Chapter 7

## Charged Particle Monitor

Satellites in the Low Earth Orbit (LEO) pass through the trapped radiation belts of the South Atlantic Anomaly (SAA), where the particle environment can change very drastically within a few tens of seconds. Due to high density of very high energetic particles (mostly protons), there are adverse scientific and technological effects like, glitches in the data, aging of the scientific instruments and even permanent damage to the detectors. Hence, this region should be monitored properly and all scientific instruments should be shut down/corrective action taken during the satellite's passage through the SAA region. The charge particle monitor (CPM) warns the satellite instruments about the approximate entry and exit points of this region and thus serves the purpose of a monitor.

The Charge Particle Monitor is an auxiliary payload on ASTROSAT. The main objective of CPM is particle count rate measurement above an energy threshold. The detector used for the Charge Particle Monitor is a CsI(Tl) scintillation detector. This has an entrance window of 0.12 mm Teflon reflector along with 50 micron aluminized Mylar as the outermost layer. A thin copper box is put over the assembly as an IR protection. Specification of CsI(Tl) is mentioned in the table below. CsI(Tl) is preferred over more common NaI(Tl) which is hygroscopic in nature. A Si-Pin diode is placed on one surface of the scintillation crystal.

This crystal and photodiode assembly is much cost effective than semiconductor detectors, and lighter than scintillator photomultiplier assembly (as used in RXTE). Moreover, the photomultiplier needs high voltage biasing and the gain may vary with time. In such cases it is better to read out the detector output with a photodiode which can be rugged, compact and reliable.

| Scinti-llator | Type | Density | R.I. | Light output (% of an-thracene) | Decay con-stant (ns) | Wavele-ngth (nm) | Principal applica-tion |
|---|---|---|---|---|---|---|---|
| CsI(Tl) | Crystal | 4.31 | 1.788 | 95 | 1100 | 580 | Heavy Particle, $\gamma$ |

The detector light output peaks at 580 nm and the light intensity is proportional to the energy of the incident radiation. This light is proportionally converted to electrical signal by the photodiode. A charge sensitive preamplifier (CSPA) is used to amplify the photodiode output to milli volt range. CSPA is preferred over a voltage sensitive preamplifier as the output voltage of the CSPA does not depend on the intrinsic capacitance of the detector. Capacitance of the Si-Pin photodiode is likely to change with temperature. The detector, photodiode and CSPA are combined in a compact 1 $cm^3$ box made by SCIONIX, Holland to form the detector module.

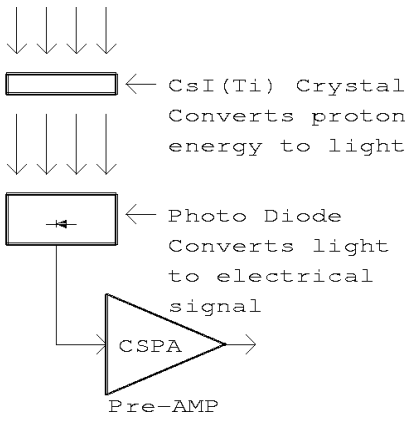
We estimate that gamma-ray bursts and solar gamma-ray flares which give a measurable count (> 10 counts/s) above 0.5 MeV occur very rarely (a rate of less than once per year). The time-scale for detecting the entry and exit of SAA would be kept large enough to ignore even such rare events.

SAA occurs at an altitude of about 500 km spanning $-50^0$ to $0^0$ latitude and $-90^0$ to $+40^0$ longitude. This SAA region changes slowly over time dominant drift being westward of approximately 0.3 degrees/year (as reported in 1997) or somewhat greater. As a back up to CPM, it is envisaged that Astrosat will have time tagged commands to alert the entry/exit of SAA, based on a SAA model. The CPM will measure the intensity of energetic charge particle rates and help in refining this model.

## Instrument details

The Charge Particle Monitor (CPM) is a stacked assembly of 2 modules: CPM POWER MODULE at the bottom and CPM LOGIC PCB containing front end electronics, processing electronics and Detector mounted on it, at the top.

CPM Power Module (CPM PM) generates +5V,+12V,-12V voltages from Satellite Raw Bus of +42 Volts and consumes about 4W power. +5V supply is used to power the CPM logic circuits, +12V and –12V supply is used to power Detector and Amplifier circuits.




All electronics is mounted on this card along with detector module. The Detector module consists of Cesium Iodide Thallium activated [CSI (Tl)] crystal along with Si-Pin Photodiode and charge sensitive preamplifier (CSPA) eV product. All these are combined into small module of 1 cc by SCIONIX, Holland. The energy of charge particle striking the crystal gets converted into photon (light energy). Photodiode converts this photon energy into electrical energy by generating electrons corresponding to energy of incident photons. CSPA amplifies this small electrical signal to a measurable milli-volt range.

The pulse corresponding to every energy particle from detector is passed through post amplification, where milli-volt signal is converted to volt level. The total gain of amplifier is kept around 500 with bandwidth such that it generates 0.5 microsecond rise time pulses.

These amplified pulses are passed through a Low Level Discriminator (LLD) circuit to cut-off noise level and select the Charge Particle signals above a defined value of 0.5 MeV or so. The LLD reference voltage value is programmable from ground station through telecommand. It is a 12 bit DAC and 4096 discrete values are possible.

The pulse signal from LLD circuit output is digitized and fed to a 14 bit counter. The 14 bit counter is a free running counter default gated every 5 sec and hence count rate profile will be every 5 sec. Gate time is also programmable from ground through telecommand. All digital processing electronics is embedded in a FPGA. The telemetry and telecommand interface with the satellite bus is also embedded into FPGA. The general health of Instrument is monitored through the analog channels of satellite telemetry.

## CPM data / alert availability

The CPM count rate is transmitted through telemetry to ground station. Also it is available for onboard users in serial format as Data, Clock and a Latch. Maximum three users can be supported.

This count rate is compared with the preset value set from ground station through telecommand. Whenever count rate is greater than a preset value the output is activated. The output is de-activated whenever count rate is less than preset value. To avoid false triggering, output is activated/de-activated only after 3 successive confirmation of count rate (filtering). This SAA warning outputs are available for users. Maximum eight users can be supported.

All the digital processing electronics is embedded into FPGA. The telemetry and telecommand interface with the satellite bus is also embedded into FPGA. The general health of Instrument is monitored through the analog channels of satellite telemetry.

The energy threshold of CPM is nominally set at 500 keV and this can be changed unto 10 MeV with a few keV steps. The count threshold for the automatic onboard sensing of SAA can be set from 1 to 16384 counts with step of 1 count and the integration time can be set from 1 s to 32 s with a step of 1 s. Additionally, there is a command facility to automatically step up the energy threshold so that, at stable non-SAA regions, integral energy spectrum can be obtained.