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Calibration of HEPD on KOMPSAT-1 Using the KCCH Cyclotron

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Abstract : Space Physics Sensor (SPS) on-board the KOMPSAT-1 consists of the High Energy Particle Detector (HEPD) and the Ionospheric Measurement Sensor (IMS). The HEPD is to characterize the low altitude high energy particle environment and the effects on the microelectronics due to these high energy particles. It is composed of four sensors: Proton and Electron Spectrometer(PES), Linear Energy Transfer Spectrometer (LET), Total Dose Monitor (TDM), and Single Event Monitor (SEM). 35 MeV proton beam from the medical KCCH cyclotron, at Korea Cancer Center Hospital in Seoul, is used to calibrate the PES. Primary proton beam of 35MeV scattered by polypropylene target is converted to various energy protons according to the elastic collision kinematics. In this calibration, the threshold level of the proton in the PES can be determined and the energy ranges of PES channels are also calibrated.

Key Words : detector, high energy particle, calibration, KOMPSAT-1

1. Introduction

In the end of 1999, the Korean Multi-Purpose Satellite(KOMPSAT-1) will be launched. The Space Physics Sensor(SPS) on-board the KOMPSAT-1 consists of the High Energy Particle Detector (HEPD) and the Ionosphere Measurement Sensor(IMS). The IMS is a kind of Langmuir probe to measure the temperature and the density of ambient plasma. The KOMPSAT-1 orbit with an altitude 680 Km is dominated by the inner Van Allen radiation belt. This region has a large population of high energy protons which contribute significantly to long-term and transient radiation effects on micro-electronics. The purpose of the High Energy Particle Detector(HEPD) is to study the space radiation environment as encountered by the earth orbiting KOMPSAT-1. It consists of four sensors: Proton and Electron Spectrometer(PES), Linear Energy Transfer Spectrometer(LET), Total Dose Monitor(TDM), and Single Event Monitor(SEM). The PES

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measures the high energy particle flux in KOMPSAT-1 orbit and the LET provides a mechanism for measuring the Linear Energy Transfer(LET) spectrum (in a silicon detector) of ionizing radiation particles passing through the spacecraft over short intervals of time. The TDM provides a mechanism for measuring the long-term total accumulated ionizing radiation dose (in SiO2). The radiation sensors are solid state RADFET/MOSFET dosimeters, which are monitored for changes in threshold voltage. The SEM measures Single Event Upsets (SEUs) occurred in four 4Mbit SRAMs which are a candidate for future mission. These four sensors provide the opportunity to study the short and long term radiation effects on electronics of the spacecraft as well as the high energy particle flux variation during the solar maximum. In this paper, we present the calibration result of the proton channel of the PES using the medical KCCH cyclotron, at Korea Cancer Center Hospital in Seoul.

2. Instrument Description

1) PES(Proton Electron Spectrometer)

As shown in Fig. 1, the mechanical analyzer of the PES consists of four Li-drifted surface barrier silicon detectors(SSD~SSD4) with same sensitive depth of 250μm and 100mm^2 active area. Opening aperture with 22° opening angle is designed to minimize backgrounds due to secondary electrons and high energy photons. Right behind this aperture, thin (0.2mm) aluminum plate is placed to block UV photons and to prevent any contamination during launch time. Fig. 2 shows the proton energy loss in each of four SSDs which is calculated by Ziegler Code (Ziegler, 1985). As lost energy of high energy particle in the SSD converts charge carriers, it is closely related to the pulse amplitude of the amplifier. If the threshold of the signal amplitude is chosen as shown in LLC2 of Fig. 2, the energy range of the proton channels can be determined. Like this scheme, three electron energy channels can be determined by lower threshold. But, the alpha particle in the PES has only one channel and counts every pulse that has larger energy loss than 5MeV due to the ambiguity of the energy loss characteristics in alpha particle. So the PES counts the particle flux with total seven channels. The particle species and energy range of each channel are shown in Table 1.

Fig. 3 shows the electric block diagram of the PES. The chain of Charge Sensitive Amplifiers (CSAs) is connected to SSDs to collect the charge carrier generated by passing high energy particle and amplify the signal. The characteristics of the SSD and the Discriminator are shown in Table 2. To verify the entrance of the particle into this mechanical analyzer, the coincidence logic is implemented behind the logic gate. To fully deplete the SSD, +100V bias voltage is applied to each detector. The overall dead-time of the system is less than 5μs.

Table 1. The energy range of the PES channel

channel	Particle Species	Energy Range(MeV)
eE1	electron	0.23 ~ 0.62
eE2	electron	0.62 ~ 1.78
eE3	electron	> 1.78
pE1	proton	5.5 ~ 12.7
pE2	proton	12.7 ~ 24.5
pE3	proton	24.5 ~ 36.1
aE	alpha particle	13.6 ~ 59.2

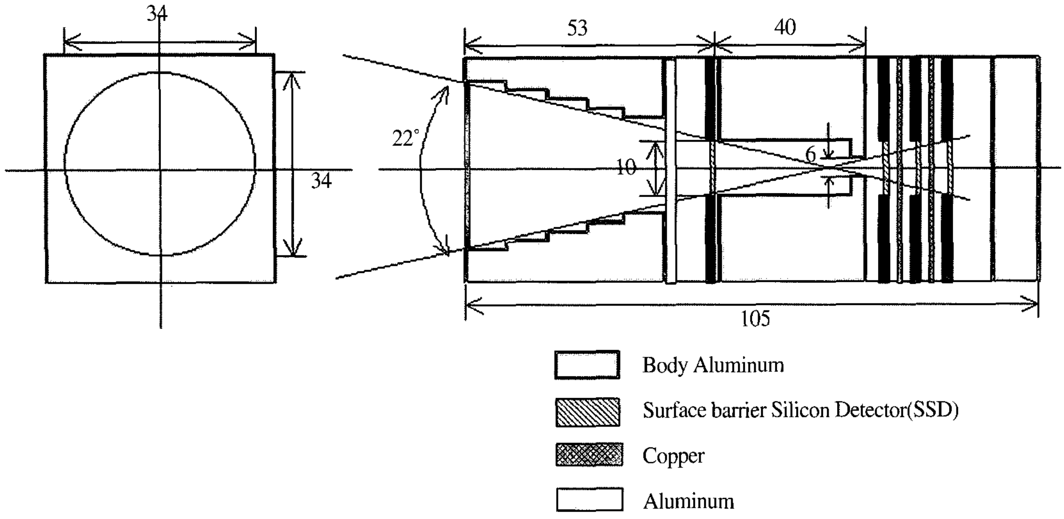

Fig. 1. The schematic of the PES mechanical analyzer

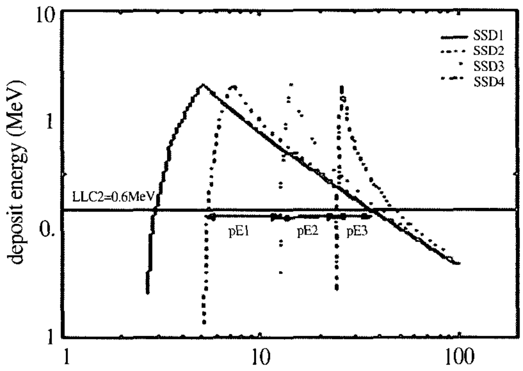

Fig. 2. Deposited energy of incident proton on the SSD

Table 2. Characteristics of the PES Detector and the Discriminator

Nominal Thickness(mm)	0.25
Active Area(mm2)	100
Discriminator Threshold(MeV)	1
Discriminator Dead Time(μs)	10
Scaler Bin No. (Bits)	16

2) Geometrical Factor

The coincidence counting rate of the particle telescope depends upon the effective dimensions and relative positions, i.e. the geometry, of the

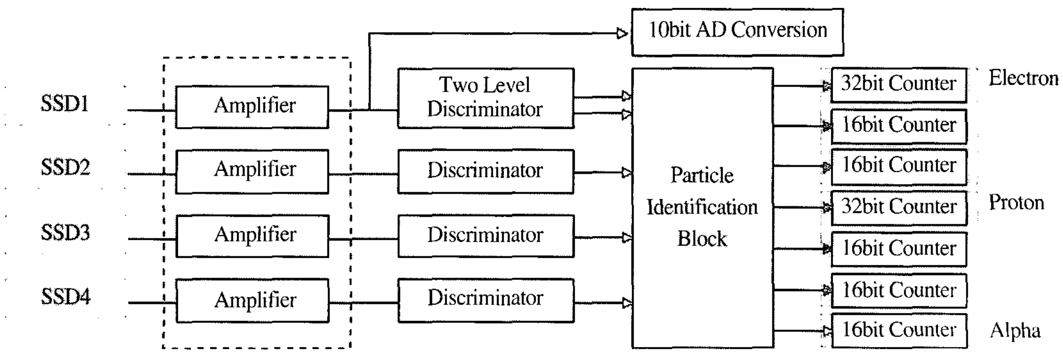

Fig. 3. Electronic Block Diagram of the PES

particle telescope sensor as well as the intensity of radiation surrounding space and the sensor efficiencies. The designer of the detector system must compute the intensity of radiation given by the coincidence counting rate and the parameters (e.g. sensor dimensions) of the telescope. For an ideal telescope the factor of proportionality relating to the counting rate C to the intensity I is defined as the gathering power of the telescope (Sullivan, 1971). When the intensity is isotropic, i.e. $I = I_0$, the factor of the proportionality is called the Geometrical Factor G.

$$C=GI_0 \qquad (1)$$

If we assume that particle spectral intensity J is independent of position and time, then Eq.(1) becomes

$$J(E, \omega)=J_0(E)F(\omega) \qquad (2)$$

$$C=[\int_{\Omega}d\omega\int_{S}d\sigma.\gamma F(\omega)]\, I \qquad (3)$$

where

$$I=\int_{E}dEJ_0(E)$$

An ideal cylindrically symmetric telescope with two planar detectors is shown in Fig. 4. As ever geometrical factor is given by Eq.(3), the geometrical factor of this shape of the detector is written as

$$G=\frac{1}{2}\pi^2\{[R_1^2+R_2^2+h^2-\sqrt{[(R_1-R_2)^2+h^2][(R_1+R_2)^2+h^2)]}\} \qquad (4)$$

where R_1 : Radius of first detector

R_2 : Radius of second detector

h : Distance between two detectors

Instrument geometrical factor of each channel of the PES is calculated and shown in Fig. 5. Expected flux of protons and electrons in the KOMPSAT-1 orbit can be calculated by the standard NASA model: AP-8 for proton and AE-8 for electron (Sawyer and Bethe, 1976). From the calculation result of the geometrical factor in Fig. 5 and expected particle flux, the expected coincidence count rate of the PES channel can also be calculated as shown in Table 3. The maximum count rate of the PES is well below 200,000. It means that all particles incident on the

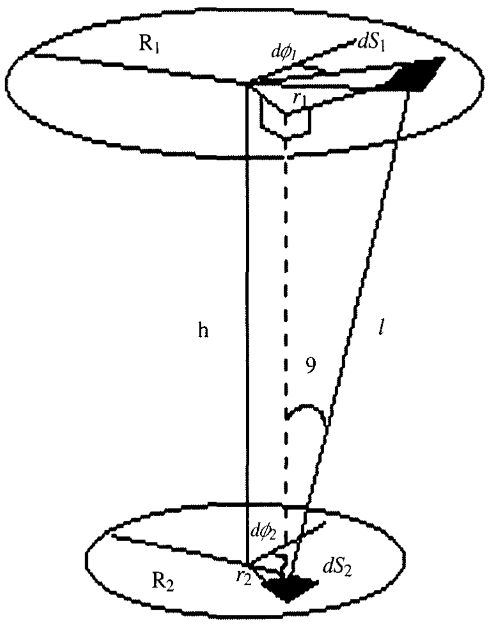

Fig. 4. An ideal cylindrically symmetric telescope with two circular detectors

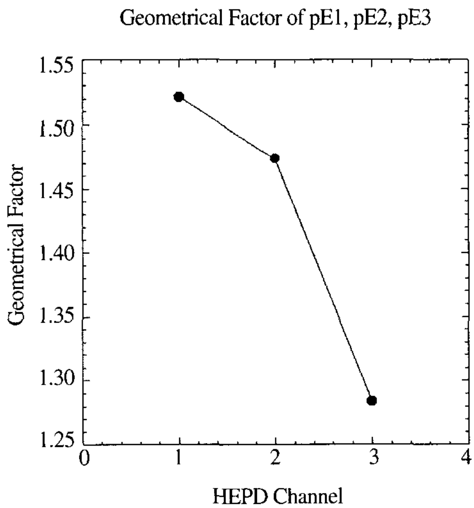

Fig. 5. The geometrical factor of each proton channel

Table 3. Expected count rate of the PES channels

Name	Energy Range(MeV)	Solar Max.	Solar Min.	Expected Count Rate
eE1	0.23 ~ 0.62	1.0×10^8	1.0×10^8	183,028
eE2	0.62 ~ 1.78	1.0×10^6	5.0×10^5	915
eE3	> 1.78	1.0×10^4	1.0×10^4	18
pE1	5.5 ~ 12.7	5.0×10^4	2.5×10^4	2,000
pE2	12.7 ~ 24.5	1.0×10^4	5.0×10^3	1,500
pE3	24.5 ~ 36.1	1.0×10^3	1.0×10^3	700

PES particle telescope can successfully be counted by the PES electronics whose dead-time is below 5μs.

3. PES Calibration

1) Output Linearity Test with Test Pulser

The PES was initially calibrated with test pulser which generates pulses whose height corresponds to 1~6MeV proton energy. It was stimulated to perform limited tests of coincidence logic and measure the threshold of discriminators. By this test the gain, linearity and long-term stability of the pre-amplifier and amplifier can be checked. Input pulses are shaped as bipolar with peaking time of 0.1μs and shaping time of 5μs. Total gain of the preamplifier and amplifier is about 1.1 V/MeV and detector response is linear over maximum transferred energy of 6MeV. Fig. 6 shows the good linearity between the amplitude of the input test pulse and that of output pulse, which means the good amplification linearity of the PES amplifier.

2) PES Calibration with the Cyclotron

The KCCH cyclotron was installed at Korean Cancer Center Hospital (KCCH) in 1985 and have been running for the neutron therapy and radio isotope production (Lee *et al.*, 1994). Primary proton beam of 35MeV is scattered by the polypropylene target and various energy protons can be obtained according to the elastic collision kinematics as shown in Fig.7. This makes it possible to calibrate the whole PES proton energy ranges without changing primary proton beam energy. At first, secondary beam

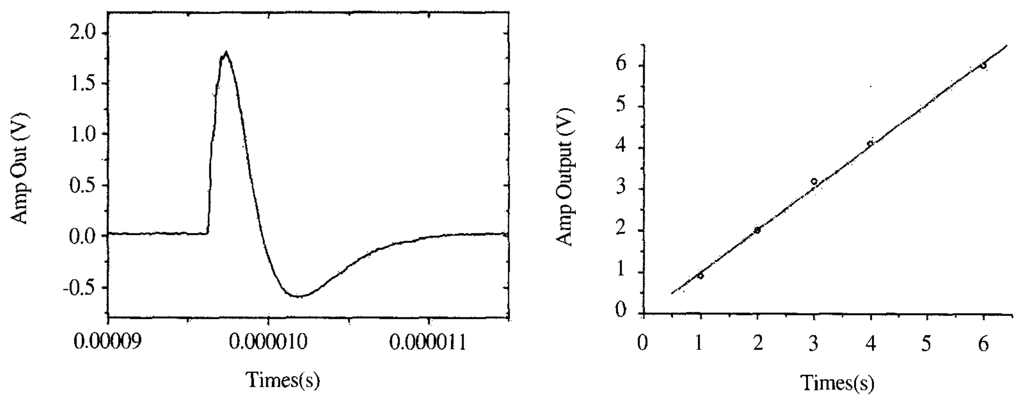

Fig. 6. SSD response for test pulse

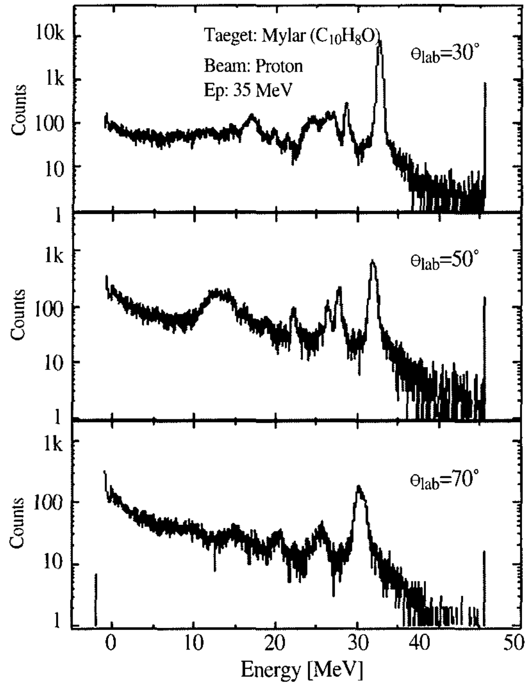

Fig. 7. Proton Energy Spectrum Measured by CsI(Tl) detector at various angle

profile is measured by calibrated CsI(Tl) detector and the condition of the beam from cyclotron is also checked compared to previously published data (Lee *et al.*, 1994). The PES mechanical analyzer is placed in the conjugate angle of CsI(Tl) detector as shown in Fig. 8 and data from two detectors are simultaneously archived. To determine the threshold level of the proton, data from calibrated CsI(Tl) are binned and summed to calculate possible threshold level of the PES. After that, we try to find the appropriate threshold level (LLC2 in Fig. 2) to explain simultaneously measured PES proton count data of three different angle (30°, 50°, 70°). From this analysis, most appropriate threshold level of the PES is 2.06MeV and the energy ranges of the PES proton channels are shown in Table 4.

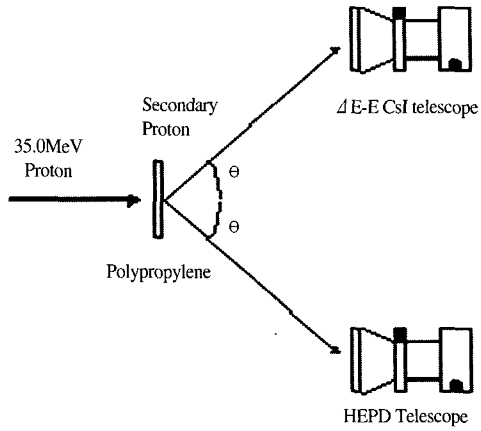

Fig. 8. PES Calibration Setup

Table 4. Calibrated energy range of the PES proton channels

channel	Species	Energy Range(MeV)
pE1	proton	7.75 ~ 13.5
pE2	proton	14.60 ~ 19.82
pE3	proton	26.80 ~ 30.74

4. Conclusion

We have designed high energy particle detector for KOMSAT-1 and calibrated it with test-pulser and the cyclotron in KCCH. The amplifier gain of the detector is about 1.1V/MeV and quite linear over the maximum transferred energy. Energy ranges of each proton channel are calibrated using proton beams of primary energy of 35MeV with simultaneous measurement of calibrated CsI(Tl) detector. This method shows good result in calibrating this type of solid state detector with cylindrical analyzer. The calibration of the PES electron channels are our future work.

References

Lee C.S. , J.C. Kim, H.T. Chung, J.H. Ha, Y.K. Kim, S.J. Chae, J.S. Chai, Y.S. Kim and J.D. Lee, 1994, A Telescopic Method of Proton Identification in Scattering Experiments Using 50MeV Protons, *JKPS*, 27(5):469-457.

Sawyer D.M and J.I. Bethe, 1976. AP-8 Trapped Proton Environment for Solar Maximum and Solar Minimum, *NSSDC/WDC-A-R&S* 76-06, NSSDC.

Sullivan J.D., 1971, Geometrical Factor and Directional Response of Single and Multi-element Particle Telescope, *Nuclear Instruments and Methods*, 95:5-10.

Ziegler J.F., J.P. Biersack and U. Littmark, 1985, *The Stopping and Range of Ions in Solids*, Pergamon Press.