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On-board analysis of X-ray CCD based X-ray fluorescence spectrometer on MUSES-C spacecraft

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X-ray CCDs are used as X-ray detectors of X-ray fluorescence spectrometer on-board MUSES-C spacecraft. X-ray spectrum is obtained by analysis of CCD images. Under the situation where it is possible to analyze a lot of images, such as X-ray astronomical satellites, X-ray CCDs obtained good results with their wide effective areas and high-energy resolution.

Wide effective areas and high-energy resolution of X-ray CCDs are attractive to X-ray fluorescence spectrometer for space probes. Detector areas of 25 square cm or greater are needed for use in X-ray remote sensing systems. Energy resolution of less than 200eV at 5.9keV is also required to separate characteristic X-ray lines of major elements, such as Mg, Al, and Si. X-ray CCD satisfies these two requests.

However, the data size generated by X-ray CCD is disadvantage using planetary exploration because of the limitation of data transfer rate. If this problem is resolved, X-ray CCD becomes a useful X-ray detector of X-ray fluorescence spectrometer for planetary explorations.

Therefore, data reduction methods keeping the data quality must be developed when X-ray CCD is used. Here we report the data reduction methods and their results.

The background of the success that data reduction methods worked correctly, is the existence of SH-OBC, which is the motherboard developed especially for space use. SH-OBC has two attractive points; one is to adopt CPU with high frequency processing, and the other is to use triple CPUs, ROMs, and Rams for a redundancy. CPU is SH7708 (SH-3) and the speed is 60-MHz. This speed is high frequency for space use. SH-3 is also widely used in computers. Therefore the environment to develop software worked on SH-3 is customized enough and the efficiency is increased significantly. Triple CPUs, another characteristic of SH-OBC, allow data to correct errors using voter methods. The errors may be occurred on a CPU due to radiation effects and so on. Developing software on this SH-OBC, it gets possible to work XRS operation and on-board analysis of X-ray CCD in addition to the fundamental jobs of previous CPUs, such as command and telemetry.

Even if CPU processes with high frequency, the speed of hardware is higher than that of software. Therefore the roles of hardware and software should be shared.

Considering the analysis of X-ray CCD, X-ray event extraction is implemented by hardware because event extraction must be performed synchronized with CCD readout. Grade judgments of X-ray CCD images after X-ray event extraction have some complexity and should be implemented with flexibility. We decided these judgments of Grade were software works.

In a viewpoint of performance, XRS implements line Binning and Voltage operations. Binning is the process of combining charge from adjacent pixels in a CCD during readout. Vertical 16 pixels are regarded as 1 pixel. Voltages affect the energy resolution of X-ray CCD, and the operation of voltage is significantly important function using X-ray CCD.

XRS has Ground Test Mode and On-board Analysis Mode. In Ground Test Mode, the images of XRS output external bus. In On-board Analysis Mode, XRS records the data after event extraction of CCD images into FIFO memory. After event extraction, GRADE judgments were performed by software. Comparing with these two modes, the two spectra had the same energy resolution, while Ground Test Mode generated 200 MB data and On-board Analysis Mode generated 11 KB.

The energy resolution of out XRS is 180eV@5.9keV. In the experiments of the measurements of fluorescent X-rays from samples, XRS actually separated the X-ray fluorescence lines of Mg, Al, and Si.