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Particle monitors to survey radiation environment in the radiation belts onboard Japanese satellites, USERS and SERVIS-1

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USERS satellite launched on 10 Sep. 2002 and SERVIS-1 satellite launched on 30 Oct. 2003 employed space-based observatory to provide spatial distribution of energetic charged particles and its variation to study the nature of radiation environment in the radiation belts. USERS satellite carries light particle detectors looking at different three directions to measure electrons, protons and alpha particles and a dose monitor. SERVIS-1 also carries a light particle detector to measure electrons, protons, alpha particles and heavy ions, single event upset monitors, dose monitors and shielded dose monitors. The flight performance of the instruments and the observation of energetic electrons, protons, alpha particles and heavy ions measured in the radiation belts were described.

1. Introduction

The radiation environment in radiation belts is highly dynamic, varying particle fluxes on timescales ranging over many orders of magnitude from minutes to months. The spatial and temporal variations are driven by a complex and dynamic chain of process extending from the solar activity into the inner radiation belts. The most dramatic changes in the radiation belts are found in fluxes of energetic electrons and protons in association with geomagnetic activity. The particles observation provides essential clues to study the nature of radiation environment in the radiation belts and their origin, redistribution process and loss mechanism of trapped particles. Recently, the study by observation of energetic charged particles in the radiation belts has achieved by SAMPEX [1, 2], CRRES [3, 4], AKEBONO [5, 6], NINA [7] and TSUBASA [8, 9] and led a new understanding of the structure and its variation of trapped particles within radiation belts. Moreover, energetic charged particles in the inner magnetosphere is essential from the point of space weather disturbance, the impacts to space dosimetry and bulk charging effect of space vehicle.

USERS (Unmanned Space Experiment Recovery System) satellite [10] was launched on 10 Sep. 2002 into the low altitude orbit of 500 – 600 km with the inclination of 30.4 deg. SERVIS-1 (Space Environment Reliability Verification Integrated System 1) satellite [11] was launched on 30 Oct. 2003 with an orbit of 1000 km, in altitude and of 99.5 deg in inclination. The objectives of USERS are to establish and develop the technology for recovery of a reentry module, to resolve the crystal growth mechanism by performing the experiments for crystal growth of large high temperature superconductive material in microgravity environment and to examine the capability of commercial off-the-shelf (COTS) parts in radiation environment. The objectives of SERVIS-1 are to establish the evaluation of parts and equipment and to make the design guidelines required to utilize COTS parts, such as CPU's and memories, and relating technologies in space. In order to observe the radiation environment, both the satellites have the Environment Measurement System (EMS). The EMS

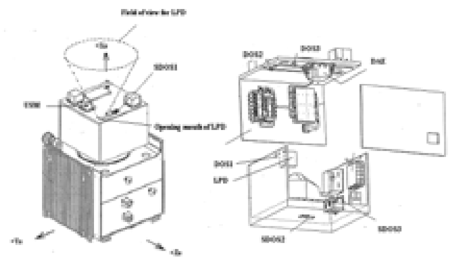

Figure 1. Instrumental configuration of the EMS onboard SERVIS-1

onboard USERS satellite consists of three light particle detectors (LPD) installed on different planes and a dose monitor (DOS), while the EMS onboard SERVIS-1 satellite consists of a LPD, two single event upset monitors (USM), three DOS and three shield dose monitors (SDOS). Figure 1 shows the instrumental configuration of the EMS onboard SERVIS-1.

USERS satellite terminated its operation in 25 Feb. 2005. SERVIS-1 satellite keeps on making the observation. USERS and SERVIS-1 satellites provide us a good opportunity to study important issues in the radiation belts. In this paper, we overview the particle instruments of the EMSs onboard both the satellites, their flight performances and initial results. Preliminary results of particle observations are described in [12] (another presentation of SH12 in this conference).

2. Light Particle Detector (LPD)

The LPDs are designed for the study of radiation environment due to high energy charged particles that are primarily responsible for radiation damage to on-orbit electronics. Each LPD has various features and capabilities as described below.

1. USERS LPD

The USERS LPD measures 15.9 − 131.5 MeV protons, > 0.7 MeV electrons and > 16.5 MeV alpha particles. USERS satellite has three LPDs looking at different three directions, X, Y and Z axes, which correspond to the opposite direction toward the Sun, the southward direction and the direction perpendicular to X and Y axes, respectively. The LPD system consists of four 200 μm thick solid-state silicon detectors (SSD), a 2.5 mm-thick-copper plate and a 7.0 mm-thick-tantalum plate to degrade particle energies among SSDs. LPD has a collimator defining the acceptance angle and an aluminum window absorbing visible photons and low energy charged particles. The LPD system identifies the nuclear charge and its energy bin in combination of each deposit energy in SSD1 − SSD4 and the energy degraders. The schematic drawing of the LPD system on board USERS satellite is shown in Fig 2. The characteristics of LPD are also summarized in Table 1.

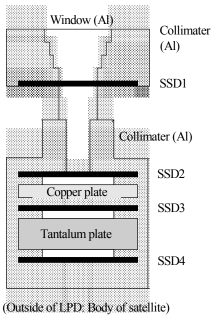

Figure 2. Schematic drawing of the LPD

Table 1. Characteristics of USERS LPD.

Energy range ・Proton ・Electron ・Alpha particle	X-axis (3 enegy bins) 15.9 – 131.5 MeV 0.7 – 18.2 ~ MeV 16.0 – 101.0 MeV	Y-axis (3 enegy bins) 16.3 – 131.5 MeV 0.8 – 18.3 ~ MeV 16.5 – 101.0 MeV	Z-axis (3 enegy bins) 16.2 – 131.5 MeV 0.8 – 18.3 ~ MeV 16.5 – 101.0 MeV
Direction	Anti-sunward	South-ward	Perpendicular to X and Y axes
Count rate	115 kcps max		
Identification	ΔE × E method		
Count interval	1 sec or 4 sec		
Geometric factor	0.0197 – 0.0228 cm^2 sr		
Weight	11.51 kg		
Power	11.32 watts		
Size	360 × 260 × 230 mm^3		

2. SERVIS-1 LPD

The SERVIS-1 LPD measures 1.2 − 150 MeV protons, 0.3 − 10 MeV electrons, > 7 MeV alpha particles and > 2 MeV/n ions heavier than alpha particles. The LPD continuously looks at the anti-sunward direction. The PD system consists of a single 500 μm thick SSD and a 24 mm-thick-Yttrium-Aluminum-Perovskite (YAP) scintillator with an excellent stopping power for electrons because of their relatively high Z number. Scintillation lights are detected by Hamamatsu metal photomultiplier tube (PMT). A collimator defines the acceptance angle and an aluminum and gold plated kapton window rejects visible photons and low energy charged particles. The LPD system identifies the nuclear charge and its energy interval using the ΔE × E relation between the energy deposition in SSDs and YAP scintillator. Figure 3 shows the configuration of the LPD system. The characteristics of LPD are also summarized in Table 2. New technology of the state-of-the−art analog electronics coupled with modern digital electronics are made full use in the LPD system.

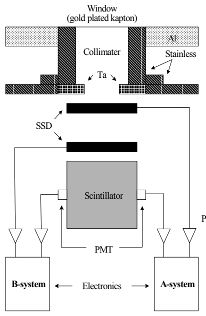

Figure 3. A configuration of the LPD system. A-system is usually operated, and B-system is backup one when A-system is breakdown.

Table 2. Characteristics of SERVIS-1 LPD.

Energy range ・Proton ・Electron ・Alpha particle ・Heavy ion	 1.2 – 150 MeV (6 bins) 0.3 – 10 MeV (4 bins) 7 – 640 MeV (1 bin) 2 – 160 MeV/n (1bin)
Direction	Anti-sunward
Count rate	200 kcps max
Identification	ΔE × E method
Count interval	4 sec
Geometric factor	0.17 – 0.26 cm^2 sr
Weight	4.2 kg
Power	7.5 watts
Size	120 × 120 × 150 mm^3

3. Observations by USERS and SERVIS-1 satellites

Data of energetic electrons and protons observed by one of the LPDs were analyzed in this study. Figure 4 shows the daily variations of the X-axis fluxes of electrons and protons measured by the LPD onboard USERS satellite in the period between Jun. 2003 and Dec. 2004. The reason that flux of both particles vary periodically is mostly attributed to the periodicity related to satellite orbit, in particular, due to the passage over South Atlantic Anomaly (SAA). Figure 5 also shows the daily variations of electron and proton observed by the LPD onboard SERVIS-1 satellite in the period between Dec. 2003 and Dec. 2004. The large peaks of both fluxes are due to giant solar flares.

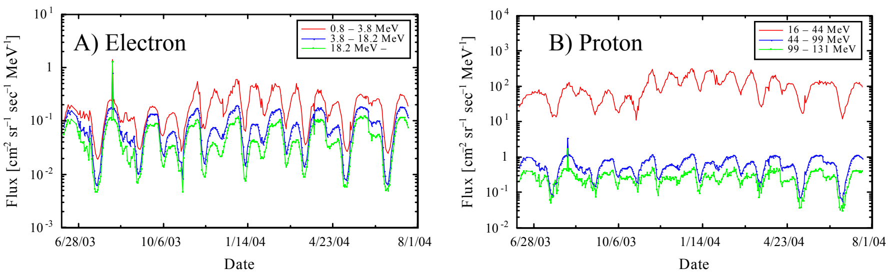

Figure 4. The daily variations of electron and proton observed by LPD with X-axis onboard USERS satellite. A) electron flux and B) proton flux.

Figure 6 shows the world maps of electron fluxes observed by both satellites. The influences of SAA, and outer radiation belts are clearly appeared on the world map observed by SERVIS-1 satellite.

5. Summary

USERS and SERVIS-1 satellites have the Environment Measurement System (EMS) to observe the radiation environment. The EMS consists of the light particle detector (LPD) to measure the energetic particles, the single event upset monitor (USM), the dose monitor (DOS) and the shield dosemonitor (SDOS) to measure

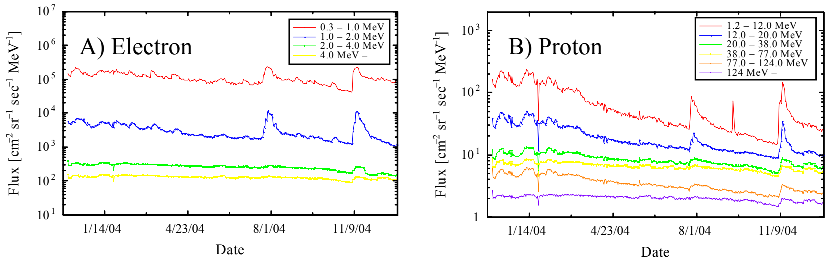

Figure 5. The daily variations of electron and proton observed by LPD onboard SERVIS-1 satellite. A) electron flux and B) proton flux.

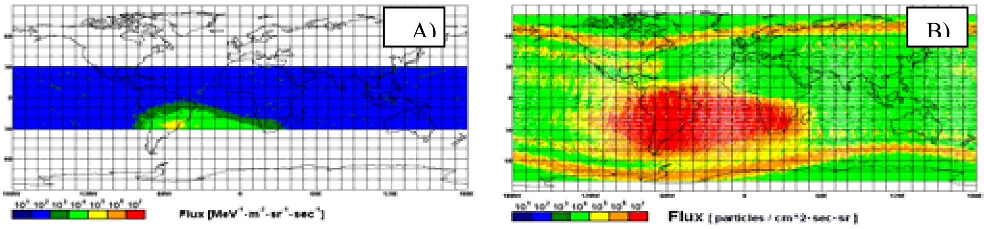

Figure 6. The world maps of electron flux. A) between Dec. 2002 and Dec. 2004 observed by USERS satellite and B) between 28 Jun. 2004 and 11 July. 2004 observed by SERVIS-1 one.

the radiation environment. The LPD measures 1.2 – 150 MeV protons, 0.3 – 10 MeV electrons, > 7 MeV alpha particles and 2 MeV/n ions heavier than alpha particles. The EMS onboard the both satellites have been operated successfully and accumulating high quality data since its turn-on in late 2002 and 2003, respectively. The correlations of data between the both satellites which have different altitudes and inclinations would offer new possibilities for the study of origin, redistribution process, loss mechanism of trapped particles and effects on the radiation belts due to the solar flares.

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