Standard Radiation Environment Monitor SREM

Characteristics

1. Online radiation monitoring and scientific data accumulation
2. Coarse spectroscopy of protons and electrons
3. Alarm flags for hyper and under activity
4. 3 Silicon Detectors in Al/Ta shielding
5. Directional sensitivity/telescope
6. Fast discriminators coupled with 15 scalers
7. Count rates >100 kiloevents/sec
8. Integrated dead time correction (3 scalers)
9. Energy threshold: 10 MeV p⁺, 0.5 MeV e⁻
10. Mass: 2.5 kg
11. Dimensions: 96x122x217 mm³
12. Power consumption: ≈ 2W
13. Temperatures: -20 to +55°C (o)
14. In-orbit operation time 10 years

Designed and manufactured by Contraves Space AG
in cooperation with PSI/ESA

10 SREM units fabricated and 2 are already flying
Calibration Procedure

GOALS
- Key performances verification
- Response function determination
- Computer model testing
- Proper understanding for space collected data

STEPS
- Two tests with radioactive sources $^{60}$Co/$^{90}$Sr
- Proton response calibrations in PIF
- Linearity and sensitivity
- Dead time and pile-ups
- Total sensitive area
- Long term stability
Facilities

1. Calibrated radioactive sources:
   - Gamma rays $^{60}$Co; $\langle E \rangle = 1.25$ MeV
   - Electrons $^{90}$Sr; $E_{\text{max}} = 2.28$ MeV
     Point-like sources placed on detector heads (and sides)

2. Protons from PIF/PSI - Proton Irradiation Facility:
   - Initial energies - $E_{\text{low}} = 60$ MeV, $E_{\text{high}} = 300$ MeV
   - $E_{\text{low}}$ used at $0 \leq \theta \leq 180^\circ$, $0 \leq \phi < 360^\circ$
   - Flat beam field, on-line monitoring
   - Low dose (below 3 rad)

   Full energy range: 6 - 300 MeV
   Full angular range: $0^\circ \leq \theta \leq 180^\circ$, $0^\circ \leq \phi < 360^\circ$
   Full flux range: $0 < F < 2 \times 10^5$ p/cm$^2$/sec

   Energy set for comparison:
   12, 18, 24, 28, 32, 36, 42, 50, 60, 70, 100, 150, 300 MeV

3. EGSE from CS AG and from PSI for protons
   - Remote operation from control room Ñ 40m
   - SREM unit placed on the angular stage
     (and two plastic detectors in front - up)
Modeling

Mass model constructed using GEANT code
- Exact description of Si-detectors and housing
- Simplified printed boards, cables, connectors
- About 350 volumes/shapes introduced

Extensions for comparison with calibration data
- Single elements and geometry of PIF introduced
- Beam profiles and energy degrading included
- Realistic flux normalization using plastics
- Comparison with sources takes into account source geometry, position and activity for both $e^-$ and $\gamma$

Steps
- Introducing individual parameters and corrections
- Computations and comparison (more fine tuning)
- Full response function calculations
**Linearity**

**Minimum Sensitivity:**
Low energy threshold for detectors: 0.5 MIP (Minimum Ionizing Particle Energy) - 79.1 keV in 500 μm Si

**Energy resolution of the analogue channel:**
In agreement with calculations

**Linearity Region:**
Confirmed to be in a range: Ω - 30 MIPs (0.079 ~ 4.75 MeV)

Fulfils specifications for all p and e channels

Measured for two SREMs and indirectly verified for all 10 units
Measured during calibration

Exposures at 0∞ and 300 MeV
Low intensity, flat beam
Consistency within < 10%

*Differs from nominal values (connected with det. technology)*

D1 $<A> = 0.69 \text{ cm}^2$
D2 $<A> = 1.09 \text{ cm}^2$
D3 $<A> = 0.68 \text{ cm}^2$
*(Error for single detector < 0.01 cm$^2$)*
Dead-time and Pile-ups

Measured using DT and TC scalers
Exposures at 0\(\infty\) and 300 MeV
Intensity from \(10^3\) to \(1.5\times10^5\) \(\text{cm}^2/\text{s}\)
Normalization to fast plastic detector

DT corrections smaller than required:
20% maximum at \(10^5\) \(\text{cm}^2/\text{s}\)
Only a few percent pile-ups for realistic space environment (at higher energies)
Low energy threshold

Measured using TC scalers and ICs
Exposures at $\Theta=0^\circ$ and $E_0 = 60$ MeV
Degrader steps 0.33 mm Al

Threshold fit for each detector
Result within 5-10% with specs.
D1 $E_{\text{thr}} = 22.8 \pm 0.5$ MeV
D2 $E_{\text{thr}} = 44.0 \pm 1.6$ MeV
D3 $E_{\text{thr}} = 9.1 \pm 0.4$ MeV

Relatively large scatter of results
I. Low energy response at 0°

Example: Comparison of PROBA results

Calculations include beam and facility features

*In general agreement is very good but closer to thresholds and bigger deviations*
II. Low energy response at 0°

Comparison for SREMs PFM3 to PFM9:

Agreement generally very good!

Again - far from thresholds n better (see e.g. S14 at 40 and 60 MeV)

Jump from PFM06 in coincidence scalers (see C1,C2 from PFM06) n fit of thresholds?
Angular distributions

Example: PROBA results at 100 MeV

Angle pairs \((\Theta, \phi) = (0,0), (30,0), (45,270)\)

Agreement is pretty good

Response quickly decreases with angle
High energy response vs. angle

Example: PFM05
(selected angles & scalers)

Strong energy dependence even at 0∞

High angular sensitivity even at high E
1. Calibration results generally successful
2. In average, agreement better than 10%
3. Some coincidence channels differ more
4. Using response for typical mass model
5. Corrections for area and thresholds fits
Gamma Responses

60Co data normalized to 1000 kBq source activity

60Co data comparison with 1st check - ratio

60Co data comparison with SREM Proba - ratio

- Two test routinely performed,
- Only half of scalers can be tested with 60Co
- Very sensitive to any changes in threshold sensitive area and Contact changes.

All SREMs up to PFM09 similar
Electron Responses

Comparison with calculations

Good agreement already for calculations with no free parameters

All SREMs behave in a similar way
Full Response Matrix - Protons

Discriminator levels are set to select proton energy
The range extends from 8 MeV

Single channels cover lower energies
Coincidence channels are sensitive to higher energies
Full Response Matrix - Electrons

Discriminator allow to select electron energy

The range extends from 0.6 MeV
Typical Responses

Electron Belt Spectrum

Proton Belt Spectra

Counting Rate in Electron Belt

Counting Rate in Proton Belt
Detection Limits

Example of Solar Protons

Galactic Cosmic Rays integral fluxes used in simulations

Counting Rate Example - Solar Events (trend only)

Galactic Cosmic Rays background in SREM counters
Response with Satellite

Only high energy proton sensitivity changes but responses for typical space spectra differ little.
PROBA with SREM Onboard

Until now only limited data available (SREM mostly OFF) due to satellite tiny power budget and restricted planning
First Environment Maps

Electrons (E > 0.65 MeV) and Protons (E > 9 MeV)
First Orbital Data

PROBA SREM Particle spectra and AE8/AP8
(Power low and step function fit)
Expected Radiation Environment

PROBA SREM Count rate for TC3 compared with AE8/AP8
($E_p > 9$ MeV, $E_e > 0.7$ MeV)