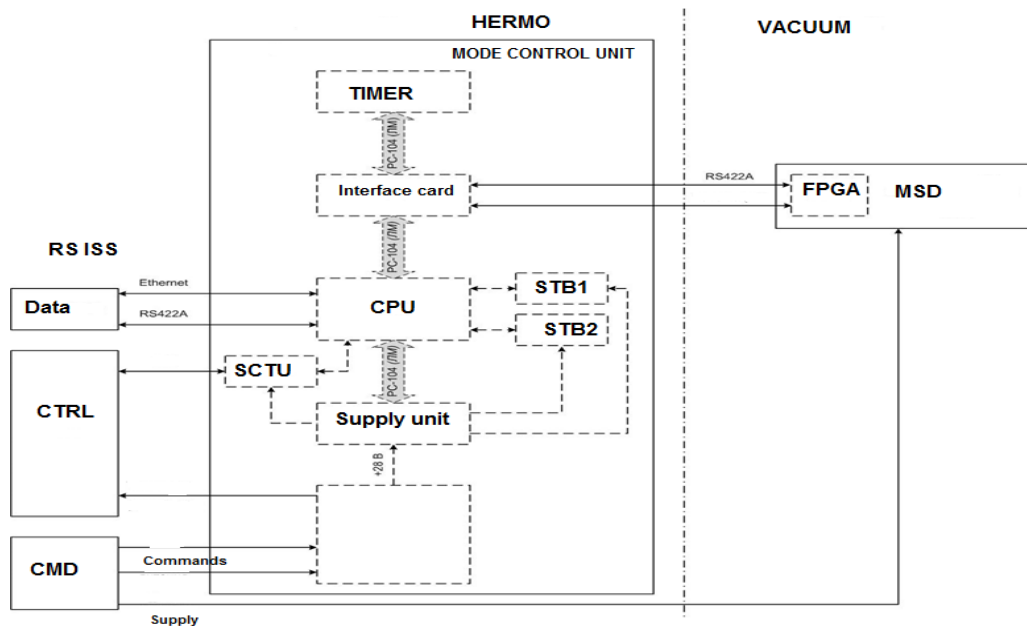
**Figure 4.** The content of the main MSD data format.

## 5. The MCU functional description

The data collecting and treatment control system of the spectrometer consists of the MSD data system and the CPU system with interfaces to the MSD and the RS ISS aboard data systems (see figure 5).

The MSD module is installed out of the RS station in vacuum and special interface is needed. Industrial RS-422 interface is a good decision for robust data collection system. The CPU, system timer, supply unit, clock generator unit (STB1-STB2), interface card (RS422 type) are localized in special single board computer (SBC) for space implementations. The CPU module is realized on new generation of single board computers. All mentioned above modules are contained in mode control unite (MCU) box (see figure 6), placed in internal volume of the RS ISS.

We began the testing of the prototypes of the MSD and the MCU in our laboratory [4]. The main problems are minimization of particle registration time intervals for a more value of burst particles efficiency, buffering of the main formats transferred from the MSD to the CPU in local memory and conducting of online data format preprocessing for it uploading to the RS ISS data system.



**Figure 5.** The functional scheme of the spectrometer CPU.



**Figure 6.** The common view of the MCU box.

## 6. Conclusion

We presented the new space instrument for particle measurement in near Earth vicinity. The data collecting and treatment control system on base of the front-end MSD FPGA and single board computer is described. The new telescope-spectrometer for the ALFA-ELECTRON space experiment is in laboratory ground testing mode now.

## Acknowledgements

Authors thank for the support from National Research Nuclear University MEPhI in the framework of the Russian Academic Excellence Project (contract No. 02.a03.21.0005, 27.08.2013).

## References

- [1] Bell T F, Pasko V P and Inan U S 1995 *Geophys. Res. Lett.* **22** 2127
- [2] Fishman G J *et al.* 1994 *Science* **264** 1313
- [3] Batischev A G *et al.* 2015 *Physics Procedia* **74** 132-8
- [4] Naumov P Y *et al.* 2015 *Physics Procedia* **74** 261-5