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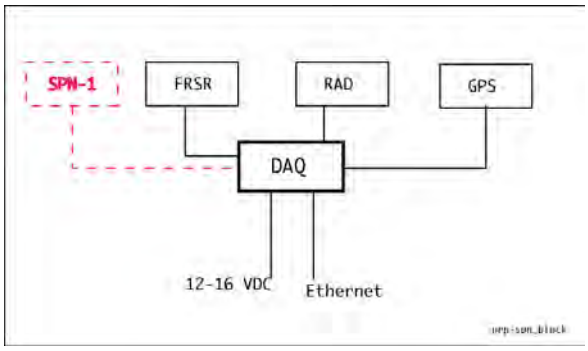
December 7, 2011

Memorandum: M1107-draft

Plan to Integrate the SPN1 Radiometer to the AMF2 PRP

SUMMARY

This document provides engineering design for installing the Delta-T "SPN1 Sunshine Pyranometer" into the Portable Radiation Package for the ARM Mobile Facility (AMF2). The PRP system is described on line here. Note in the photos and diagrams for the PRP that a spare waterproof connector has been provided. The SPN-1 could be connected into this connection easily. The analog voltages or the serial RS232



What is the PRP? The Portable Radiation Package (PRP) combines shortwave and longwave broadband radiometers with a RAD interface (Eppley PSP and PIR) with a fast-rotating shadowband radiometer (FRSR) into a single package suitable for radiation measurements from a moving platform such as a ship. The Data Acquisition module (DAQ) for the PRP incorporates a network serial to ethernet hub.

What is the serial-to-ethernet hub? The "hub" makes the serial outputs from a GPS, Tilt sensor, FRSR, and RAD available on a single ethernet TCP/IP connection. It is located in the PRP's DAQ unit under the FRSR control board. Currently the hub in the DAQ is an ICP PDS-752(D). This device has four serial RS232 and one RS485 connections. All the four serial ports are occupied, but it is possible to install a new hub, the PDS-782(D) and have three more serial inputs.

What is the DAQ modular software? For the past several years a script-based software package has been developed for the PRP and other equipment used by RMR Co. The Expect-Perl-Kermit package is described on page 3.

What are the SPN-1 analog outputs? The SPN-1 has both analog and digital outputs. The two analog outputs are in millivolts and calibrated to be 1 mv per Wm^{-2}. The analog voltages are derived from the internal computer and a digital-to-analog converter (DAC). The channels are direct beam and diffuse irradiances. Power input is 5-15 VDC at 2 mA. The power, heater, and analog outputs are available as a separate plug, Lemo M12, 8 pin.

What is the SPN-1 RS232 output? A digital output is also available on a separate plug; Lemo M12, 5-pin. This is a continuous output, typ 2-sec, binary string. Output is 9600 baud (selectable). I am now learning about the digital stream. Company engineers tell me it is binary but that is all I have so far.

tbd – How does the SPN-1 compute solar components?

tbd – How is the SPN-1 analog integrated into the PRP?

tbd – How is the SPN-1 RS232 integrated into the PRP?

DAQ Modular Software

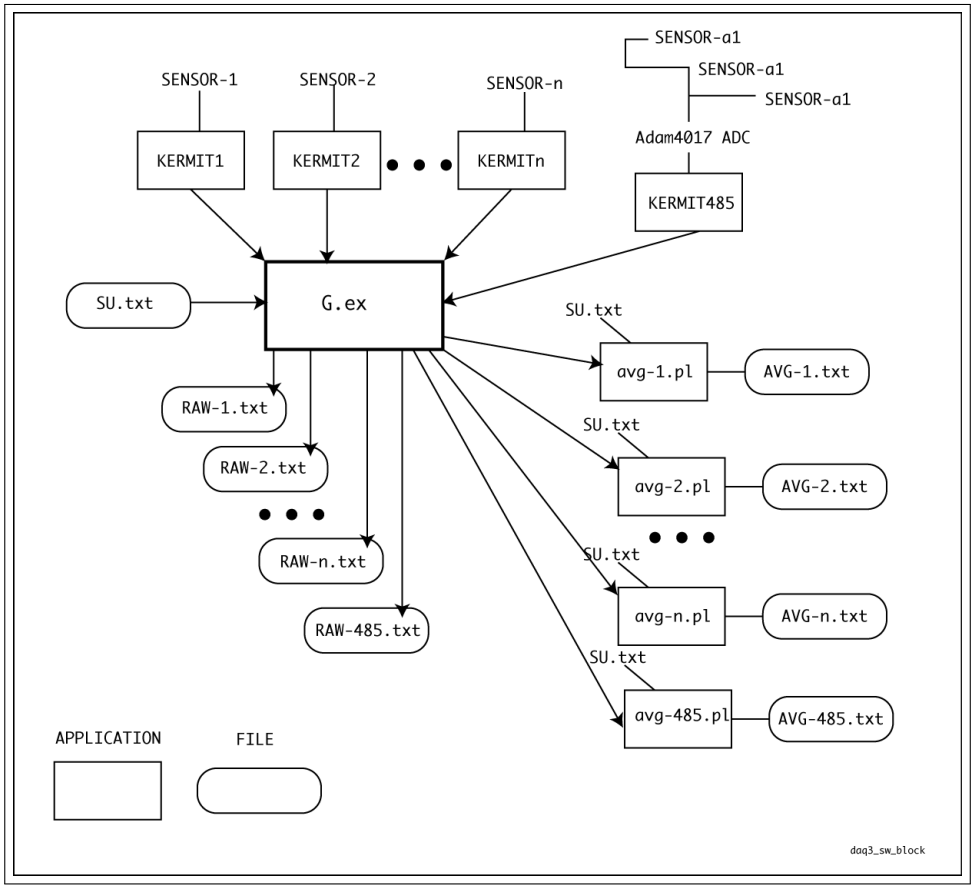


Figure 1: A generic block diagram of the DAQ software.

The core of the software is "G.ex" a program written in the Expect language. Read more here. "Expect is a Unix automation and testing tool, written by Don Libes as an extension to the Tcl scripting language, for interactive applications such as telnet, ftp, passwd, fsck, rlogin, tip, ssh, and others. It uses Unix pseudo terminals to wrap up subprocesses transparently, allowing the automation of arbitrary applications that are accessed over a terminal."

Serial in/out ports are set up using the "Kermit" software package that was developed at Columbia University. Kermit ports can set up as TCP/IP, ordinary serial, modem, or any of several interface types. The Network Hub has 4 (or seven) serial RS232 ports and one RS485 port. The RS485 connection can address modules on a 485 network. Thus the possible input network is virtually limitless. A setup file, "`su.txt`" defines all the input sensors and any necessary processing parameters.

`G` keeps track of each input port. When a data string comes in it is appended to file "`RAW-i.txt`" with a time stamp. The raw string is then sent to be processed by the corresponding application "`AVG-i.txt`" which produces statistical averages and any derived variables. The output from these programs are appended to the output files "`AVG-i.txt`".

Overall, the Expect-Perl-Kermit has proven to be highly modular, easily expanded and tested–modules can be developed and tested then introduced to the `G` umbrella. Of course other languages than Perl can be used. Fortran, C, and Python have been integrated in the DAQ system.

Delta-T Devices - Data Sheet

Sunshine Pyranometer type SPN1

The new SPN1 measures Global (Total) and Diffuse radiation and Sunshine Duration – in one instrument!

- **Global (Total) and Diffuse irradiance in W.m^{-2}**
- **WMO sunshine threshold: 120 W.m^{-2} direct beam**
- **No routine adjustment or polar alignment**
- **No moving parts, shade rings or motorised tracking**
- **Works at any latitude**

The Sunshine Pyranometer is a patented, meteorological class instrument, with built-in heater, designed for long-term outdoor exposure. It is an affordable alternative to shade-ring pyranometers, pyrheliometers and traditional sunshine recorders.

The SPN1 is exceptionally easy to use; it needs no routine adjustment or polar alignment and works at any latitude

Unique design

The Sunshine Pyranometer uses an array of seven, miniature thermopile sensors and a computer-generated shading pattern to measure the direct and diffuse components of incident solar radiation.

The shading pattern and thermopiles are arranged so that at least one thermopile is always fully exposed to the solar beam, and at least one is fully shaded from it, regardless of the position of the sun in the sky.

All seven thermopiles receive an equal amount of diffuse light. From the individual thermopile readings, a microprocessor calculates the global and diffuse horizontal irradiance and from these values an estimate of sunshine state is made.

The Sunshine Pyranometer is protected by patents EP 1012633 & US 6417500

- **Precision ground glass dome**
- **Wideband thermopile sensors**
- **Near ideal spectral and cosine response**
- **Standard output sensitivity**

Outputs

The Sunshine Pyranometer provides 2 analogue voltage outputs for global and diffuse radiation, and a digital output for sunshine duration, which can be connected to data loggers, such as the Delta-T DL2e and GP1. Readings can also be obtained directly from the RS232 port.

Heater

An internal heater keeps the dome clear of dew, ice and snow down to -20°C (in still air conditions), ensuring reliable readings in difficult climatic conditions.

SPN1 validation and testing - direct and diffuse

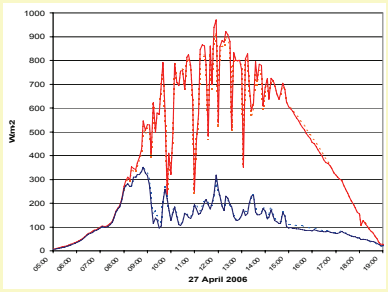
SPN1 Design Principles

The principles used in the Sunshine Pyranometer have been tried and tested in the Delta-T BF3 Sunshine Sensor. The original design has been enhanced, using miniature thermopile sensors, a high quality ground glass dome and aluminium housing. The electronics have also been redesigned for higher accuracy and lower power consumption.

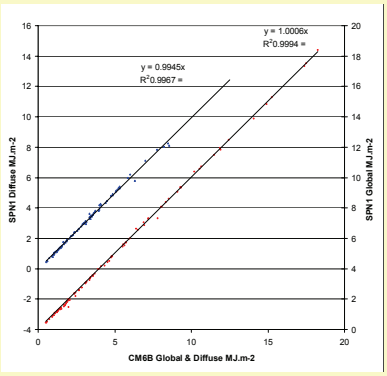
The SPN1 computes direct radiation by subtracting the diffuse from the global (total) radiation.

Comparison Results

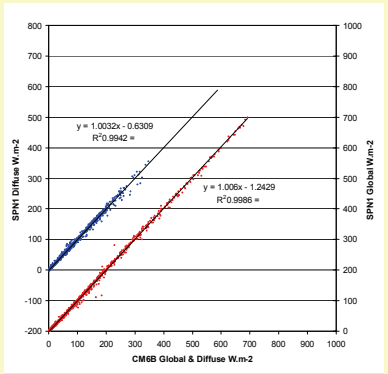
Prototype versions of the Sunshine Pyranometer have been tested over several months against Kipp & Zonen CM6B sensors, one shaded by a solar tracking disk. Sample results are shown on this page.



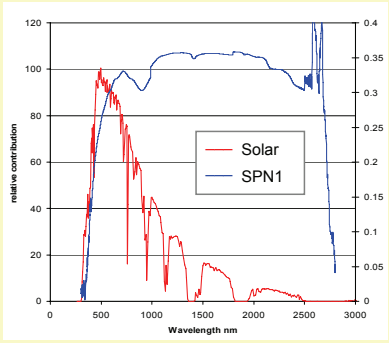
SPN1 Direct and Diffuse Outputs (solid traces) compared with a pair of Kipp CM6B pyranometers with solar tracking and shading disk (broken traces).



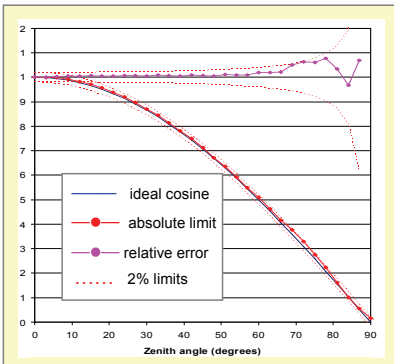
SPN1 Daily Integrals Global & diffuse compared with Kipp CM6B & tracking disk Sept – Dec 2004, daily integrals. (Note use of offset axes to make traces visible).



SPN1 Hourly Averages Global & diffuse compared with Kipp CM6B & tracking disk Sept – Dec 2004, hourly averages. (Note use of offset axes to make traces visible).

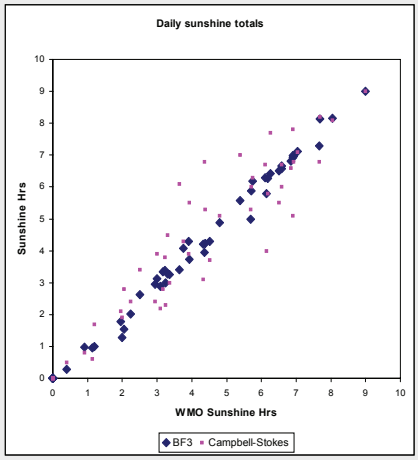


SPN1 Spectral Response Graph shows the spectral response of the SPN1 (thermopile, diffusers and dome combined) and the solar spectrum at ground level.



SPN1 Cosine Response Graph shows the typical cosine response of the SPN1 compared to the ideal cosine curve. The upper curve shows the relative accuracy.

SPN1 validation and testing - sunshine duration



Sunshine Duration

The WMO threshold for bright sunshine is 120 $W.m^{-2}$ in a plane perpendicular to the direct solar beam. This cannot be measured directly using horizontal cosine-corrected sensors, and so the SPN1 uses an algorithm based on the ratio of direct to diffuse radiation, combined with their absolute values, to estimate this to within a few percent of the WMO standard.

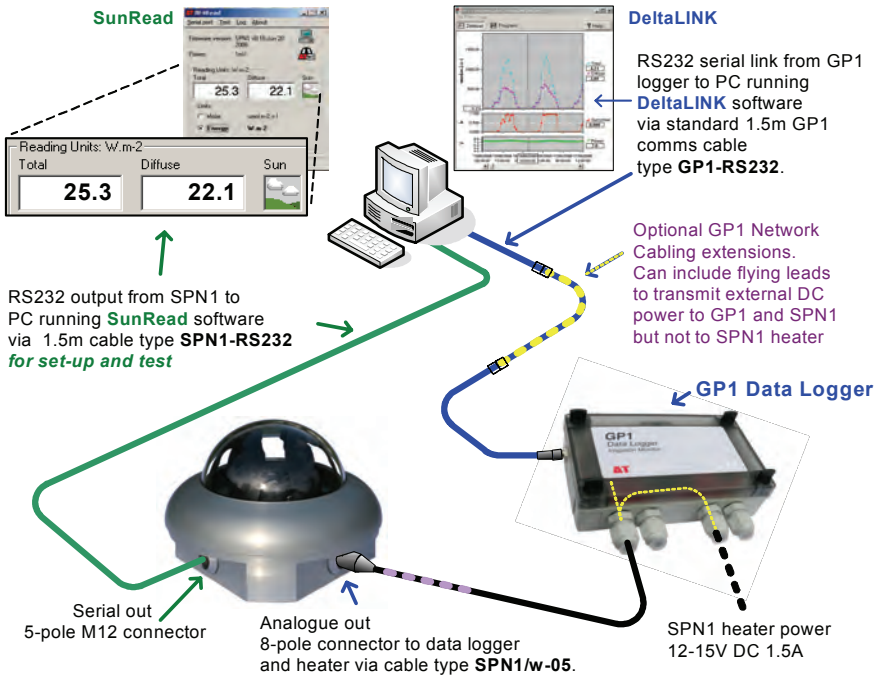
The graph compares the performance of the BF3* and a Campbell-Stokes sunshine recorder over a trial period of several months. Against the WMO standard, the BF3's typical daily error was 20 minutes. In contrast, the Campbell-Stokes was less precise, giving a typical daily error of nearly an hour.

** The SPN1 is an advanced version of the current BF3 Sunshine Sensor. Both instruments use the same sunshine hours algorithm.*

GP1 Data Logging Solution

The GP1 Data Logger from Delta-T Devices is a powerful general purpose data logger that provides a low cost logging solution for the SPN1 Sunshine Pyranometer. The diagram below shows how a GP1 can log SPN1 readings and later upload them to a PC or PDA.

Also illustrated is an alternative recording method where the SPN1 serial output is connected directly to a PC or other serial device.



Applications

Meteorology

- Solar radiation
- Climate change
- Air pollution
- Sunshine duration
- Cloud cover research

Agronomy & plant science

- ET and heat flux studies
- Canopy analysis and modelling

Architecture and building design

- Building Management Systems
- PV efficiency and energy balance

Specifications

Overall accuracy: Global (Total) and Diffuse radiation	±5% Daily integrals ±5% ±10 $W.m^{-2}$ Hourly averages ±8% ±10 $W.m^{-2}$ Individual readings *Accuracy figures give 95% confidence limits, i.e. 95% of individual readings will be within stated limits under normal climatic conditions.*
Resolution	0.6 $W.m^{-2}$ = 0.6mV
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1mV = 1 $W.m^{-2}$
Analogue output range	0-2500mV
Sunshine status threshold	120 $W.m^{-2}$ in the direct beam
Accuracy: Sunshine status	±10% sun hours with respect to the threshold
Accuracy: Cosine Correction	±2% of incoming radiation over 0-90° Zenith angle
Accuracy: Azimuth angle	± 5% over 360° rotation
Temp coefficient	± 0.02% per °C typical (-20 to +70°C)
Temperature range [1]	-40 to +70°C

Recalibration / stability	Factory recalibration recommended every 2 years.
Response time	< 200ms
Spectral Response	400-2700nm
Spectral sensitivity variation	10% typical
Non-linearity	<1%
Tilt response	Negligible errors
Zero offsets	<3 $W.m^{-2}$ for a change of 5°C/hr in ambient temperature <3 $W.m^{-2}$ dark reading
Latitude capability	-90° to +90°
Environmental	IP67 sealing
Sunshine status output	No sun = open circuit Sun = short circuit to ground
Power requirement	2mA (excluding heater power), 5V – 15V DC
Heater power	12V – 15V DC, up to 1.5A
Heater control	Continuously variable up to 20W output for external temperatures below 0°C
Lowest snow & ice-free temperatures (with heater in use)	-20°C at 0 m/s wind speed -10°C at 2 m/s wind speed
Mounting options:	3 x M5 tapped holes in base; 108mm pcd, 120°spacing
Size & weight	140mm dia x 100mm (h), 940g

[1] Provided: dome is frost-free, SPN1-RS232 cable is not flexed when <-30°C and SPN1/w-05 cable is not flexed when <-5°C.

Ordering Information

Product	Item code	Description
Sunshine Pyranometer	SPN1	Fitted with 5 and 8 pole M12 plugs. Supplied with 5m data cable to bare wire, type SPN1/w-05, 1.5 comms cable type SPN1-RS232, Quick Start Guide and calibration certificate. Does not include baseplate or support arm.
Baseplate	SPN1/BP	Levelling baseplate for SPN1. 150mm diameter, with 3 levelling screws.
Support arm	SPN1/ARM	Support arm for SPN1. Length 1m, suitable for mast mounting.
Desiccant unit	SPN1-SD	Spare desiccant unit for SPN1. 2 spare desiccant canisters (does not include RH indicator assembly).
5m extn cable	EXT/M12-05	5m SPN1 extension cable. IP68 M12 connector (f) to IP68 M12 connector (m)
10m extn cable	EXT/M12-10	10m SPN1 extension cable. IP68 M12 connector (f) to IP68 M12 connector (m)
25m extn cable	EXT/M12-25	25m SPN1 extension cable. IP68 M12 connector (f) to IP68 M12 connector (m)
Recalibration	SPN1-CAL	Factory recalibration and 2 year servicing of SPN1

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