

# 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). 35MeV 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.

## I. 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

Ionospheric 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 680Km 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 microelectronics. 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 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 SiO<sub>2</sub>). 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 is 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

### 2-1. PES(Proton and Electron Spectrometer)

As shown in Fig.1, the mechanical analyzer of the PES consists of four Li-drifted surface barrier silicon detectors(SSD1 ~ SSD4) with same sensitive depth of 250 $\mu$ m and 100mm<sup>2</sup> 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[1]. As the energy loss of high energy particle in the SSD converts the charge carrier, it is closely related to the pulse amplitude of the amplifier. If the threshold of the signal amplitude is chosen as

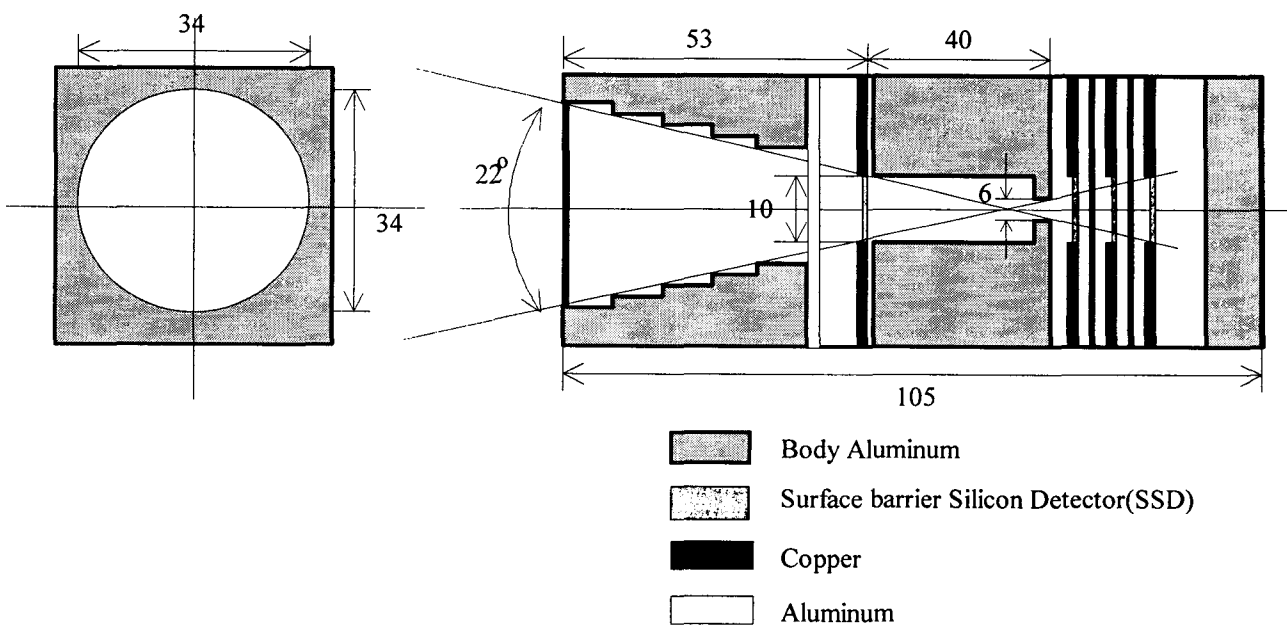


Figure 1. The schematic of the PES mechanical Analyzer

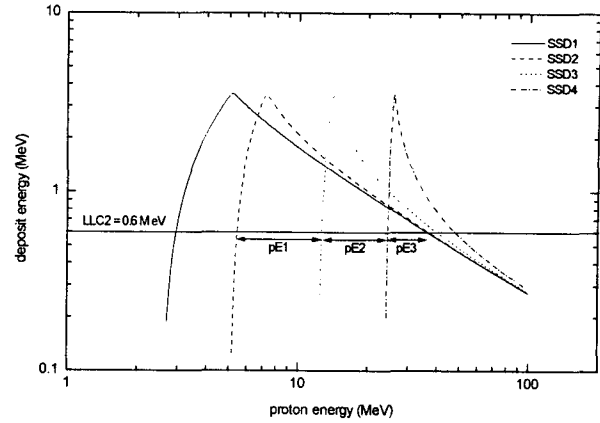


Figure 2. Deposited Energy of incident proton on the SSD

shown in LLC2 of Fig.2, the energy range of the channel can be determined. Like this scheme, three electron energy channels can be determined by lower threshold. But, the ambiguity of the energy loss characteristics in alpha particle, the alpha particle in the PES has only one channel and counts every pulse that has larger energy loss than 5MeV. 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 Amplifier (CSA) and amplifier is connected to each SSD to collect the charge carrier generated by passing high energy particle and amplify

the signal. The characteristics of the SSD and 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 5 $\mu$ s.

**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

**Table. 2** Characteristics of PES Detector, Discriminator

Nominal Thickness(mm)	0.25
Active Area(mm <sup>2</sup> )	100
Discriminator Threshold(MeV)	1
Discriminator Dead Time( $\mu$ s)	10
Scaler Bin No.(Bit)	16

## 2-2. Geometrical Factor

The coincidence counting rate of the particle telescope depends upon the effective dimensions and relative positions, i.e. the geometry, of the 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  $\Gamma$  of the telescope[2]. When the intensity is isotropic, i.e.,  $I = I_o$ , the factor of the proportionality is called the Geometrical factor  $G$ . That is If we assume that particle spectral intensity  $J$  is

$$C = GI_o \quad (1)$$

independent of position and time and separate into

Then the eq.(1) becomes

$$J(E, \omega) = J_o(E)F(\omega) \quad (2)$$

$$(3)$$

$$C = \left[ \int_{\Omega} d\omega \int_S d\sigma \cdot \hat{r} F(\omega) \right] I$$

Where

$$I = \int_{E_1}^{E_2} dE J_o(E)$$

An ideal cylindrically symmetric telescope with two planar detector as shown in fig. 4. As ever geometrical factor is given by eq.(3), the geometrical factor is written as

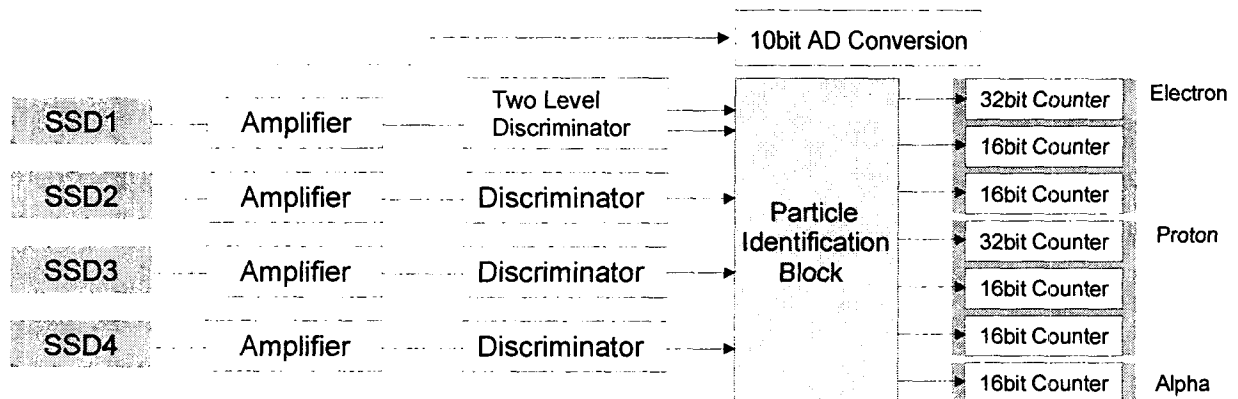
$$G = \frac{1}{2} \pi^2 \left[ R_1^2 + R_2^2 + h^2 - \sqrt{\left\{ (R_1 - R_2)^2 + h^2 \right\} \left\{ (R_1 + R_2)^2 + h^2 \right\}} \right]$$

where

$R_1$  : Radius of first detector

$R_2$  : Radius of second detector

$h$  : Distance between detectors



**Figure 3.** Electronic Block Diagram of the PES

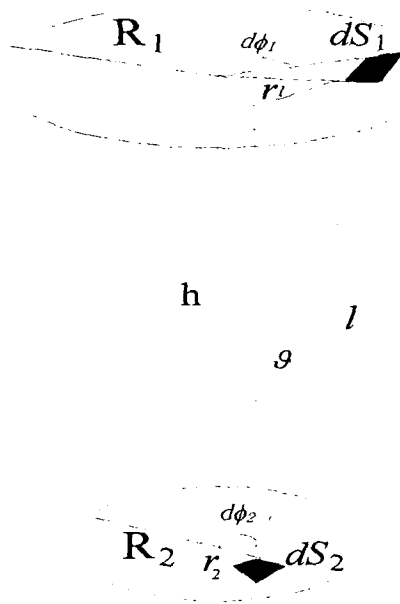


Figure 4. An ideal cylindrically symmetric telescope with two circular detectors

Instrument geometrical factor of each channel of the PES is calculated and shown in Fig.5.

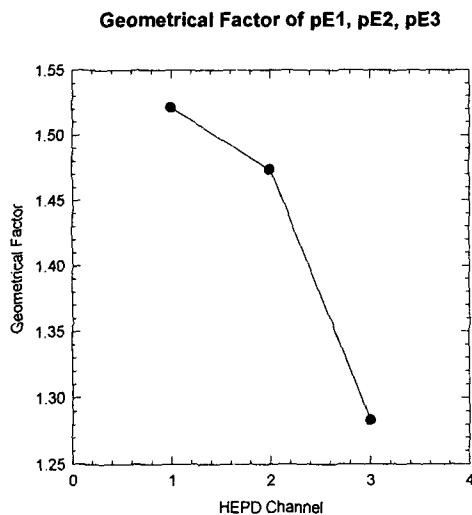


Figure 5. The geometrical factor of each proton channel

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[3]. 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 Table3. The maximum count rate of the PES is well below 200,000. It means that all particles incident on the PES particle telescope can successfully be counted by the PES electronics whose dead-time is below 5 $\mu$ s.

Table 3. Expected count rate of PES

Name	Energy Range(MeV)	Solar Max	Solar Min	Expected Count Rate
pE3	29 ~ 38	$10^3$	$10^2$	700
pE2	15 ~ 29	$10^4$	$5 \times 10^3$	1500
pE1	6.3 ~ 15	$5.0 \times 10^4$	$2.5 \times 10^4$	2000
eE1	0.23 ~ 0.62	$1.0 \times 10^8$	$1.0 \times 10^8$	183,028
eE2	0.62 ~ 1.78	$10^6$	$5 \times 10^5$	915
eE3	> 1.78	$10^4$	$10^4$	18

### 3. PES Calibration

#### 3-1. Output Linearity Test with Test Pulser

The PES was initially calibrated with test pulser which generates pulses height of which corresponds to 1~6MeV proton energy.

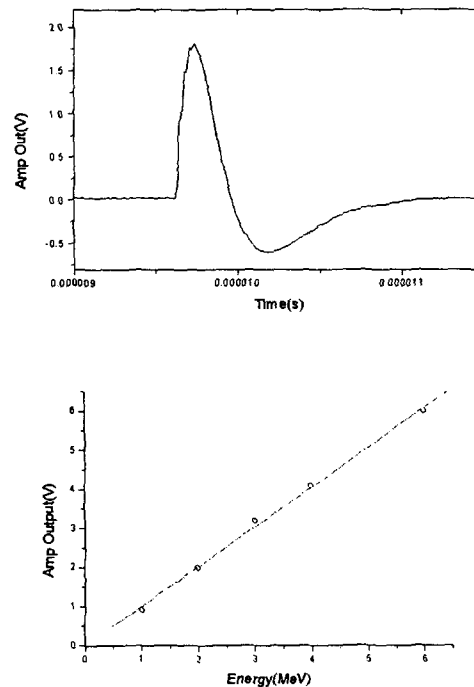


Figure 6. SSD response for test pulse

It was stimulated to perform limited tests of coincidence logic, measure threshold of discriminators and check the gain, linearity and long-term stability of amplifier and

pre-amplifier. Input pulses are shaped as bi-polar with peaking time of  $\sim 0.1\mu\text{s}$  and shaping time of  $\sim 5\mu\text{s}$ . Total gain of pre-amp and amp is  $\sim 1.1\text{V/MeV}$  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.

### 3-2. 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[4]. 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 profile is measured by calibrated CsI(Tl) detector and the condition of the beam from cyclotron is also checked compared to previously published data[4]. 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

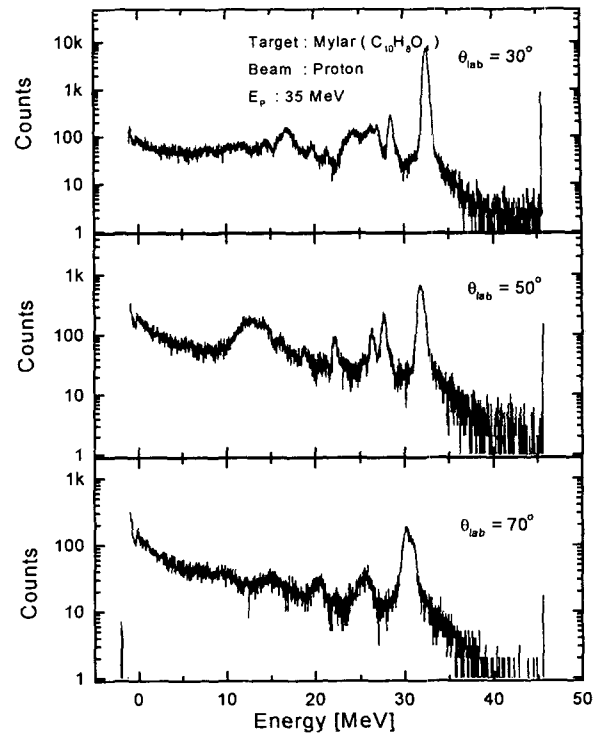


Figure 7. Proton Energy Spectrum Measured by CsI(Tl) detector at various angle.

threshold level of the proton, data from calibrated CsI(Tl) are binned and summed to 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 ( $30^\circ$ ,  $50^\circ$ ,  $70^\circ$ ). From this analysis, most appro-

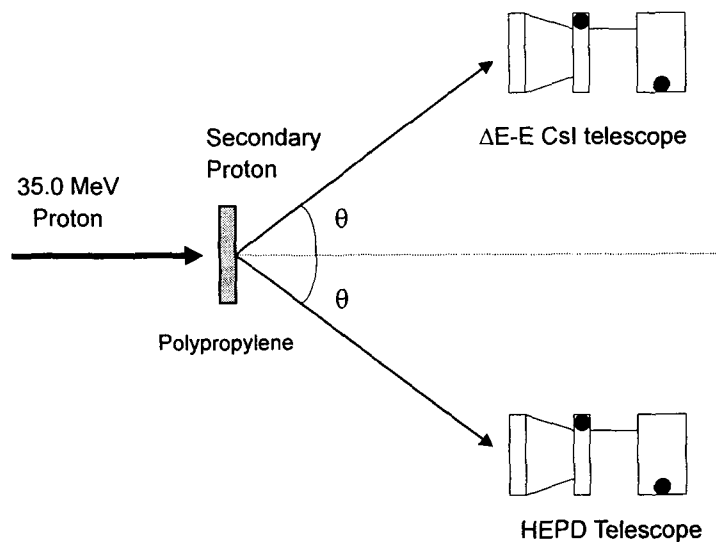


Figure 8. PES Calibration setup

priate threshold level of the PES is 2.06MeV and the energy ranges of the PES proton channels are shown in Table.4.

**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  $\sim 1.1\text{V/MeV}$  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 PES electron channels are our future work.

#### Reference

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