CURRENT DEVELOPMENTS OF THE MINIATURE RADIATION MONITOR (MRM)

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1. ABSTRACT

Sensys was established at Noordwijk in 1984 and became active in space technology since 1988.

Over the years they developed among series of technical and scientific instruments, the first MRM prototype (1992), and the MRM flight models for EQUATOR-S, YES (1997) and PROBA (2001).

Main strong points of the Sensys MRM are very low power consumption, low weight, small size, extremely wide energy range and an easy data interface. They may fit in virtually every satellite.

For long-term missions or for satellites with a long lifetime, an MRM offers stability of response and automatic data output. It can be powered up and down, re-starting automatically every time.

In a nutshell the key characteristics of the various MRM types and derivatives will be presented.

Effectively two main types of MRM are now available :

A) A radiation integrating MRM based on advanced scintillator – detector combinations

B) An energy – and particle type discriminating MRM, based on detector pulse analysis

Special versions of the MRM exist, like a subminiature general-purpose portable unit, a laboratory version and a prototype ecological monitor. Commercial availability of Flight MRM is foreseen.

2. MODE OF MRM OPERATION : 2.1 Fibre-optic version A)

The fibre-optic MRM is composed of 3 parts : the probe, containing a special scintillator crystal, a flexible optical cable and an MRM electronic unit containing a light detector and the control computer. The probe is located at an outer panel or at a location designated to be monitored.

The probe light signal is accurately proportional to radiation dose. The thickness of screening metal around the probe can be made equivalent to the average system package thickness, so that the probe output represents the true radiation level remaining inside a system or a component enclosure.

The probe is coupled to the electronics box by a flexible optical cable. This makes it possible to place the scintillator probe at an arbitrary place away from the electronics, and vice versa to place the electronics at a more favourably shielded location to protect it from excessive radiation.

More probes for different locations and / or energy / particle type ranges are optional.

At the electronic system end, the light output delivered by the optical cable is detected by a special rad-hard photodiode, converted into current and measured by a sensitive current amplifier.

In contrast to pulse-counting nuclear detectors, the fibre-optic MRM has an extremely wide dynamic range due to the vast light signal range that can be handled by the scintillator crystal and by the (solid state electrometer) current amplifier. Moreover, the radiation data obtained may realistically represent the radiation doses as deposited in comparably screened electronic parts.

Operation of the whole MRM system is governed by a microcomputer, which takes care of error correction, temperature compensation, data processing and data interfacing.

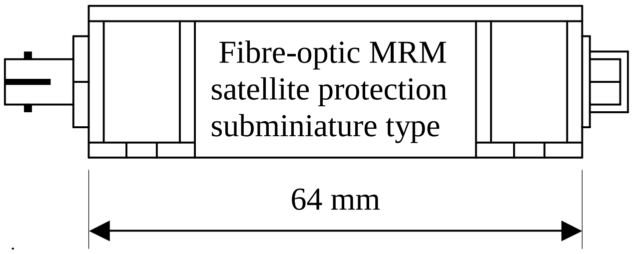
Programming of the MRM can be performed at the factory, on-site or even after launch. Also, data interfacing can easily be adapted to the spacecraft requirements. The MRM restarts automatically from a power-down state, loading and starting its operating software autonomously.

2.2 ADVANTAGES of the Fibre-Optic MRM version

- stable calibration
- very wide dynamic range
- small housing (64 x 42 x20 mm)
- light weight (< 200 grams in total)
- simple and (re)programmable interface
- very low power consumption (< 0.1 W)
- separation between sensor and electronics

2.3 MAIN TECHNICAL DATA

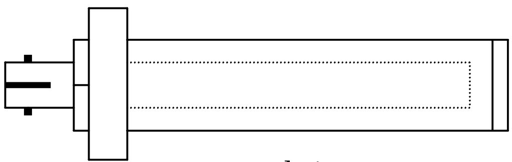
- probe minimum energy range : electrons (e-) >150 keV, protons (p+) > 4 MeV
- typical probe ranges : e- >0.5 MeV, p+ >10 MeV or > 4 MeV, >40 MeV
- detection limit, dynamic : < 1 MeV deposited per second (a few particles/sec)
- dynamic range : from 0.01 fA to >100 µA or 1 to >10^{12} particles/sec
- power supply : single + 5 V at 9 mA (45 milliwatts)
- radiation hardness : operating 50 kRad Co60 in 260 hours - no effect



actual size

typical probe with crystal rod and screening

smaller probes available, type scintillating fibre



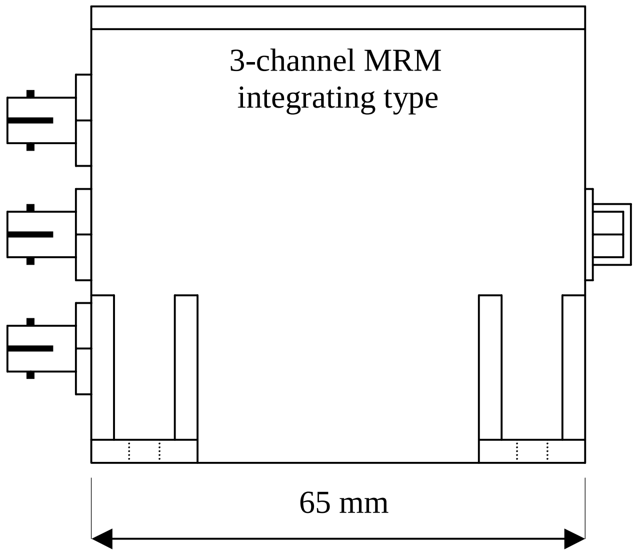
thru-panel mounting, flush mount available

actual size

2.4 MICROPOWER MRM VERSION built as a PORTABLE unit, key data :

power consumption	: 25 microamperes at + 3 V
data output	: digital (memory) and analogue (dynamic)
readout mode	: bit serial readout and analogue output
over-range output	: one digital bit, at a programmable level
data retention	: by Lithium battery, typically 1 year
case size	: 64 x 42 x 20 mm
total weight	: 93 grams

2.5 Three – channel MRM type as flown on EQUATOR-S and on YES :



3. MODE OF MRM OPERATION : 3.1 Particle counting/discriminating version B)

SHOWN AT THE MEETING IS A PROTOTYPE MRM VERSION LAUNCHED ON PROBA

3.2 MAIN FEATURES of the PROBA version :

- Discriminates between protons and electrons
- Fully controlled by an internal micro-computer
- Wide detection range from 150 keV / 4 MeV for e- / p+ respectively, up to > 50 MeV
- Energy / particle type and -rate spectra with 2 x 8 (or more) energy channels
- Small size, 10 x 10 x 3 cm (the current MRM model is even smaller)
- Automatic data output (serial, parallel or analogue)
- Low power consumption, less than 0.3 Watts
- Low weight, 300 grams

3.3 MODE OF OPERATION, current MRM Flight Model prototype type B

The particle-discriminating MRM is based on the behaviour of special scintillator materials. Its radiation probe consists of an optical light guide with a scintillator crystal. Directionality is obtained by the geometry of scintillator crystal screening and / or by coincidence techniques.

Light pulses are accurately proportional to deposited energy. A light guide makes it possible to place the detector + electronics away from excessive radiation at the scintillator location.

The particle discriminating MRM analyses each light pulse and makes a difference between proton versus electron detection events. Options to detect soft X-rays, neutrons and higher Z particles are not described here, although the MRM concept has provision for these modes.

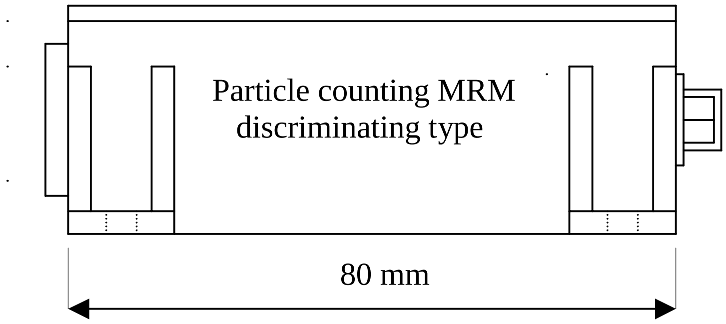
Operation of the whole MRM system is governed by a built-in microcomputer. Programming of the MRM can be performed at the factory, on-site or even after launch. The MRM restarts automatically from power -down states by loading and self-starting its operating software.

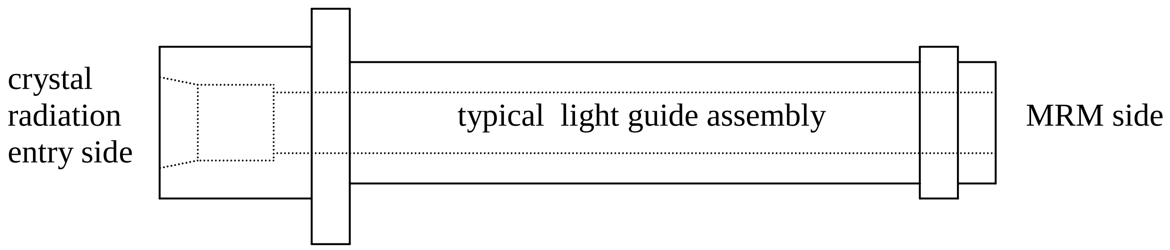
3.4 ADVANTAGES of the particle counting/discriminating MRM version

- separation of electron and proton events
- both particle count rates available
- spectra of up to 2 x 255 energy bins possible
- small housing (ca. 80 x 40 x 50 mm)
- light weight (ca. 200 grams)
- easy power and data interface
- stable calibration (no photomultipliers used)
- wide dynamic range plus analogue rate output
- low power consumption (< 0.5 W)

3.5 TECHNICAL DATA

• probe aperture thickness	: 0.1 mm Aluminium foil (Beryllium as an option)
• probe minimum energy range	: e- 150 keV, p+ 4 MeV (determined by foil)
• number of energy bins	: 255 for both electrons and protons
• system maximum energy bin	: e- 5 MeV, p+ 50 Mev (may be changed)
• dynamic range	: 0.15 to >50 MeV and <1 to >1000 particles/sec
• electronics box weight	: ca. 200 grams (PROBA ca. 300 g)
• power supply	: dual + and - 12 V at < 20 mA (< 500 milliwatts)





4. PROPOSED COMPLEMENTARY INSTRUMENT : Charged Particle Net Flux Meter

One important aspect of the space radiation environment is the quite high density of lower energy charged particles in and near the radiation belts. There is a direct relation between charging due to particle fluxes and the devastating discharges on spacecraft system parts.

Based on MRM technology (proven on EQUATOR-S) a charged particle Net Flux meter can be realized as an on-board monitor to indicate the actual net rate of incident charged particles.

With a wide range from a 100 to some 10^{14} particles/sec/cm² the MRM is able to directly measure the incident rate of mainly electron and proton radiation above an arbitrary energy limit (as an example 10 keV for electrons) by using a modified, upgraded Faraday Cup as the sensor.

This can be implemented as a cylindrical housing, shielding against particles from other directions, with one face covered by a conducting foil. Inside the housing is an insulated disc electrode with an area of e.g. 1 or 10 cm². With the necessary refinements to make it insensitive to discharges, EMI and microphony, it is a very reliable, rad-hard and sufficiently sensitive detector.

It is expected that there is a relation between charged particles and soft X-rays caused by their incidence on the spacecraft. The combination of static discharges and soft X-rays may seriously damage non-metallic parts such as insulators, cabling, cover glasses or lenses. With a charged-particle net flux meter, one may correlate material decay and measured charged particle flux.

4.1 MODE OF OPERATION

The flux probe is located at an outer panel and connected to a sensitive bipolar current detector by means of a tri-axial cable. Alternatively, the Faraday Cup can be integrated into the electronics unit. Operation of the MRM system is governed by a microcomputer, which takes care of current measurement, error and temperature compensation, data processing and data interfacing.

4.2 ADVANTAGES of the charged-particle Net Flux meter

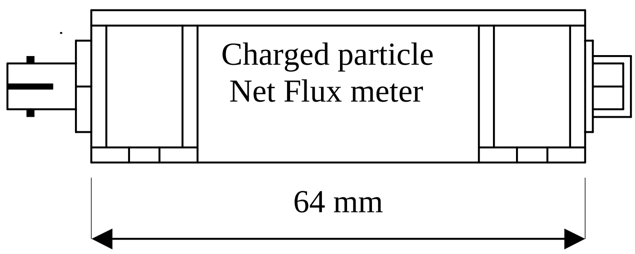
- direct measurement of electron-proton flux
- extremely high incident rates measurable
- proven technology, stable calibration
- small housing (80 x 40 x 30 mm or smaller)
- light weight (ca. 200 grams)
- easy power and data interface
- low power consumption (< 0.1 W)

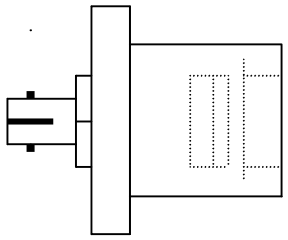
4.3 TECHNICAL DATA

- probe aperture thickness : 10 µm Aluminium foil (Beryllium as an option)
- probe minimum energy range : e- 10 keV, p+ 0.5 MeV (determined by foil)
- detection background : noise equivalent to less than 100 particles/second
- dynamic range : 100 to 10^{14} particles/sec/cm^2
- probe dimensions : 1 cm² electrode behind 10 µm Al foil
- electronics, probe + cable weight : less than 200 grams
- power supply : single + 5 V at < 10 mA (< 50 milliwatts)
- radiation hardness : operating 50 kRad Co60 in 260 hours - no effect

4.4 OPTIONAL FEATURES of the charged particles Net Flux meter

- several probe disc electrodes can be stacked to differentiate in energy. In that case the output signal per disc will be the difference of positive and negative particle fluxes at the chosen penetration depth in the disc stack. Just as with the integrating MRM, a division into energy bands per particle type and per probe can be obtained by selective absorption.





Faraday Cup (example)

QCA – TOS presentation day at Estec 9 april 2002. Comments on item 4-4.4 are especially invited.

For more information on MRM versions please contact Cees Boeder at address sensys@euronet.nl

Data given in this resume are for orientation only. Latest information will gladly be provided.

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