Energetic particle observations on-board CubeSats

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With special thanks to
Arttu Punkkinen and the rest of the
RADMON and Aalto-1 teams
Energetic particles @ LEO by Aalto-1

RADMON
Mass: 0.4 kg
Power: 1 W
Volume: 0.4 U

Analog Board
Digital Board
PSU Board
Detector Unit
RADMON measurement principle: \( \Delta E \) vs \( E_{\text{res}} \) method

\( \Delta E \) @ constant \( E_{\text{res}} \) gives the species

\( \Delta E + E_{\text{res}} \) gives the energy

\begin{align*}
\text{RADMON Mass:} & \quad 0.4 \text{ kg} \\
\text{RADMON Power:} & \quad 1 \text{ W} \\
\text{RADMON Volume:} & \quad 0.4 \text{ U}
\end{align*}
The Finnish Student Satellite

RADMON early data coverage

scrubbing

pulse height

raw pulse

housekeeping

scientific

Credit for GOES flux plot: NOAA
Radiation storm 4-6/9/2017

Credit for GOES plots: NOAA & KSWC
Highly perturbed magnetic field makes electrons rain down from radiation belts to Aalto-1 orbit and atmosphere.

Credit for GOES plots: NOAA & KSWC
UTC time = Thursday, 14 September 2017, 17:22:00.
Sun is at 80° West; Aalto-1 is at 130° West, i.e., LT 08–09
RADMON early data coverage

- scrubbing
- pulse height
- raw pulse
- housekeeping
- scientific
- OBC reboots
- electron event
- Measurement campaign carried over the autumn

Credit for GOES flux plot: NOAA
Energetic (>10 MeV) protons

Inner-belt protons observed in SAA at a stable rate [not much orbit-to-orbit variations]
Relativistic (>1 MeV) electrons

Inner-belt electrons observed in SAA at a stable rate
Outer-belt electrons observed at higher latitudes more variable
Quasi-trapped electron flux increases with longitude from trapped region

Fig. A. Punkkinen
RADMON electron event on 2017-09-14 is observed at inner edge of average outer belt. Local times correspond (roughly) to 08, 09 and 21. While typical for lower energies, the morning sector is atypical for REP events (Yahnin et al. 2016)?
Summary of RADMON/Aalto-1

• A simple, low-power low-mass radiation monitor for CubeSat observations was constructed, launched and operated
  – Mass 0.4 kg; Volume 0.4U; Power 1 W; Geometric factor 0.023 cm² sr
• Measures >10 MeV protons and >1 MeV electrons
• Observational campaign has so far produced
  – LEO measurements of a large SEP event, which can be correlated with GEO measurements and local effects
  – LEO measurements of a magnetospheric electron event which can be correlated with auroral and geomagnetic activity
  – Maps of >10 MeV protons and >1 MeV electrons from a two-month campaign from Oct-Dec 2017
• Challenges
  – Electron sensitivity with the scintillator is not optimal
    \[\Rightarrow\] energy and flux calibration challenging, not yet completed
  – Tumbling state of S/C does not allow assessing measurement directions
    \[\Rightarrow\] no understanding of pitch-angle distributions (trapped/precipitating)