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STRADIUM: a telemetry&telecommand system for LDB flights

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Abstract. STRADIUM LDB is a telemetry system for Long Duration Balloon flights realized by an Italian team in collaboration with the Italian Space Agency (ASI). It provides a near real time, bi-directional, continuous telemetry/telecommands link. It is composed of two sub-systems: a "Primary" TM/TC module, for flight management and house-keeping data monitoring; a "Scientific" TM/TC module for managing scientific data link. The communication system is based on the IRIDIUM satellite network; this choice permits to have full terrestrial coverage particularly for polar flights. However, the system design flexibility allows to use also other available communication networks. Another important feature of STRADIUM is the modular design, to satisfy requirements even when large and complex payloads are involved.

Key words. Long Duration Balloon (LDB), telemetry, remote control

1. Introduction

Long Duration Balloons (LDB) offer a great opportunity for scientific experiments to operate in stratospheric environment, very similar to space, up to several weeks. Astrophysics, as well as other disciplines, may take advantage of this possibility because of lower costs and access time with respect to space mission, which in turn can benefit of preliminary technological tests. However, LDB can be flown only from Polar regions, where ground infrastructures are difficult both to realize and manage. That scenario has driven, starting 2000, the design of BaR-SPOrt (Balloon-borne Radiometer for Sky Polarization Observations), that develops its own telemetry/telecommands system using IRIDIUM Cortiglioni et al. (2003); Macculi et al. (2001). The MSITel (Multi Source Intelligent Telemetry) module, which represents the basic telemetry unit of STRADIUM, is a further development of that preliminary design. A relevant contribution has come even by the experience of PEGASO (Polar Explorer for Geomagnetism And

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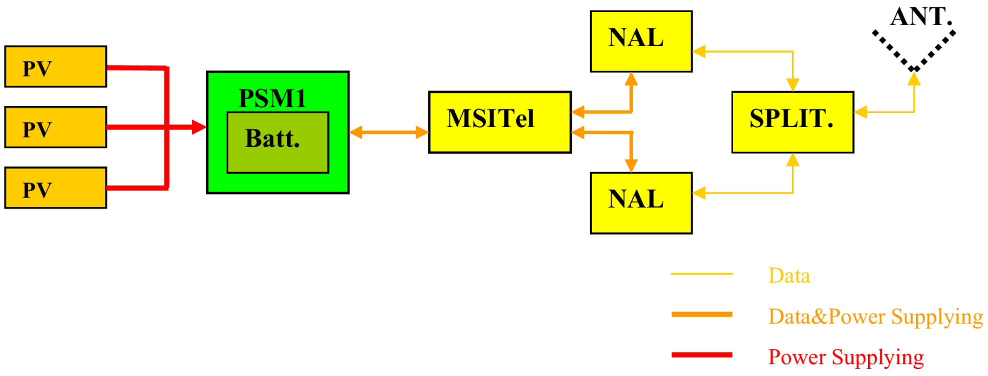

Fig. 1. The Flight PTTM block diagram.

other Scientific Observations), a small LDB experiment flown by Polar regions, which allowed a preliminary test of the IRIDIUM link Iarocci et al. (2008); Peterzen et al. (2005); Romeo et al. (2004). PEGASO carried a 3-component flux-gate magnetometer, because its scientific purpose was to investigate the earth magnetic field in areas not well covered by ground or satellite measurements.

MSITel main task is to interface I/O intelligent units and external instrumentations with a satellite communication system, based on the IRIDIUM technology. The Primary Telemetry/Telecommand Module (PTTM) is composed of one MSITel module and two IRIDIUM channels (for active redundancy/twice bandwidth) with a total data rate of 2.4/4.8 kbps (depending on operating mode). The Scientific Telemetry/Telecommand Module (STTM) is composed of six MSITel modules and twelve IRIDIUM channels with a total data rate of 14.4 kbps. The system includes power supply modules, both for the PTTM (PSM1) and the STTM (SPSys). They are able to interface themselves with different power sources, like solar panel arrays, batteries and fuel cells.

2. The MSITel module

The MSITel module performs the following functions: – management of two terminals IRIDIUM; – management of two integrated onboard GPS units; – polling of external instrumentations by commands and defined priorities from a dedicated macro language: the feature is implemented by a RS232 - IEE485 connection; – local I/O data acquisition as written in the macro language; – sending of telemetry data as defined in the macro language; – execution of telecommands sent by the ground console; – redirection of TCs addressed to external units (other payload modules) – onboard storage (on Compact Flash cards) both of scientific and h/k data. The MSITel module manages directly two IRIDIUM transceivers, model A3LA-D produced by NAL NAL Research Corporation - USA , one active and the other for backup (backup mode). The system may use one antenna for each transceiver or it could be equipped with power splitters to halve the number of antennas. An alternative operating mode (split mode) may be set to double the transmission band, from 2.4 kbps to 4.8 kbps, by using two transceivers at the same time. The module controls I/O units, both digital and analog, and six security outputs for no-back operations, like ballast release and flight termination. An important feature of the MSITel module is that, in case of temporary line-break, it provides automatically to attempt the connection restoring and to retransmit missing data lost during the blackout. Moreover, it provides both housekeeping and scientific data storage into non-volatile onboard memory. Communications between the MSITel module and external (payload) instru-

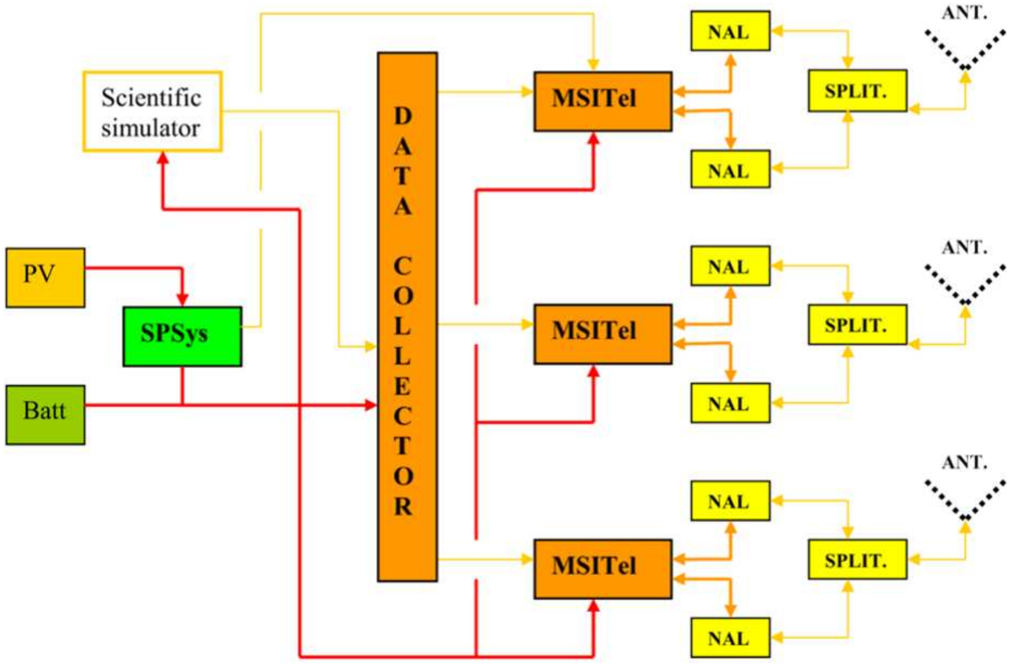

Fig. 2. The flight STTM configuration with three MSITel modules.

mentation are provided by high speed rate (up to 115 kbps) interface RS232 or IEE485. The I/O lines available are: – 8 protected digital inputs (0-5V); – 6 open collector digital outputs; – 4 analog inputs (internally digitized at 10 bits); – 2 analog outputs (coming from 10 bits DACs, 0-8V); 6 security outputs at 0.5A-40V.

One MSITel module is used to satisfy requirements of the PTTM unit (Fig. 1), that represents the basic unit for LDB flight management.

Since the STRADIUM STTM requirements were for a transmission baud rate higher than 2.4 kbps, the current configuration is made by an array of six MSITel modules (in Fig. 2 the configuration with three MSITel modules). In this configuration the STTM is equipped with an additional module, called Data Collector, that manages and distributes the scientific data flux to MSITel modules. The maximum number of MSITel modules that can be connected is 8, with up to 16 transceivers, to provide a nominal maximum bit-rate of 38.4 kbps. To satisfy stratospheric environmental requirements, MSITel has been successfully tested in a range of temperature from -50C to +60C and in the 01000 mbar pressure range.

3. The Power Supply modules

3.1. The PSM1 module

The PSM1 supplies the power to the PTTM MSITel module (and related IRIDIUM transceivers). PSM1 receives energy from three solar panels and provides 10W output (in sunshine). The solar array modules (amorphous Si) are disposed circularly, in order to have sun azimuth independence. The system (Fig. 3) is based on two separated switching regulators (step-down converters) and two batteries, to increase the system reliability. The load is connected to the system through an electronic switch. The Pb-Sn batteries have a capacity of circa 9.5Ah, so in case of no-sun conditions the power supply is guaranteed for 9 hours. The system is supervised by a

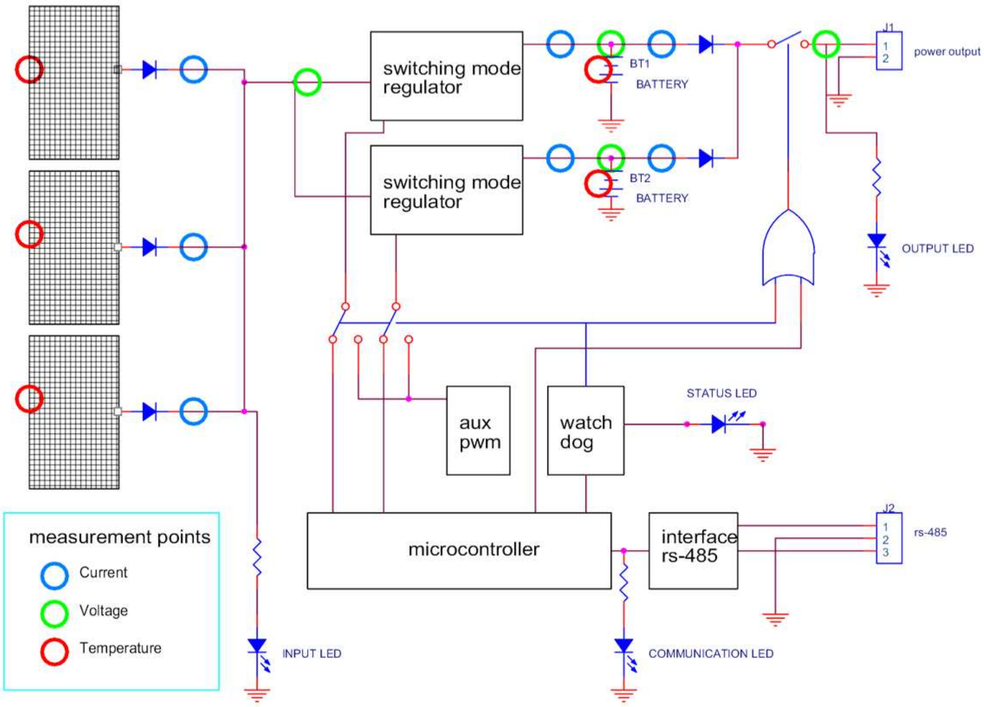

Fig. 3. The PSM1 block diagram.

microcontroller. Its main task is to optimize the power coupling between the solar array and the batteries, and, at the same time, to safeguard the batteries health. The battery charge voltage, in fact, depends on temperature. For this reason batteries temperatures, voltages and currents are internally monitored and included in a control loop with the two switching regulators. The goal is to get Maximum Power Point Tracking (MPPT) conditions, where the maximum power point varies continuously, depending on solar array temperature, radiation level and sun angle, batteries temperature and their charge status. Safe mode is guaranteed providing the system with an additional external watchdog. In case of microcontroller malfunctioning, the external watchdog excludes it and supplies switching regulators with a fixed Pulse With Modulation(PWM), as well as it switches on the load switch. So the MSITel is still powered and the batteries continue to recharge themselves. Moreover the system is able to exclude a battery in case of failure and to disconnect the load if the batteries voltage falls below critical values. The last action is needed to avoid a complete battery discharge. PSM1 communicates with the MSITel module by means of an RS-485 interface, sending its internal data when receiving a query from MSITel, to transmit its housekeeping data by telemetry.

3.2. The PSM2 (SPSys) module

SPSys is the module that performs full management of both STTM unit and scientific payload batteries, by supplying the power from available external sources (for example PV array). This unit, interfaced with MSITel through RS232 and IEE485 connections, manages solar panel array and up to three batteries groups; it provides output up to 20A @24V in MPPT or PWM mode. The SPSys module guaran-

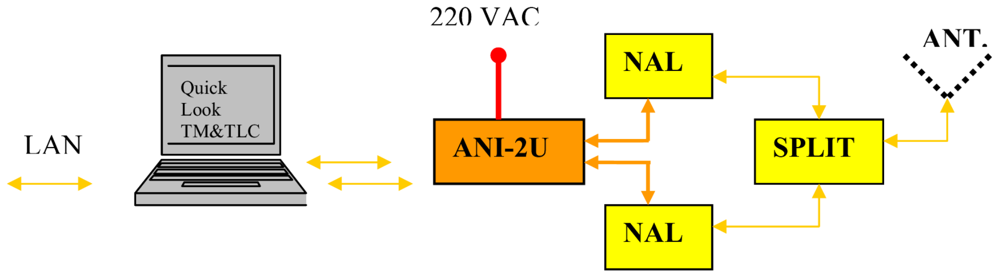

Fig. 4. The PTTM Ground Equipment.

tees that the recharge of each battery is performed considering their status of charge and temperature (the system can be equipped with different type of batteries). If necessary, the battery charge can be manually managed by user through telecommands sent by the ground station (PWM mode). The SPSys structure is modular, so up to 14 units can be connected to provide more output power to scientific payloads.

4. The PTTM/STTM Ground Equipment

The Fig. 4 shows the PTTM Ground Equipment (GE) block diagram . The two NAL transceivers, one active and the other for backup, are connected to the ANI-2U module. The latter supplies power to them and converts data and telecommands from the level RS232/IEE485 (characteristic of NAL transceivers) to USB 1.1 (and vice-versa). The Quick Look PC manages the link with the flight unit by means of a suitable procedure (MSITel_Link_Decode); moreover it decodes and sends data to other PCs through a LAN network. The format data transfer is TCP/IP compatible. The GE s/w for the PTTM, provides to: – start and/or maintain the link with the payload through MSITel; – receive data packets and store them into any available storage device; – decode and distribute received data via TCP/IP to other user programs. These programs may run on the GE PCs as well as on remote PCs; – send Telecommands (both single and stream); – make possible a routing technique to send commands not only to MSITel but also to other (compatible) onboard equipments (through MSITel); – full monitoring of housekeeping data, both in alphanumeric and graphic windows.

The STTM GE configuration is composed by n x PTTM GE configuration, where n is the number of MSITel modules of the STTM. It is guaranteed an independent and simultaneous management of the remote MSITel modules, both in up and down link. The Fig. 5 shows the typical configuration of the STTM GE in the case of three MSITel modules on-board the flight unit. In this case, the Quick Look procedure provides the following additional functions: – remote analysis; – real time quick look and data analysis by a lookup table; – data storage in database and binary format; – multiple IP address access for MSITel STRADIUM configuration; graphics facility for webcam inspection image decoding.

5. Conclusions

STRADIUM LDB represents an easy (and low cost) way to access LDB flights from Polar regions. No infrastructures are needed at all to operate full control and monitoring of LDB payloads. Ground Stations can be easily distributed everywhere, if needed, to access flight data simply by a Notebook PC wired/wireless connected to Internet. STRADIUM LDB is then a real support to LDB flights, even with complex payloads that require a near (true) real-time, bi-directional and continuous link. In its current configuration it can fulfil the needs of most of LDB payloads; it has still

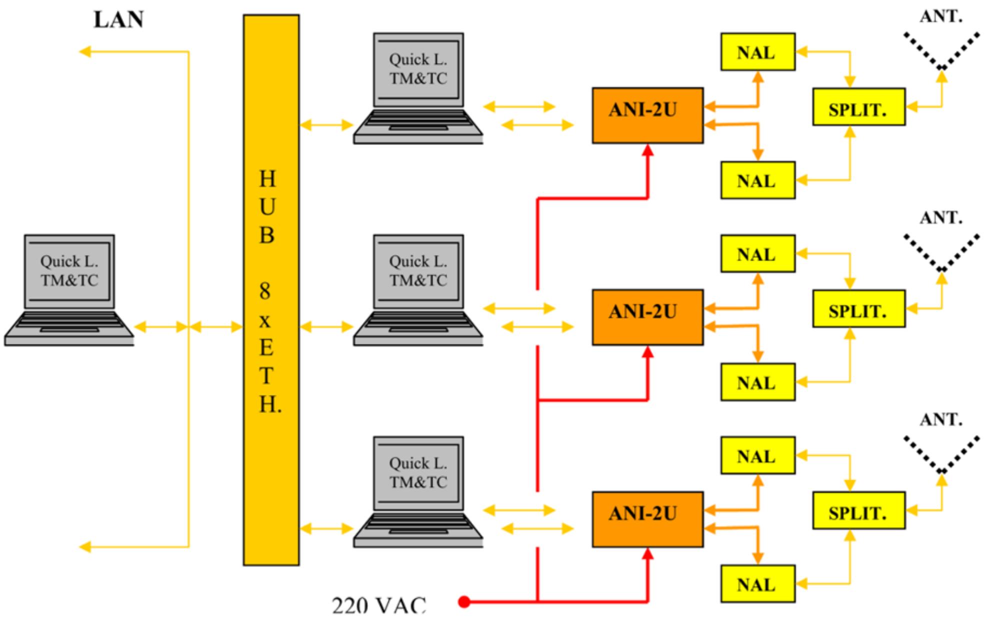

Fig. 5. The STTM Ground Equipment.

great capabilities for future developments. Last but not least, MSITel and SPSys modules can be used for remote control/monitoring of any instrumentation located everywhere.

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