# Spectrometry Of Charged Particle Flows Aboard Small Spacecraft

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***Abstract*—The peculiarity of measurements of charged particle fluxes aboard small spacecraft consists in the limitation of the overall dimension occupied by the equipment, mass and power consumption, as well as in a difficulty of transmission of large amount of information from a spacecraft to the Earth. Features of the measured radiation are the following: a wide range of changes in the density of particle fluxes and their amount, mixed streams of radiation, a presence of significant background flows, etc. Along with the limited overall dimensions and weight of detecting devices the following most characteristic features of the considered equipment are determined: the principles of its construction, choice of the circuit design, and detecting elements. These issues are the subjects of this work.**

***Keywords*— spacecraft, charged particle, semiconductor detectors, spectrometer**

## I. Introduction and Statement of the Task

Now use of small satellites increases both applied and basic researches [1]. For the last decade a problem of space weather develops intensively. In this problem the account of interactions between solar influences and particularly terrestrial processes is important. Studying of dynamics of the energetic charged particle fluxes in the nearby-Earth environmental space and interplanetary environment can give helpful information on this problem [2]. Investigations aboard small space vehicles can make a big contribution into the decision of this problem. For these satellites the devices of small sizes and weight and at a time with good functional features are necessary.

Spectrometers and spectrometers-dosimeters of the charged particle fluxes are well-known. Similar devices are enough sensitive to the low-energetic charged particles.

Their energy range of measurement is limited by the path length of measured particles.

For example, spectrometers of the charged particle energies [3-5], which contains semi-conductor detectors, pulse amplifiers and amplitude analyzer, are known. The spectrometer-dosimeter using a ΔE−E method of registration of the charged particles, consists of the system of two ΔE−E - detectors.

Our purpose is the increase of information capacity and expansion of the energy range of measurement of the particle registration.

## II. Device of the Spectrometer

The aim is achieved by that the spectrometer contains an anti-coincidence security detector made in the form of through cylinder. Inside the cylinder the semi-conductor 1-4 detectors compounding a telescope are installed. The detector's exits are connected with inputs of the spectrometric 5-8 amplifiers. The amplifier exits are connected to the inputs of analogue- digital converters 9-12. Their exits are connected with the inputs of programmable logic array.

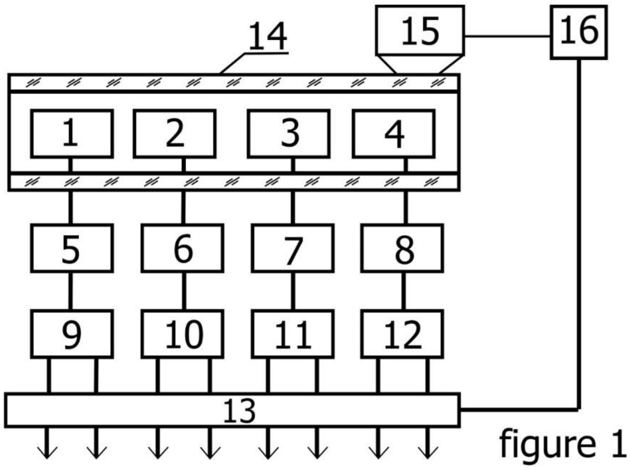


Figure 1. The spectrometer's block diagram

The spectrometer of the charged particles operates as follows:

The charged particles in interacting with a substance of 1-4 detectors cause the ionization which is described by the Bethe, Bloch [6, 7] relation:

$$-\frac{dE}{dz} = \left(\frac{2Cmc^2z^2}{p^2}\right) F(Z, p^2),$$

Where C is the total area occupied by a cross section of electrons containing in 1 g of the decelerating environment;

z – the charge of particle related to a charge of the electron;

Z - the charge of nucleus in the substance of detector related to the charge of electron;

$mc^2$ - the rest energy of a particle;

$F(Z, \beta^2)$ - dimensionless function of the energy whose parameters depend on the environment physical constants and decelerating ;

ʒ - thickness of material expressed in terms of units of surface density (g/sm$^2$) which is equal to the product of detector thickness into the material density (ʒ =x*p).

The calculated values of ionization losses for the semi-conductor detectors 1-4 are shown in Fig. 2.

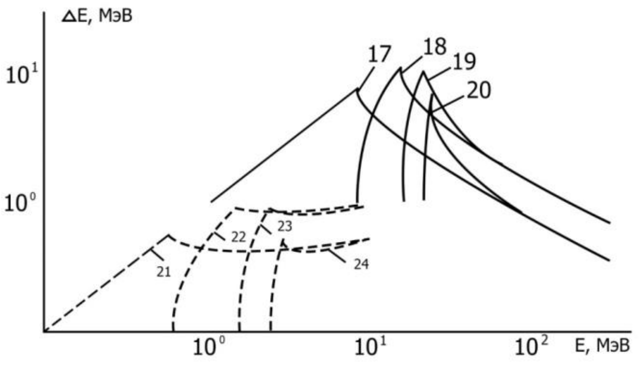


figure 2

Figure 2. Ionization losses in silicon detectors are shown.

In passing of the charged particle through the semi-conductor 1-4 detectors, the energy isolated in it, is transformed into the exit impulse and through the spectrometer 5-8 amplifiers it is transferred to the analogue-digital 9-12 converters of the spectrometer of the charged particles.

The thickness of semi-conductor detectors d is chosen based on the energy ranges of registered particles. Because the particles at first get on external (extreme) detectors and should give corresponding signals, their thickness should be less than the internal ones. Otherwise, at the same energies of the particles from the soft area it is necessary to involve internal detectors too, but there is no point in it. For convenience of choice of the range let's make a thickness of external detectors to be thinner by a factor of 2. The indicated thicknesses of detectors (0.05 cm for the external detectors and 0,1 cm for the internal ones) cover a practical energy range of proton radiation.

## III. SPECTROMETER FUNCTIONING

Let's consider the operation of spectrometer of the charged particles when registrations of the proton flux. Protons with the energy from 1 to 8 MeV are completely absorbed in semi-conductor detectors 1 and 4 (see Figs. 1, 2, the curve 17), i.e. in this energy interval one can make a spectrometry of proton flux from two directions. The protons with the energy up to 15 MeV are completely retarded in detectors and also from the opposite direction in detectors 3 and 4 that allows to make measurements from two directions in the energy interval from 9 to 15 MeV (see Figs. 2 - curves 17 and 18). The protons with greater energy ,but up to 20 MeV , are registered by semi-conductor 1-3 detectors from one direction, and 2-4 detectors from the opposite direction. The protons with the energy of 21.5 MeV pass through the whole system of 1-4 detectors. Thus, for example, at energy of protons of 40 MeV in the semi-conductor 1detector we receive a signal in the power units of 1-1,4 MeV (see Fig. 2 - the curve 17), in the 2 detector – of 1,65 MeV (see Fig. 2 - the curve 18), in the 3 detector – of 2,9 MeV (see Figs. 2 -the curve 19), in the 4 detector – of 3,1 MeV (see Figs. 2 - the curve 20). If protons with the energy of 40 MeV get into the system from the 4 detector , we receive the following signal: in the 4 detector -of 1,4 MeV, in the 3 detector – of 1,65 MeV, in the 2 detector– of 2,9 MeV, in the1 detector – of 3,1 MeV. Thus, one can make spectrometry of proton fluxes with the energy of more than 21,5 MeV, and also to distinguish directions of arrival of particles. The upper limit for determination of the energy and a direction of particles in this case with four semi-conductor detectors accounts for 60 MeV. It is possible to expand this limit if we use thicker 2 and 3 detectors or increase the total number of detectors.

Against the background of protons one can make a spectrometry of electrons from two directions in the energy interval from 200 keV to 7 MeV. Let's consider the operation of this spectrometer of the charged particles at registration of electrons.

The 21-24 curves (see Fgs. 2) correspond to ionization losses of electrons in semi-conductor 1-4 detectors. The 21 curve of the path of electrons with the energy up to 0,58 MeV is specific to the thin semi-conductor 1-4 detectors, i.e. one can measure electron energy from two directions up to energy of 0,58 MeV.

The electrons with energy above 1,4 MeV, but up to 2,4 MeV are registered by 1-3 or 2-4 detectors from other direction. Otherwise, the electrons possessing the energy above 2,9 MeV can pass through1-4 detectors . In this case it is possible to measure the energy and to define the direction of electrons up to the energy of 7 MeV.

As a whole, the principle of operation of this spectrometer of the charged particles consists in the following.

Signals from semi-conductor 1-4 detectors through spectrometer 5-8 amplifiers are transferred to the analogue-digital 9-12 converters where they are transformed and transferred to the programmable13 logic array which has N inputs and n exits.

Possible levels of exit discharges of all analog-digital 9-12 converters (i.e. a level of exit discharges of a programmable logic13 array at both directions of hit of particles and type of particles (1 and p) at different energies) are calculated. After that we prepare the

Table of exit levels on logic array buses, program the direction of arrival of particles (1 bit), particle type (in this case - 1 bit) and particle energy (n = 2 bits). The accuracy of measurements depends on the capacity of logic array and possibility of capacity increase. The plastic 14 scintillator serves for exclusion from the analysis those events at which particles get into the 1-4 detectors passing the telescope aperture.

## THE CONCLUSION

The use of such spectrometer of the charged particles will allow the following:
* to extend the energy range of measurements;
* to measure fluxes of particles of different intensities from two opposite directions independently and simultaneously.

Thereby, there appears a new functional possibility and the information capacity of the device increases without increasing of dimensions, weight and power consumption that is especially important for small satellites.

## Acknowledgment

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