DEDICATED INSTRUMENTS TO MONITOR THE SPACE RADIATION ENVIRONMENT

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ABSTRACT

The space radiation environment is becoming an increasingly important issue that has to be considered, during the selection process of space-born components. This is mainly due to the new developments in component technologies potentially more radiation sensitive (e.g. sub-micron technologies) and a desire by the space community to employ the latest technologies available on the market for new high performance space applications. Hence, the need to understand and map the environment in which future space applications will operate. In support of ESA projects three radiation monitoring instruments have been developed to expand our knowledge with regard to the dynamic space environment. These are:

a) Standard Radiation Environment Monitor (SREM)
b) Proton Monitor (PM)
c) Scintillating Fibre Detector (SFD)

The following is a short description of the above instruments and other activities performed at the Radiation Effects and Analysis Techniques Section, Component Division.

SREM

A decision was made by the ESA management board to develop and fly a Standard Radiation Environment Monitor on future ESA projects with the following objectives:

✔ To aid satellite performance, anomaly and failure investigations.
✔ With preloaded radiation thresholds to act as a warning / alarm system for the spacecraft.
✔ To assist in the improvement of design of future spacecraft
✔ To allow the creation and maintenance of a European radiation database.

SREM is an improved version of a previous Radiation Environment Monitor (REM) flown on the MIR space station and the micro-satellite STRV. The SREM has been improved with regards to mass, weight, power and functionality. The first SREM flight is planned on STRV1-C and is illustrated in figure 1.

Figure 1 SREM proton flight model intended for flight on the STRV1-c spacecraft.

The following are some SREM specifications:

✔ The SREM energy resolution for electrons is between approximately 300keV and 7MeV. For protons the energy resolution is approximately between 10MeV and hundreds of MeV. SREM can qualitatively detect heavy ions.

✔ SREM employs three solid state detectors. Two are mounted in a telescope configuration to detect electrons, protons and ions. The third detector is in a stand alone configuration for low energy electron and proton counting.

✔ The SREM should have a free viewing cone of ±20°.

✔ The overall dimensions of SREM for STRV1-C are: 246mm x 122mm x 105.7mm
✔ The power consumption of SREM is approximately 2.6W and it weighs approximately 2.5 kg.
✔ SREM provides for a simple RS422 level interface using the TTC-B-01 protocol.

Proton Monitor (PM), Thomson & Nielsen Electronic Ltd. (CA)

ESA identified the need for a low-mass, low power proton monitor to be used on spacecraft where the trapped proton radiation belts or solar flares are of particular concern. Based on this it was decided to support the adaptation of a terrestrial Radon monitor developed by Thomson & Nielsen Electronics Ltd. which has shown to possess the required characteristics for a proton monitor. Figure 2 illustrates the proton monitor.

✔ The dimensions of the PM are 135mm x 100mm x 25mm
✔ The PM power consumption is 300mW. PM may be powered by 12V to 40V.
✔ The PM mass is 350g.
✔ The PM saturation cross section across the energy range 20MeV to 500MeV has been found to be $2x10^{-11}$ cm^2/bit.
✔ The PM is based on a 256k DRAM which is very sensitive to upsets by protons in the 20MeV to 500MeV range.
✔ The PM OBDH interface is via RS422 lines.
✔ The first flight of the proton monitor will be on STRV1-C.

Figure 2 The PM Proto-Flight Model intended for flight on the STRV1-c spacecraft.

Scintillating Fibre Detector SENSYS (NL)

The development of a fibre-optic nuclear radiation detector based on the principal of measuring light emitted from a short piece of scintillating fibre, connected to a sensitive photo detector was initiated by ESA. The detector design advantages are its compactness, ruggedness, light weight and minimal power consumption. Testing, with various radiation sources, illustrated a sensitive system and a wide dynamic range.

The flight version of the SFD flown on EQUATOR-S was designed to measure the omnidirectional energy flux of protons and electrons. Particle discrimination was obtained using different shielding and using scintillating material of different scintillating properties and stopping power. Three scintillating probes were used.

✔ SFD power consumption < 105mW at 12V DC.
✔ SFD total mass 397g (electronics plus probe)
✔ SFD dimension85mmX65mmX60mm.
✔ Good dose rate linearity achieved for 1MeV gamma, 50-300MeV protons, 3MeV beta and various heavy ion species at 66 to 176MeV.

A study has been initiated to investigate the possibility of PULSED mode operation of the SFD to obtain more reliable particle discrimination measurements. Figure 3 illustrates a single channel Scintillating fibre.

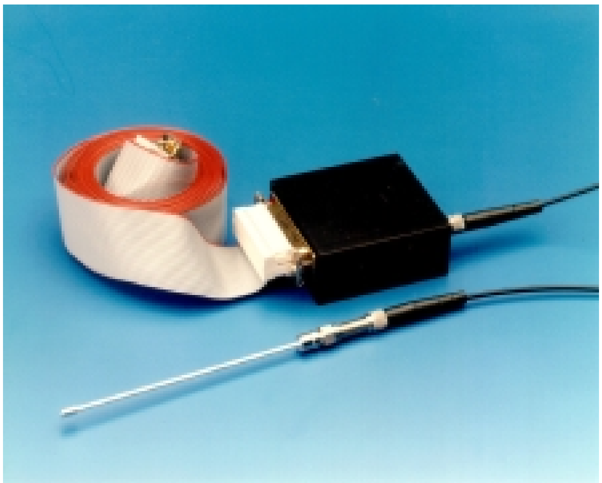

Figure 3 Scintillating Fibre Detector employing one fibre.

Local Dosimetry in Spacecraft

In addition to the radiation detectors already described, other devices are used to provide dosimetry in various forms for different applications. Two examples for total dose measurements are:

✔ Thermoluminescent dosimeters (TLDs)

The electron and hole traps in some crystalline materials are filled when exposed to radiation. When heated, the holes and electrons recombine and light is emitted from the material. These devices may easily be manufactured to various sizes and forms. Thus, they are suitable for local dosimetry at critical points of a spacecraft. The TLDs have to be retrieved for measurements.

✔ RadFETs (MOS structures sensitive to ionising radiation)

The RadFET is basically a MOS structure where a change in the electrical properties of the device due to charge generation and trapping in the MOS gate insulator is used to measure the total ionising dose received. The RadFET may be used for local real-time dosimetry at critical points of a spacecraft. Figure 4 depicts a real-time RadFET dosimeter developed by NMRC (Ireland) to be flown on the BIOPAN ESA experiment (the RadFET device is marked as number 6 on the PCB).

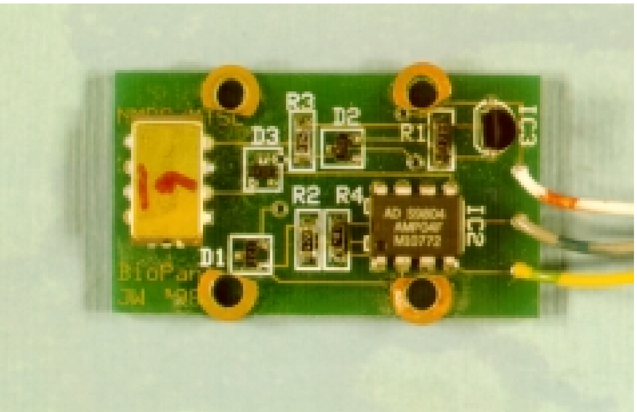

Figure 4 Real-time dosimeter based on a RadFET intended for flight on the ESA experiment

Conclusion

The increasing need to understand the space radiation environment and its effects on space-born components have resulted in the development of several radiation environment monitors. These instruments have already flown or are about to fly on various spacecraft. Previous radiation environment monitors (REM) flown on MIR and STRV1 provided excellent data on the radiation environment. The latest radiation monitors intended for flight on STRV1-c (it is foreseen that SREM also fly on future ESA missions) will generate more accurate data compared to their predecessors.

With an increase in the launch of small satellites (constellations) in orbits passing through areas with high radiation levels it is important to obtain an accurate picture of the particular radiation environment. However, flying radiation monitors on small satellites places strict requirements on the size, weight and power consumption of the instrument. Thus, a key issue for the success of future space radiation monitors is miniaturisation.