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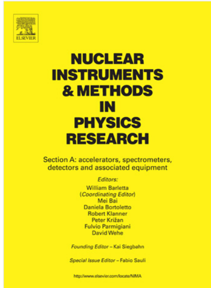

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Single Event Upset Analysis: On-Orbit Performance of the Alpha Magnetic Spectrometer Digital Signal Processor Memory aboard the International Space Station

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Abstract

Based on the collection of error data from the Alpha Magnetic Spectrometer (AMS) Digital Signal Processors (DSP), on-orbit Single Event Upsets (SEUs) of the DSP program memory are analyzed. The daily error distribution and time intervals between errors are calculated to evaluate the reliability of the system. The particle density distribution of International Space Station (ISS) orbit is presented and the effects from the South Atlantic Anomaly (SAA) and the geomagnetic poles are analyzed. The impact of solar events on the DSP program memory is carried out combining data analysis and Monte Carlo simulation (MC). From the analysis and simulation results, it is concluded that the area corresponding to the SAA is the main source of errors on the ISS orbit. Solar events can also cause errors on DSP program memory, but the effect depends on the on-orbit particle density.

Keywords

AMS, On-Orbit, SEU, SAA, Solar Event, Memory

1. Introduction

The Alpha Magnetic Spectrometer is a state-of-the-art instrument employing high energy particle physics detection techniques. AMS was installed externally on the ISS 19 May 2011, and continues to conduct its long-term mission of performing precision measurements of cosmic rays. This long-term measurement provides insight into baryogenesis, antimatter asymmetry, the search for dark matter and the origin and propagation of Cosmic Rays [1, 2].

The AMS data acquisition system (DAQ) digitizes and records data from ~200,000 analog channels. These channels correspond to the readout of different AMS detectors including: the Transition Radiation Detector (TRD), the Time of Flight (TOF) and Anti-Coincidence Counters (ACC), the Silicon strip Tracker, the Ring Image Cherenkov Detector (RICH), the Electromagnetic Calorimeter (ECAL), as well as the Level-1 Trigger module (LV1) [3]. A block diagram of the DAQ tree is shown in Figure 1 [4]. It consists of over 300 computational nodes based on the ADSP-2187L Digital Signal Processors and a Main DAQ Computer.

The operation of large electronic systems in space is a challenging task as the systems must be resistant to radiation and fault tolerant. All the computational nodes based on the ADSP-2187L in AMS use commercial off-the shelf (COTs) components. Before exposure to the mission environment of space, all of the components have been carefully checked using accelerator based radiation tests [5]. Single Event Effects (SEE) like SEU and Single Event Latchups (SEL) are fully tested for and the reliability of the components is evaluated based on the test data. Even so, the beam test is just an approximation of what will happen in the space environment. i.e. The SEU and SEL rates obtained from the test data are predicted rates. In general, when considering SEUs, data from long duration on-orbit experiments have limited availability. However, AMS provides a good platform for such on-orbit SEU research given its long-term mission aboard the ISS.

While on board of the ISS AMS is in low earth orbit with altitude between 330 km and 410 km. This orbit circles the earth about 16 times per day with each orbit potentially crossing the SAA and geomagnetic poles. The irregular variation of earth's magnetic field leads to more low energy particles appearing in the SAA region. Due to the parallel trajectory between the direction of the magnetic field lines and the particles, particles appear in both polar regions with more probability than in other regions. These two parts of the orbit have a larger probability of electronic components suffering SEUs. The study of the error rate on the different parts of the orbit is one of the objectives of this paper.

Solar activity is also an important factor influencing on-orbit devices. When a solar event occurs, it ejects energetic ionized particles into space; such the ejected plasma includes electrons and a dominant component of protons. When protons hit a target material such as a DSP, the protons can induce a nuclear reaction. The produced secondary particles can in turn generate SEUs. To assess the impact on reliability, a detailed analysis of the proton flux during solar events and the interaction of protons with the device is needed.

To analyze the influence of different orbital positions on the electronic components, real-time position information is needed. It is easy to reconstruct the AMS trajectory by using ISS ephemeris data. It is not, however, easy to identify whether the solar events have relations with SEUs. In order to understand the different contributions to SEU rates of protons and other ions, MC simulation based on Geant4 is used to rebuild the memory modules tested in the accelerator beam data sample. The MC allows for full reconstruction of the physical

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