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Generic S-Band Radio Frequency System for Earth Observation Leo Satellite

[1]L. Hadj Abderrahmane, [2]M. Benyettou, [3]P. Garner, [3]J.R. Cooksley, [3]M.N. Sweeting
[1]National Centre of Space Techniques, Division of Space Instrumentation, N°1, Avenue de la Palestine, BP13 Arzew-Oran-Algeria
[2]Department of Data Processing, Industrial Optimization and Modelling Laboratory, University of Sciences and Technology of Oran, BP 1505, El M'Nouar, Oran, Algeria
[3]Surrey Satellite Technology Limited, Surrey GU2 7XH, Guilford, United Kingdom

Abstract: The generic S band communication sub-andsystem is designed to support the mission and the telemetry/telecomand data. The imaging system is supported by a total storage capacity of 1 Gbytes of data which could be downloaded to a ground station within 10 min. The downlink and the uplink, both operate in S band at high rate (8 Mbps) in normal operation and low rate (38.4 kbps) during commissioning for the downlink and at amateur low rate (9.6 kbps) for the uplink. This study describes the different module constituting the generic S band communication subsystem.

Key words: Communication system, Receiver, Transmitter, Antenna, Downlink, Uplink, Imaging system

INTRODUCTION

The LEO satellite is an earth observation satellite which will evolve in a sun-synchronous retrograde circular orbit. It is equipped with cameras giving images from the earth with a certain spatial resolution in three spectral bands, the Red, Green and Near Infra-Red.

Most of the satellite subsystems are designed with no single point failure. Therefore, most of the critical subsystems for the mission are redundant, such as two receivers and two transmitters to communicate with the spacecraft (Garner, 2002; Maral and Bousquet, 1999; Wiley and James, 1992; peter and john, 1995).

RF system overviem: Figure 1 gives the different part constituting the RF system.

- In the downlink configuration, two modes are considered. For the commissioning phase, we have one S-band low rate transmitter operating with a low data rate equal to 38K4. This transmitter is connected to two monopoles. The cold redundant S-band high rate transmitters can be operated in two modes. The primary mode of operation is to download the payload data (and the telemetry data) at a data rate of 8Mbps. The secondary mode of operation is to act as redundancy for the low rate transmitter if it fails during commissioning and down loads the telemetry data at data rate of 38K4. Each high rate transmitter is connected through a dedicated QuadraFilar Helix (QFH) antenna. This antenna type shapes the gain pattern to oppose the change in path loss to give a constant power flux density at the ground station.

- In the uplink configuration, there are two hot redundant S-band receivers, operating at 9k6 and each one is connected trough two circular patch antennas.
- For the uplink CPFSK is used.
- For downlink during the commissioning phase, we use the BPSK modulation scheme, with scrambling, differential encoding and RRC filtering. For normal operations, we use the QPSK modulation scheme, with scrambling, differential encoding, RRC filtering and Convolutional encoding.
- There are five CAN nodes for the RF subsystem.

Each transmitter has a CAN node located in the exciter module. For the receivers, the CAN node is located in the VHF module.

Receive system description: The S Band receiver is constituted by two module: S Band down-converter module and the VHF IF module. Between the both exist one SMI connection (Smith, 2004; Hadj, 2002).

This receiver is constituted by the following modules:

Power supply unit : To deliver 5V required

Corresponding Autohr: L. Hadj Abderrahmane, National Centre of Space Techniques, Division of Space Instrumentation, N°1, Avenue de la Palestine, BP13 Arzew-Oran-Algeria

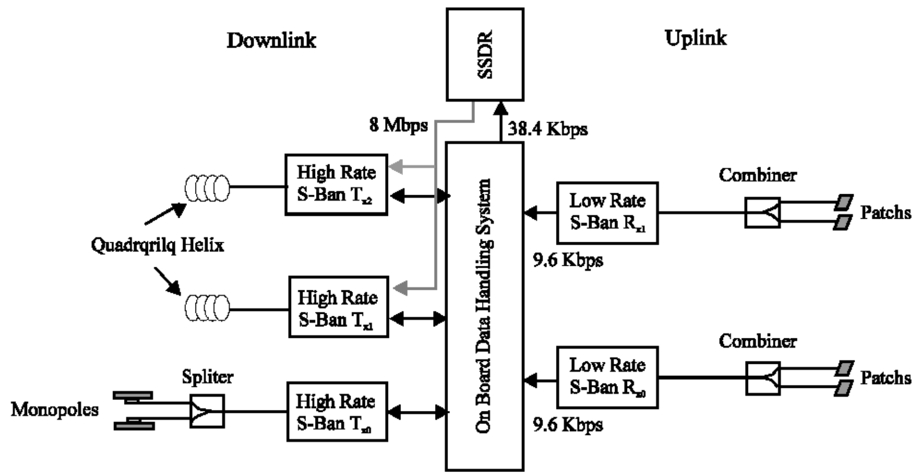

Fig. 1: The generic S band communication sub-system conceptual diagram

LNA: to must amplify the signal arriving at the antenna to a level at which they can be processed.

Receiver chip: This circuit comprises a narrow-band BPF, dual conversion FM receiver and local oscillator.

Frequency control: For frequency references with drift over temperature of around 1ppm, this gives a total drift of 2kHz over the whole temperature range. As a total frequency drift of 6kHz to 10kHz will be acceptable. The CAN controller pulse width modulator output will be routed to the S-band down converter local oscillator as a back-up frequency correction measure.

Demodulator : The uplink modulation scheme to be used is 9K6 baud FSK. The received data can be either synchronous or asynchronous, with a recovered clock being generated by the FSK demodulators. There is a de-scrambler, which are used to recover the transmitted data by locking with the recovered clock trough a flip-flop. The baud rate generator is used to produce all the required frequencies needed to make the demodulators work.

CAN andnode: The VHF module is connected to the CAN bus by a CAN node. The CAN architecture consists of a CAN micro-controller and an external EPROM. The CAN micro-controller on the receiver module provides a serial bus interface through which system telemetry data can be monitored and andtelecommands can be used.

TRANSMIT SYSTEM DESCRIPTION

The spacecraft has two different transmitters on board, one LRT for commissioning mode and two HRTx for normal operations.

The Low Rate Transmitter (LRT) will be connected to two monopole antennas via a power splitter. The monopoles were chosen as they could deliver a near omni-directional gain pattern about the spacecraft which is most suitable for when the spacecraft is tumbling.

The High Rate Transmitter (HRT) is constituted by three modules: the Exciter, the HPA and the PSU. Different SMI and coaxial connections exist between three modules.

Commercial S-band use: The commercial S-Band requirement is necessary for both LRT and HRTx. It is proposed to design a generic Exciter PCB that can be used for both the HRT and the LRT by changing only a handful of components and the programming of the FPGA.

Higher output power: A power of 4W is required for HRT. This is taken care of in the High Power Amplifier (HPA) Module. This module consists of a driver amplifier (output power of 1.5 W), a power amplifier (output power until 8 W) and a Bias Opto-Isolator Driver. The module include also a Power Supply Unit. It consists of an additional andNanotray module required to house the PSU for the HPA.

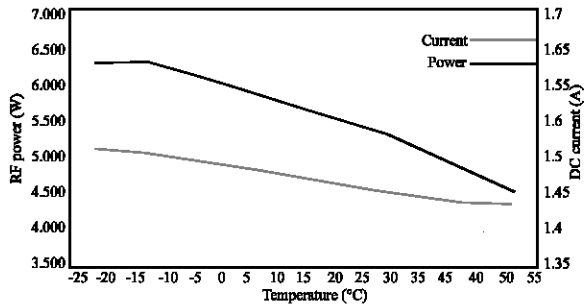

Fig. 2: RF output power and current versus temperature

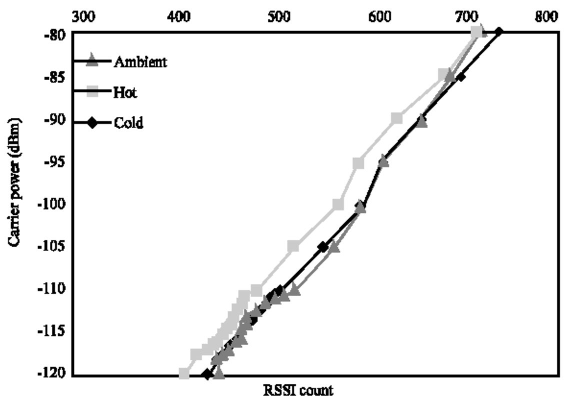

Fig. 3: RSSI profile versus temperature

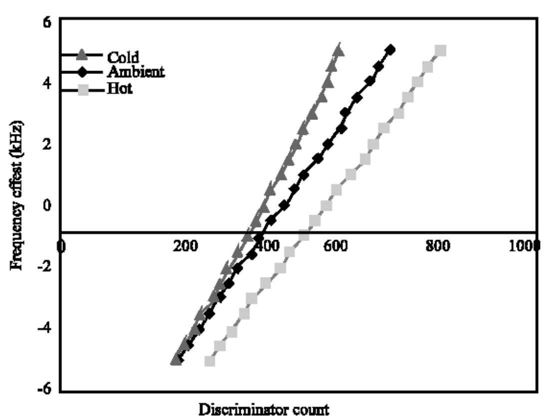

Fig. 4: Discriminator profile versus temperature

RESULTS

RF output power and module current versus temperature: The nominal DC Current requirement is 39.2W (Fig. 2). 38K4 BPSK RF power is 0.8W to 1.3W over the operational temperature range.

RSSI profile: By adjusting the carrier power with 1dB increments/decrements and record the Receive Signal Strength Indicator (RSSI) data. The test should be performed at ambient, -20°C and +50°. Figure 3 shows that a little variation on the RSSI profile is recorded regarding the temperature variation.

Discriminator profile: By varying the input carrier frequency in 0.5 kHz steps from F_C to F_C +/- 5 kHz, for each step one record the discriminator telemetry. The discriminator test should be performed at ambient, -20°C and +50°C. The frequency offset is very sensitive to the temperature Fig. 4.

Power consumption: The receivers require a 5V as voltage supply. The DC/DC converter from 28V unregulated bus is used to provide a 5V line. The power consumption for each receiver is about 1.5 W DC.

The LRTx used for commissioning phase only requires 200 mW RF output power and draws about 5.6W DC required from 28V unregulated bus. The HRTx requires 4W RF output power and draws about 41W (max.) DC required from 28V unregulated bus.

Antenna system: The pattern for Tx and Rx is symmetrical around Z axis (Cooksley, 2001, 2004; Allen, 1990; Balanis, 1997; Ott and Lindenblad, 1999; Janse, 1989). The antenna type that we have choose

- Two (02) Quadrafilar Helix Antenna left circularly polarised and has a gain of approximately 4.72 dBi peak (Boland, 2002).
- Four (04) circular Patch right circularly polarised and have a gain 7 dBi each one.
- Two (02) monopoles antenna with a gain equal to 2.14dBi.

CONCLUSION

The RF output power of both HRTs during BPSK low rate operation is less than 4W. However, the HRTs would only be used in BPSK low rate mode if the LRT were to fail during the commissioning period. andThe HRTs during QPSK high rate operation (8Mbps) is greater than 4W. QFH should have at worst a gain of -10dBi at bore-sight, leading to a worst case EIRP again of around -10dBW.

The spacecraft carry two S-band RX modules, each comprising of 2 nano-trays.

In conclusion, the RF system allows the communication with earth. The system is configured as follow:

- One low rate S-band transmitter for the commissioning mode.
- Two hot redundant S-band receivers.

- Two cold redundant S-band transmitters.
- One monopole, two QFHx and two circular patch antennas (earth facing facet).
- One monopole and two circular patch antennas (space facing facet).

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