Monitoring of the Moon radiation environment by the RADOM instrument

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Abstract

This paper describes the RADOM instrument, which is devoted to the Moon radiation environment monitoring. The instrument is a miniature (98 grams 100 mW) 256 channels spectrometer of the deposited energy (dose) in a single 2 cm^2 0.3 mm thick silicon detector. The science objectives, the block diagram, the working sequence, the data analysis procedure and the main calibration results were shortly listed and presented.

Introduction

The dominant radiation component at CHANDRAYAAN-1 orbit at 100 km above the surface of the Moon are the galactic cosmic rays (GCR) modulated by the magnetic fields associated with the low energy charged particles (the solar wind) that are continuously emitted from the Sun and the solar energetic particles events (SEP) emitted during solar flares, sudden sporadic eruptions. The GCR are charged particles that originate from sources beyond our solar system. The distribution of GCR is believed to be isotropic throughout interstellar space. The energies of GCR particles range from several tens up to 10^{12} MeV.nucleon^{-1}. The GCR spectrum consists of 98% protons and heavier ions (baryon component) and 2% electrons and positrons (lepton component). The baryon component is composed of 87% protons, 12% helium ions (alpha particles) and 1% heavy ions [1]. Highly energetic particles in the heavy ion component, typically referred to as high Z and energy (HZE) particles, play a particularly important role in space dosimetry. HZE particles, especially iron, possess high-LET and are highly penetrating, giving them a large potential for radiobiological damage [2].

The SEP are mainly produced by solar flares, sudden sporadic eruptions of the chromosphere of the Sun. High fluxes of charged particles (mostly protons, some helium and heavier ions) with energies up to several GeV are emitted by processes of acceleration outside the Sun. The time profile of a typical SEP starts off with a rapid exponential increase in flux, reaching a peak in minutes to hours. The energy emitted lies between 15 and 500 MeV.nucleon^{-1} and the intensity can reach 10^4 part.cm^{-2}.s^{-1}.sr^{-1}. SEP are relatively rare and occur most often during the solar maximum phase of the 11-year solar cycle. In the years of maximum solar activity up to 10 flares can occur, during the years of minimum solar activity only one event can be observed on average. [3].

The lunar albedo radiation (principally neutrons) produced by the interactions of GCRs and SEPs in the surface. The neutron albedo can contribute as much as ~20% to the effective dose when the radiation environment is dominated by GCRs. When SEPs dominate, the neutrons contribute ~2% to the total dose.

Science objectives

The general objective of the experiment is the Moon radiation environment monitoring onboard the CHANDRAYAAN – 1 mission. The main goal of the RADOM Instrument is the measurement of both the galactic and solar components as well as the effect of solar particles events in order to assess the dose received for future manned missions to Moon.

Instrument description

The RADOM spectrometer (Please see Fig.1.) main duties are to measure the spectrum (in 256 channels) of the deposited energy from primary and secondary particles at the board of CHANDRAYAAN-1 mission and to transmit these data toward the Earth. RADOM is a miniature spectrometer-dosimeter containing: one semiconductor detector. Pulse analysis technique is used for the obtaining of the deposited energy spectrum, which further is converted to the deposited dose and flux in the silicon detector. The unit is managed by the microcontrollers through specially developed firmware. RS232 interface provide the transmission of the stored in the buffer memory data toward the CHANDRAYAAN-1 telemetry. The instrument is very similar to: 1) The Liulin-E094 4 MDUs

Fig.1 External view of RADOM-FM instrument

flown in 2001 on American Destiny module of International Space Station (ISS) [4,5]; 2) R3D-B2/B3 instruments flown on the Foton M2/M3 spacecrafts in 2005/2007 [6, 7]. 3) R3DE instrument launched in February 2008 to EuTEF platform of European Columbus module of ISS [8].

After switching on, the RADOM starts to measure in 256 channels the spectrum of the deposited energy used further to calculate the dose and the flux of particles in the silicon detector. The exposition time of one spectrum is fixed at 30 sec. After finishing the first measurement cycle the spectrum are stored in the buffer memory. After connection of the RADOM trough the RS232 interface with the telemetry all data accumulated are transmitted to it. The RADOM contains: one semiconductor detector with 2 cm^2 area and 0.3 mm thickness, one low noise hybrid charge-sensitive preamplifier A225F type of AMPTEK inc.; a fast 12 channel ADC; 2 microcontrollers and buffer memory. Pulse high analysis technique is used for measurement of the energy losses in the detector. The unit is managed by 2 microcontrollers through specially developed software. A block schema of the spectrometer-dosimeter in the RADOM is presented in Figure 2.

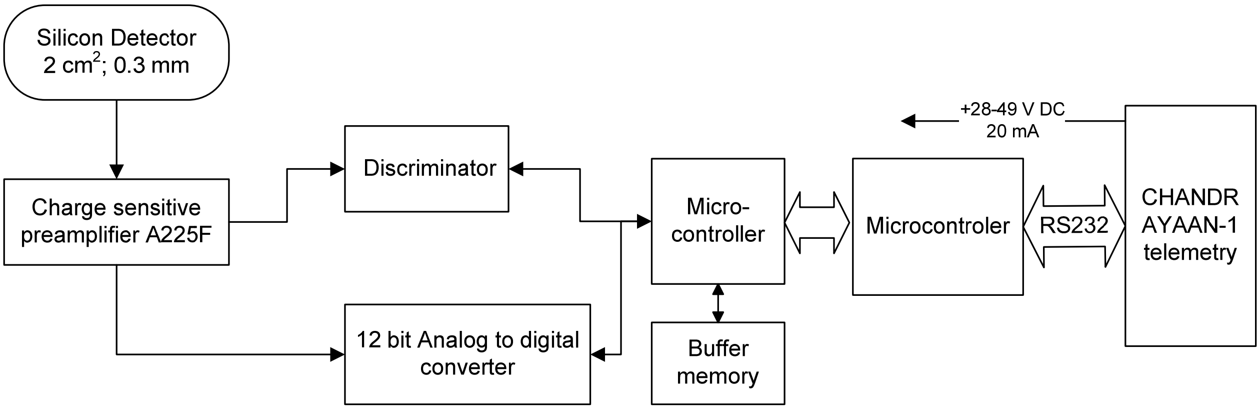


Fig. 2. Block-scheme of the RADOM-FM spectrometer

The following method for calculations of the dose is used: The dose D [Gy] by definition is one Joule deposited in 1kg of matter or:

$$D = K\sum_{i=1}^{256} A_i i / MD,$$

where *MD* is the mass of the detector in [kg] and A_i is the energy loss in Joules in channel i. *K* and k_i are coefficients.

On the base of calibrations of the Liulin type spectrometers in CERN and comparisons with TEPC measurements there was developed methodic, which allows to be evaluated the Ambient dose equivalent - H*(10) [9].

For the GCR radiation the H*(10) values are calculated by the relation

$$H_{GCR}*(10) = K\{\sum_{i=1}^{14} k_i A_i + 5\sum_{i=15}^{256} k_i A_i\} / MD \quad .$$

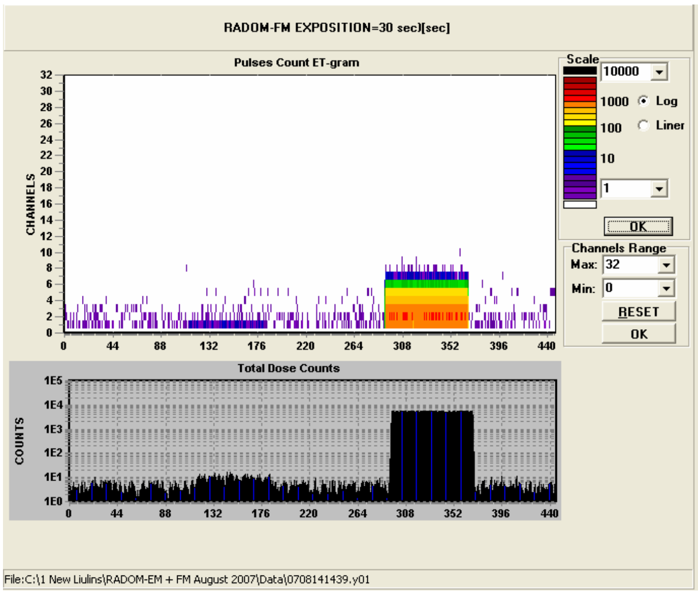
For the SEP radiation the H*(10) values are calculated by the relation

$$H_{SEP}*(10) = 1.3K\{\sum_{i=1}^{14} k_i A_i + \sum_{i=15}^{256} k_i A_i\} / MD$$

Calculations of the absorbed dose, flux and ambient dose equivalent - H*(10) are performed automatically by RADOM-FM software product during the reading of the file transferred trough the telemetry.

The RADOM-FM software product (RADOM-FM.exe) is used for the management of the spectrometer and express analysis of the results. The program includes subprograms for data listing and data visualizations.

Calibration results


RADOM-FM EXPOSITION=30 sec][sec]

Scale: 10000 – 1; ● Log ○ Liner

Channels Range Max: 32 Min: 0

File:C:\1 New Liulins\RADOM-EM + FM August 2007\Data\0708141439.y01

Fig. 3 Calibration results of the RADOM-FM spectrometer

Calibrations of RADOM precursors were performed on protons with Prof. J. Lemaire and Prof. Gh. Gregoire from Institut de Physique, Universite Catholique de Louvain, Belgique [4]. Calibrations on alphas and heavy ions were performed under the cooperation with Dr. K. Fujitaka and Dr. Yukio Uchihori from National Institute of Radiological Sciences, Chiba, Japan [10]. Calibrations of Liulin-4 type spectrometers of different modifications on gamma and neutron sources and on CERN reference field were performed under the cooperation with Prof. F. Spurny from Nuclear Physics Institute of Academy of Sciences of Czech Republic [11]. RADOM instrument was build practically with same mechanical and electric characteristics as the mentioned above instruments that is why new calibrations on gamma, neutron, proton and heavy ions sources was not necessary.

The Figure 3 shows the energy-time diagram of the calibrations performed in the laboratory of STIL-BAS with natural radiation sources with RADOM-FM instrument. Two maximums by ^{241}Am first and ^{137}Cs second are observed at the upper panel, which shows by color coding seen in the right of the panel, the count rate in channels from 1 to 32 in dependence of time. It is well seen that the ^{241}Am source, which contain a 60 keV gamma line produces high-count rate only in the first channel of the RADOM-FM what is expected because the energy loss in it is between 40 keV and 120 keV. The ^{137}Cs gamma source produces wider spectrum (up to 8th channel) with maximum count rate in the second channel. In the lover panel of Figure 3 the sum of the events in each spectrum in dependence by time is displayed.

Conclusions

The general objective of the RADOM experiment is the Moon radiation environment monitoring onboard the CHANDRAYAAN – 1 mission. The measurements of both the galactic and solar components of the radiation will allow better estimation of the doses, which will be received on future manned missions to Moon.

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