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The Radiation Environment Monitor, REM

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Introduction

The Radiation Environment Monitor is designed and constructed in collaboration with the Compagnie Industrielle Radioelectrique SA (CIR) under an ESA contract. It is a modular, programable monitor for radiation environment on spacecrafts. REM accumulates the differential linear energy transfer (LET) spectra in histograms in a programable, compressed manner. The objective is to provide a simple instrument which is nevertheless versatile, providing temporal data and some degree of discrimination, both in energy and particle species.

Radiation Problems

The Earth's radiation environment leads to a number of problems for spacecraft, including:

- radiation damage to components and materials.

- single-event upsets in electronics due to cosmic rays, solar energetic particles or protons-induced nuclear interactions.

- radiation background (interference) for sensors on astronomy satellites and other sensing systems (Earth-observing, inter-satellite communications, etc.).

- radiation hazards to crew on manned missions

- charge buildup and discharge within dielectric materials or shielded metallic parts.

The Need for a Monitor

These problems will become more important on future missions because of the increasing use of advanced component technologies, of more sensitive detection systems, the need to build lighter satellites and the ever-increasing performance demands made of systems and payloads.

There is a clear need to fly a radiation environment monitor for a number of reasons:

1. the trapped particle models used for environment predictions are more than 20 years old and are in need of updating and improving:

   a. - at low altitudes where the energetic proton fluxes are strongly influenced by interactions with the atmosphere and with the decaying and shifting geomagnetic field (ESA's Columbus elements and other LEO missions will encounter this environment).

   b. - at higher altitudes where the energetic electron environment is dynamic and where experience shows that the models are very weak. ESA plans many science and applications missions in the high-altitude environment

2. the current models provide no time, local-time or directional information.

3. there are requirements to use advanced - but radiation-sensitive - technologies. We therefore need to considerably improve our knowledge of the radiation hazard.

4. on-board monitoring will be extremely valuable in a variety of applications:

   a. in-flight calibration of RADFET dosimeters; provision of quantitative data for radiation effects technology experiments.

   b. background monitoring during an astronomy mission.

   c. monitoring of nuclear reaction processes "stars" which have important implications for manned and unmanned ESA spacecraft.

5. development of new models.

Using REM on the STRV small satellite

The REM will be installed on the Space Technology Research Vehicle, STRV, to be launched in 1993. This is a small (50kg) research satellite which will investigate the in-orbit performance of new and advanced space technologies. The STRV will fly in a geostationary transfer orbit, GTO, and will pass repeatedly through the radiation belts and be exposed to solar and cosmic-ray particles. Therefore it is an excellent carrier for studying the radiation environment through a range of altitudes and is highly relevant for the future missions mentioned above. At apogee, it gives data on the popular geostationary orbit environment. It covers most of the electron radiation belt which will be an important source of background for future astronomy missions. It passes through the proton radiation belt which is so damaging to CCDs on astronomy missions and to solar cells. At perigee, it briefly encounters the LEO regime in which Columbus will operate.

Description of the Instrument

For maximum mission flexibility, the REM includes two modules, a detector unit with its analog electronics, and a digital and control unit:

- The detector unit consists of two Si-detectors, with different, spherical shielding to discriminate between electrons, protons, and heavy ions in the two detectors. The shielding was simulated by extensive Monte Carlo calcultions. The low-noise charge-sensitive analog electronics are also included in the detector module.

- The digital and control unit houses the ADC's with programable ROM for mission dedicated histograming function, together with its communication, control, and power supply electronics.

- A built-in calibration pulser enables checking of the linearity and the dead-time of the system.
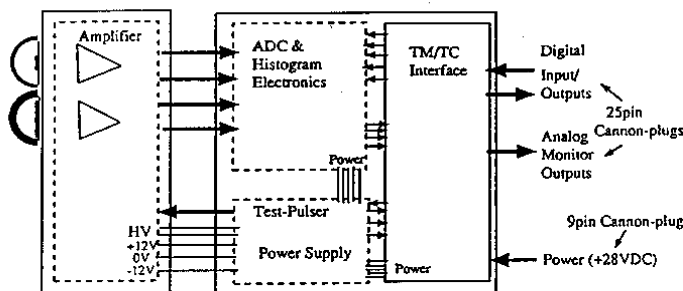
Figure 1 shows the layout of the REM.

Figure 1. The layout of the REM Instrument

Detector Performance

The LET spectra of the charged particles are measured in thin, totally depleted Silicon diodes (300µm thick, 25 and 150mm^2). The detector electronics are programmed to measure the energy deposit (which is registered by a charge-sensitive pre-amplifier and a 12-bit ADC) and increment one of 16 preset energy-deposit counter 'bins'.

The shielding was determined by calculations with the GEANT code using realistic space environment inputs for a GTO. The result is a shielding of 3mm of Al for the small (electron) detector and a sandwich of 3mm Al and 0.75mm Ta for the large (proton) detector. Figure 2 shows the simulated electron and proton histograms in 16 bins for the two detectors. For the presented simulation, a logarithmic energy scale is assumed, which allows to study low LET particles (electrons and protons), without loosing information about the high LET heavy ions.

The lowest two bins are set below the possible threshold of charged particles and monitor noise and pulses generated by electron-induced secondary bremsstrahlung photons. The next bin corresponds to minimal ionising particles (electrons as well as the small fraction of protons above 150MeV). The following bins are sensitive only to protons and allow to discriminate between different energies. The remaining channels are sensitive to ions (up to oxygen) and channel 16 holds the overflow (>1000MeVg^{-1}cm^2). For maximum flexibility, the PROM can be chosen for each mission individually.
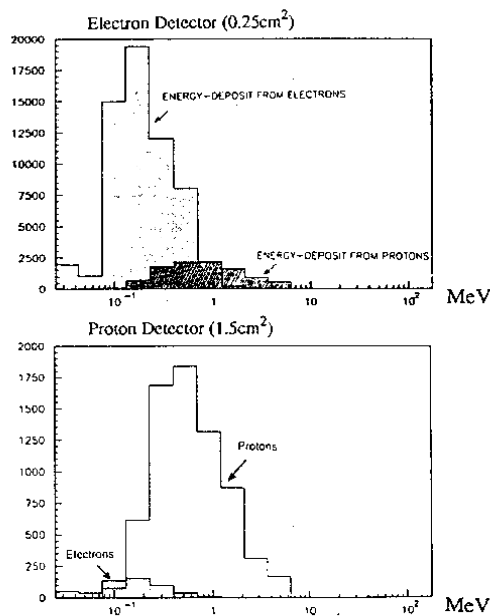

Figure 2. Contributions from Electrons and Protons

A calibration and test circuit is included in order to test the performance of the instrument. It can be activated by commands from ground. The calibration pulser is adapted to the non-linearity of the PROM. The detectors will be calibrated with protons up to 300MeV with the PIF facility at PSI, spring 1992.

42