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The Medium Energy Particle Detector in the range of 20 ~ 400 keV for the study of space storm on NEXTSAT-1

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ABSTRACT

A review of current activity for the development of Medium Energy Particle Detector (MEPD) aboard the Next Generation Small Satellite-1 (NEXTSat-1) is provided. The spacecraft is a low-altitude satellite with a scheduled mission launch date in the year 2017. The instrument is capable of measuring energy distributions of charged particles and neutrals in the energy range of 20 ~ 400 keV for a study of geomagnetic storms when the solar activity is near the maximum or in the declining phase of the cycle. The instrument is one of the suite of instruments, the Instruments for the Study of Space Storm (ISSS). The instrument capabilities, operation concepts and the current status of the instrument development will be provided in this presentation together with a short introduction to the scientific objective of the instrument.

1. INTRODUCTION

In-situ observations of accessible space have demonstrated that the radiation environment in the vicinity of the Earth is dynamically filled with charged particles that are often trapped by the Earth's magnetic fields. Further, the radiation environment is closely related with space weather phenomena such as space storms that tend to be driven by coronal mass ejection (CME) or a high speed stream of the solar wind. Space storm is described as a temporal disturbance of geomagnetic fields caused by the increase of ring currents in the magnetosphere and ionosphere. Due to the reason that

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space storms accompany abrupt increase of charged particles in radiation belt, acquisition of physical quantities in the range of a few to a few hundred keV electrons, ions, and neutrals is required for research of geomagnetic storms. Furthermore, calibration of the instrument should be implemented in order to detect significantly varying fluxes of space radiation relative to the occurrence of geomagnetic storms without saturation or loss of information on the mission orbit. This research summarizes the instrument design and subsequent development of signal processing circuit and mechanical structure for the MEPD.

2. INSTRUMENT DESIGN OF MEPD

The MEPD is one of a subset instrument within the ISSS which contains both space radiation and plasma monitoring instruments. (Choi 2014) MEPD has energy range from 20 keV to 400 keV and 8 keV energy resolution with orthogonally arranged two telescopes for the detection of charged particles in terms of different pitch angles. Capable of measurement energy range is related with stopping power, which is energy loss of charged particles due to interaction with matter, provided by the thickness of the detector. In order to satisfy the required range and resolutions, MEPD adopts 315 μm thickness of solid state silicon detector which has low energy thresholds due to the thin entrance layer, short recovery time concluding high duty cycle, and low leakage current. (Tindall 2008) The manner in which energetic particles interact with matter depends upon their mass and energy. However, different energy loss of electrons and ions due to the different mass ratio within Si at the same incident energy would lead different pulse height. In order to prevent data contamination caused by different energy loss, MEPD is able to distinguish and detect electrons, ions, and neutrals simultaneously with electrostatic field by applying high voltage onto the deflector. Based on the operation concept of the ISSS measuring both radiation and plasma from noon to midnight, MEPD will be operated in the polar region, south latitude of 90 ~ 45° and

Table. 1 Specification of MEPD instrument

Spec.	Mass	4.15 kg
	Size	358 x 208 x 100 mm^3
	Power	1.65 W/orbit
	Launch	1Q 2017
	Lifetime	2 year
	Orbit	650 ~ 800 km sun-synchronous orbit
Energy range		20 ~ 400 keV
Resolution	Energy	8 keV
	Time (Cadence)	1 Hz
Data rate		0.3 Gb/day
Field of view	horizontal	70 °
	vertical	15 °
Geometrical factor		0.02 $cm^2 \cdot sr$

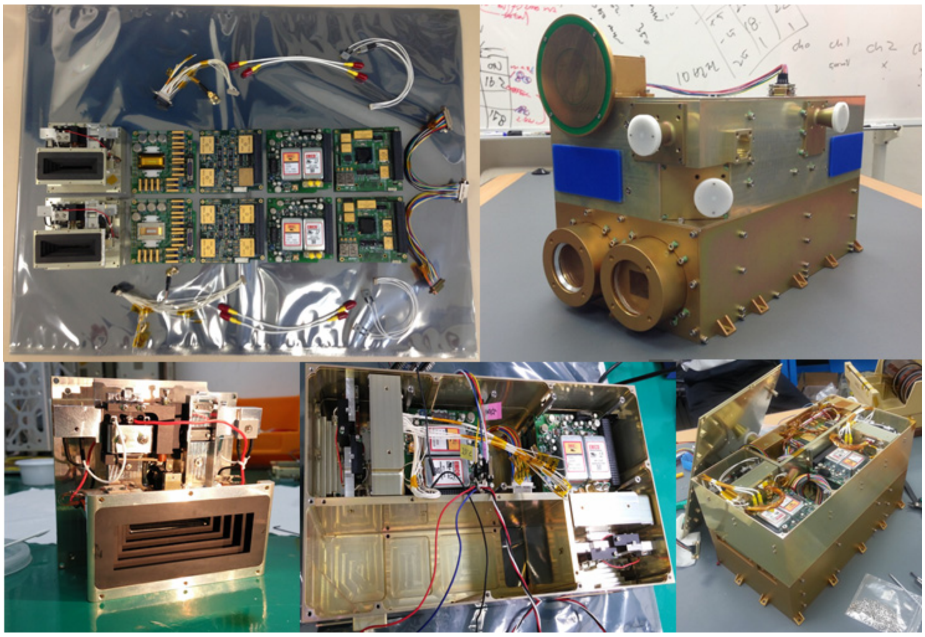

Fig. 1 Photo of electronics and mechanical structure of MEPD and ISSS

north latitude of 45 ~ 90°, covering auroral zone where the fluxes of electrons and ions become intense. The attenuator is necessary because of the wide range of particle fluxes existing at various regions along the spacecraft orbits. For the adjustment of dynamic range, attenuator which reduces input fluxes by factor of 100 is employed at the entrance of the detector.

Electronics of MEPD consists of concurrent 4 channels of signal processing chain connected to the 4 pixels of detector segments. First of all, the incident particles will create electron-hole pairs at the rate of one pair for every 3.6 eV of energy in the silicon detector. The amount of charge produced proportional to the initial energy of the incident particle is subsequently collected by charge sensitive preamplifier. The output of the preamplifier is connected to 5 pole unipolar shaping amplifier which produces quasi-Gaussian shape pulse with ~2.5 μsec peaking time. Once a signal pulse reaches up to the maximum, peak detection circuit returns a logic signal to the Field Programmable Gate Array (FPGA) in order to trigger Analog to Digital Converters (ADC). The digital electronics in MEPD also contains Low Level Discriminator (LLD) and Upper Level Discriminator (ULD) circuits composed of simple comparator to verify the validity of individual signal pulses. Finally, scientific events are recorded and accumulated into 64 channels of energy spectra with 1 Hz cadence.

Mechanical structure of MEPD consists of collimator, electrostatic deflector, attenuator mechanism, telescope housing, and structural chassis. The collimator to prevent incident photons reaching to the detector is composed of a set of five baffles of decreasing size to constraint the specific field of view. The electrostatic deflector is made up of closely-spaced blades holding common potential to provide a relatively planar deflection electric field, while significantly reducing electron scattering into the detectors. The attenuator is a rectangular piece of photo etched BeCu foil with small holes attached on an aluminum frame paddle. The total area of the holes equals one percent of the detector area to reduce input fluxes with geometrical barriers. The rest of shell or housing of telescope serves as a conduit for incident particles to the sensor.

3. TEST RESULTS AND CONCLUSIONS

Functional test of MEPD were performed by injecting test pulses often used for calibration and diagnostics to verify signal to energy channel relation based on a programmable Look-Up Table (LUT) that takes a combination of the 11 bit energy amplitude provided by the ADC and the 4 bit detector. The number of input test pulses was 100,000/sec from 0 to 2.5 V pulse height with 0.5 V amplitude interval. Test result shows that the event counts are linearly accumulated with respect to the different input pulse height based on the LUT. Despite the input pulse with 100,000/sec, approximately 45,000/sec counts were accumulated because manageable count rate of MEPD is about 50,000/sec by considering ADC conversion time which indicates the dead time of the electronics. Test result is summarized in the Table. 2. and plotted onto energy spectra with 64 channel binning in Fig. 2.

Table. 2 Signal to channel relation test result by injecting test pulse

Input voltage	16 bit ADC value	LUT value	Spectrum record		
			E ch #	cnt in Hex	cnt in Dec
0.5 V	17D	11	11	AF23	44835
1.0 V	30C	24	24	AF61	44897
1.5 V	4A2	37	37	AF62	44898
2.0 V	662	51	51	AF4B	44875
2.5 V	79C	60	60	AEC0	44736

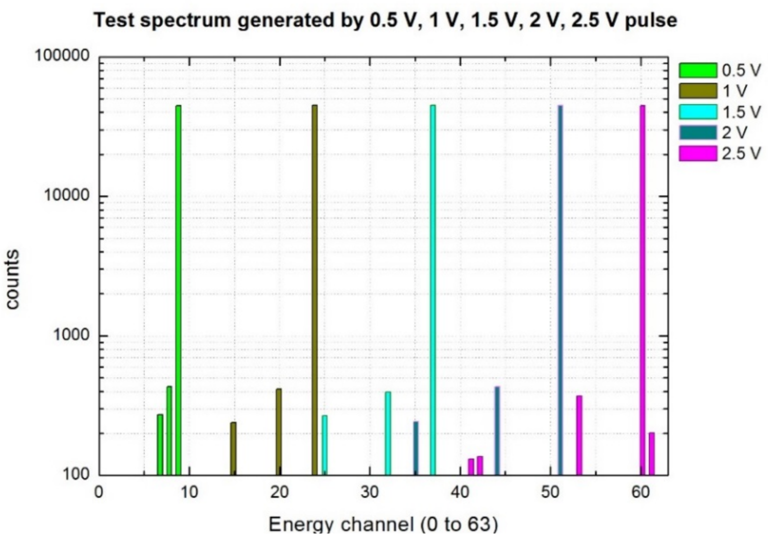

Fig. 2 Test spectrum generated by test pulse

4. CONCLUSIONS

In summary, the Medium Energy Particle Detector in the range of 20 ~ 400 keV is introduced to understand the mechanism of space storm associated with solar events. The instrument is designed to measure the charged particles in terms of diverse energy, species and fluxes by applying the solid state detector, electrostatic deflector, and attenuator. As a result of the development of engineering qualification model for the MEPD, generation of science data and housekeeping data was verified. The MEPD is expected to perform sophisticated calibration and manufacturing of flight model based on current research.

REFERENCES

Choi, C.R., Sohn, J.D., Lee, J.C., Seo, Y.M., Kang, S.B., Ham, J.W., Min, K.W., Seon, J.H., Yi, Y., Chae, J.S., and Shin, G.H. (2014), "Scientific Missions and Technologies of the ISSS on board the NEXTSat-1", *J. Astron. Space Sci.,* **31**(1), 73-81.

Tindall, C.S., Palaio, N.P., Ludewigt, B.A., Holland, S.E., Larson, D.E., Curtis, D.W., McBride, S.E., Moreau, T., Lin, R.P., and Angelopoulos, V. (2008), "Silicon Detectors for Low Energy Particle Detection", *IEEE Trans. Nucl. Sci.,* **55**(2), 797-801.