

ALCATEL 9910 OMNISAT: A NEW MODULAR, ANY MISSION EARTH OBSERVATION DATA ACQUISITION SYSTEM

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1. ABSTRACT:

In the last three years, novel techniques have allowed a drastic evolution of earth station architectures for remote sensing. An Earth Observation data reception station has evolved from a collection of discrete equipment into a PC based, integrated and modular device, built on most recent technology, being field upgradeable and capable of advanced modulation schemes (8PSK and GMSK), and allowing multi-channel reception with channel bit rates up to 500Mbit/s. This evolution has resulted in the reduce of cost of ownership and maintenance for the Earth Observation ground infrastructure. The EO satellite market is presently booming, where more countries decide to operate their own EO satellite and ground station infrastructure system. Moreover higher image resolutions are required, pushing to higher transmission rates. Since many years, Alcatel Alenia Space Antwerp offers its versatile OMNISAT demodulator to the EO satellite market, capable of handling data streams from a wide variety of Earth Observation Satellites (currently, data streams from more than 60 satellites are being demodulated worldwide with OMNISAT equipment). Meanwhile, Alcatel Alenia Space Antwerp has concluded the development of the third generation of the OMNISAT demodulator, and presents its new earth observation data acquisition system: the Alcatel 9910 OMNISAT. This paper describes the architecture of the OMNISAT equipment, which is based on the latest System On Programmable Chip (SOPC) technology, supporting a variety of modulation - and decoding schemes, allowing for the reception of a large set of earth observation satellite signals and handling the storage of the processed data stream.

2. INTRODUCTION

The Alcatel 9910 OMNISAT integrates signal processing functions of a complete receive chain (from RF signal to the decoded bit-stream) into one single, but modular equipment. The functionality is split over an X-Band Down converter (XDBC), a High Data Rate Demodulator (HDRD), a Data Ingest and Front End Processor (FEP) and a Quick-Look-Viewer.

A High Data Rate Test Modulator (HDRM) and a Data Replay module provide a full loop-back test functionality.

The Alcatel 9910 OMNISAT is capable of generating, demodulating and processing signals with bit-rates up to 500 Mbit/s. The functionality is hosted into a COTS industrial PC platform, to provide a flexible and modular device as core building block of future acquisition facilities.

The Alcatel 9910 OMNISAT, is an all-in-one solution for a complete Earth Observation station, and as such perceived as “State of the Art” .

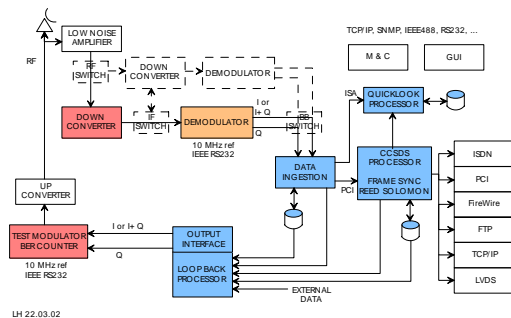


Figure 1. A9910 OMNISAT functions in a typical Earth observation station



Figure 2. OMNISAT chassis with opened keyboard drawer

Please refer to Figure 3, showing a block diagram of a typical OMNISAT equipment configuration. The architectural design of the individual functional building blocks of the OMNISAT equipment is presented thereafter.

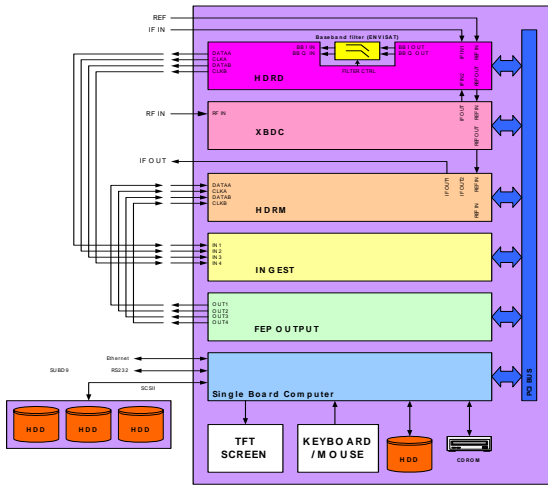


Figure 3. A typical Alcatel 9910 OMNISAT configuration

3. HIGH DATA RATE DEMODULATOR (HDRD)

The HDRD is a single PCI board, which contains all the analogue and digital circuitry. The main function of the HDRD is to receive a digitally modulated IF signal and to deliver at its output the digitally demodulated (and decoded) data.



Figure 4. Demodulator board

The HDRD can cope with a variety of modulation schemes: BPSK, QPSK, OQPSK, Unbalanced QPSK and Asynchronous QPSK; the HDRD roadmap includes the application of 8PSK. The maximum symbol rate of the IF signals is up to 250 Msym/s (that is 250 Mbit/s BPSK, 500 Mbit/s QPSK, 750 Mbit/s 8PSK).

The HDRD IF input frequency can be selected within the range from 70 MHz to 850 MHz (typical values are 375 MHz, 720 MHz, 750 MHz). The demodulator performs very fast carrier frequency acquisition (acquisition time = 250 ms) by employing FFT-based frequency estimation algorithms.

The HDRD analogue front-end performs optional IF filtering, amplifier gain adjustment and complex (I,Q) down conversion

to zero IF. The complex base band signal is then low pass filtered and sampled by two analogue to digital converters.

The remaining functionalities of the demodulator are implemented in programmable digital hardware, and are implemented using Field Programmable Gate Arrays (FPGA).

A PCI interface chip on the HDRD board allows the communication between the PCI bus of the host computer and the digital hardware on the demodulator board.

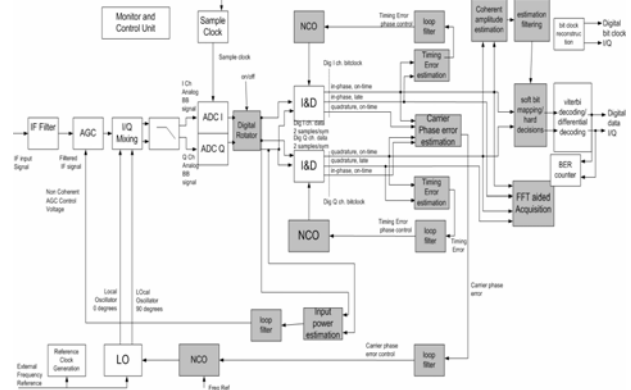


Figure 5: Demodulator block diagram

The HDRD has two digital data outputs (ECL) and two corresponding clock outputs which are directly accessible from the back panel of the equipment. In order to support a variety of extra digital output requirements, a dedicated Digital Output Board has been developed. The internal connection of the board to the HDRD is done in way that a maximum of 8 demodulator digital outputs can be provided (differential data + clock for data1, data2 or merged data 1+2). Additionally, the dedicated output board provides alternative electrical interfaces such as LVDS, RS422, TTL, and an Optical interface.

4. X-BAND DOWNCONVERTER (XBDC)

The X-band Down Converter converts the RF 8.0 to 8.4 GHz input band to a fixed IF frequency of 720 MHz. The IF output of the XBDC is internally connected to one of two IF inputs of the HDRD.

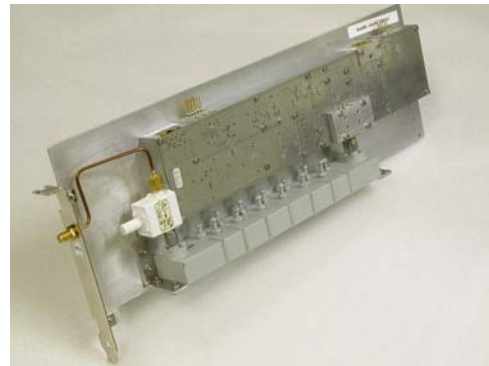


Figure 6. Down Converter board

The XBDC physically consists of an external RF band-pass filter and a shielded module, with the following functionalities: power supply filtering, RF input chain, LO and reference generation, IF output chain and monitoring and control. A single down conversion stage is used for reasons of cost and implementation simplicity.

An XBDC module has the width of two full size PCI boards..

5. HIGH DATA RATE MODULATOR (HDRM)

The HDRM is developed for testing purposes: it generates a digitally modulated IF signal that can be used in loop-back tests. Therefore, the HDRM has two IF outputs; one is connected to a IF input of the HDRD (internal loop back), the other is connected to a N-type connector on the back panel of the equipment (for external loop-back tests).



Figure 7. Test Modulator board

The HDRM supports the same modulation schemes as the HDRD, and the same range of IF frequencies.

The in-phase and quadrature test bit streams are either internally generated by Pseudo Random Pattern Generators, or taken from external data-clock inputs. In the baseline equipment, 4 ECL interfaces are provided on the HDRM board for the data and clock inputs of the external modulation data. A separate dedicated Digital Input Board (DIB) has been developed to support other electrical interfaces (LVDS, RS422, TTL, Optical) when needed. The HDRM is a single PCI board containing all the analogue and digital hardware circuitry. The PCI bus interface allows the HDRM modulator functions to be monitored and controlled via the standard COTS computer.

The HDRM board also contains a fixed noise source of which the output can be added to the IF signal. This feature supports testing of signal to noise ratio conditions, ranging from 0dB to 18 dB Es/No.

6. DATA INGEST AND FRONT-END PROCESSING

The ingest boards receive data and clock from the High Data Rate Demodulator via external wiring, and host the frame synchronisation functionality of the receive chain.

One ingest board is capable of handling the full bit rate for BPSK and QPSK; two ingest boards are needed in case of Asynchronous QPSK (AQPSK / UQPSK).

The Data Ingest and Front-End Processing (DIFEP) subsystem is a high performance data acquisition and first-level processing system.

The FEP Subsystem ingests and processes telemetry data from data+clock to Front End Processing (FEP): production of annotated raw data (VCDU) and ISP's reconstruction (Instrument Source Packets).

It consists of different HW and SW functions. On the HW board, data ingestion is performed with the following HW functions, at high bit-rates: Frame synchronisation, Reed-Solomon with Interleaving, descrambling and CRC. These functions which are highly configurable, are fully compliant with the CCSDS standard and support a wide range of other missions.

The DIFEP software functions are able to process the telemetry data (reconstruction of the ISP's by demultiplexing the VCDU's following their Virtual and Physical ID) following the CCSDS "AOS" and "PT" standards, mission specific Quick-Look processing and viewer, data reversing and packet decryption.

Each Telemetry data processing software module performs a specific task. Several modules may be linked together forming a complete processing chain, or run separately for stepwise processing. For multi-channel missions, several processing chains may run in parallel. The linkage between subsystems may be disk and/or IPC mechanisms, thus, providing a large number of processing combinations..

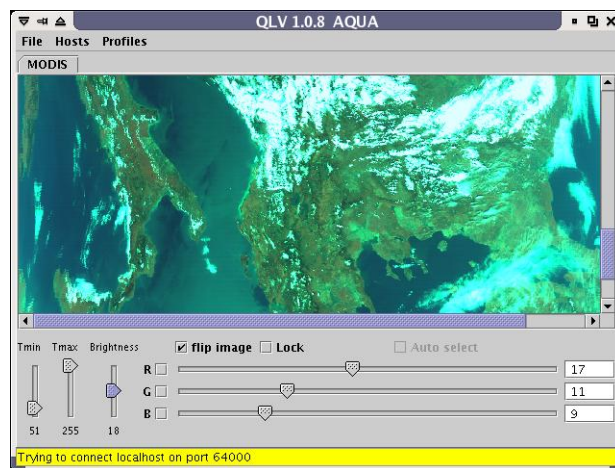


Figure 8: A9910 Image Quick-look-viewer

7. DATA REPLAY OUTPUT BOARD

The Alcatel 9910 OMNISAT can be equipped with one or two output boards that host playback functionality. These Front-End Processing output boards transform the stored data into a data+clock signal which can be fed to the input of the High Data Rate Modulator.

In case of Asynchronous QPSK, two output boards are needed for full playback capacity.

One or two output boards are foreseen for the FEP playback. The Front-End Processing output boards or Data Replay Package (DRP) can be used to play back and send data files to the connected test modulator. It transforms the stored data (Frames with synchronisation markers) into a data+clock signal, which can be fed to the input of the High Data Rate Modulator. The data supplied from either file/memory on the host computer or preloaded data from a large on-board RAM buffer is cyclically replayed into a data+clock signal, which can be fed to the input of the High Data Rate Modulator. In the local RAM buffer mode, an output rate of up to 500 Mbit/s is ensured.

The DRP Output Board consumes no bandwidth on the PCI bus when using the local RAM buffer as source for output data, which makes it an excellent solution for short loop testing directly towards the data ingestion system. Also long loop testing via data transmission and reception chain is a task which is ideally performed by the DRP Output Board. Other typical applications are pre-pass testing, for decryption of encrypted data through a decryption unit or for long-loop testing..

8. STORAGE OF ACQUIRED DATA

A scalable disk array can be connected to the Alcatel 9910 equipment to ensure the data storage of the received data. The Wide-Ultra 320 SCSI disks are well suited to insure the reception of all data during the satellite pass. In addition, the Wide-Ultra 320 SCSI RAID controllers can be used to allow for striping, to balance the data load on several disks, and to increase the fault tolerance of the equipment.

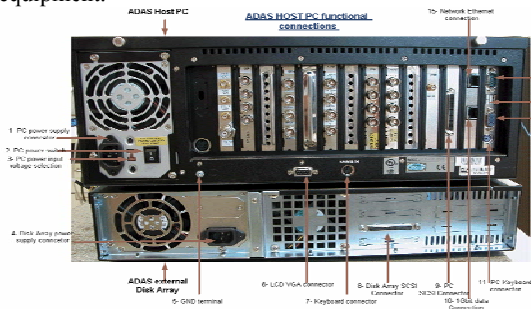


Figure 1: A9910 Storage/Backpanel view

9. OMNISAT HOST COMPUTER

The OMNISAT Host Computer is a 4U height, 14-slot rack-mount COTS Industrial PC with a 6.4" LCD display, built-in slim keyboard and Touch Pad drawer. The chassis is depicted in Figure 9. The PC's backplane (PCI), hosts the processor board (an SBC - Single Board Computer) and the OMNISAT specific boards (HDRD, HDRM, DIFEP).

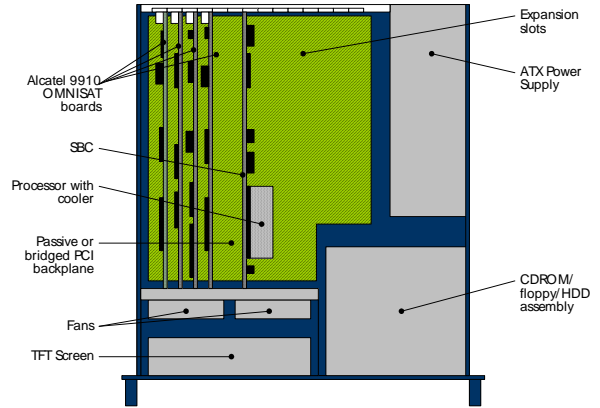


Figure 9. Alcatel 9910 OMNISAT hardware

Up to 12 slots are available; examples of full configurations are given below:

- XBDC (2 slots) + HDRD (2 slots) + DOB + HDRM (2 slots) + DIB + DIFEP (2 slots), a complete receiving system for low cost configurations;
- 4 HDRD + 4 DOB, four channels in parallel;
- 2 DIFEP, two channels data ingest and front-end processing.

The Single Board Computer is equipped with a Pentium 4 processor, contains 1 Gbyte RAM and supports a 64-bit / 66 MHz PCI bus. An on-board Ultra-320 SCSI controller allows the use of high speed storage. Optionally an external SCSI RAID controller can be used, depending upon the required performance. The board also contains a dual 10/100/1000Base-T Ethernet, BCM5703/5704 controller (64-bit PCI-X).

The SBC operating system is Linux, with RTAI real-time extensions to support high-speed interaction with the OMNISAT specific hardware. The performance of the Linux operating system is both processing - and cost efficient, and is well proven in other AASA products..

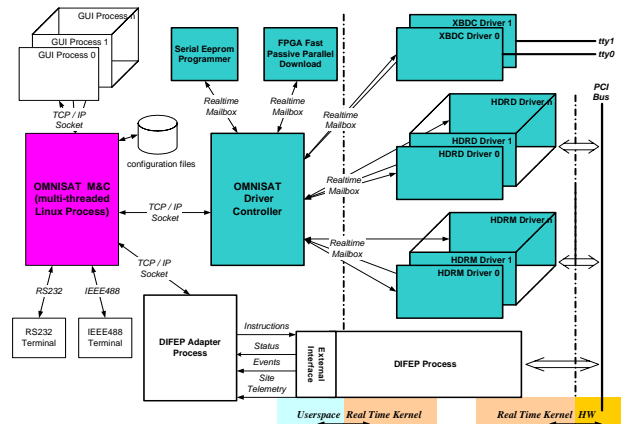


Figure 10. Software architecture

The Single Board Computer hosts the OMNISAT monitoring and control software, which is socket based. This Software architecture allows several monitoring clients and one control client to connect to the system (via TCP/IP) at the same time. Clients can run either locally or remotely. Examples of clients are the GUI (a local client), the operational control centre or the RS232 interface..

10. MONITORING & CONTROL

The monitoring and control software is socket based. It allows a number of users to connect to the system via TCP/IP. The monitoring and control software always runs locally on the equipment itself. It provides a unique interface to the various Alcatel 9910 OMNISAT subsystems.

11. GRAPHICAL USER INTERFACE

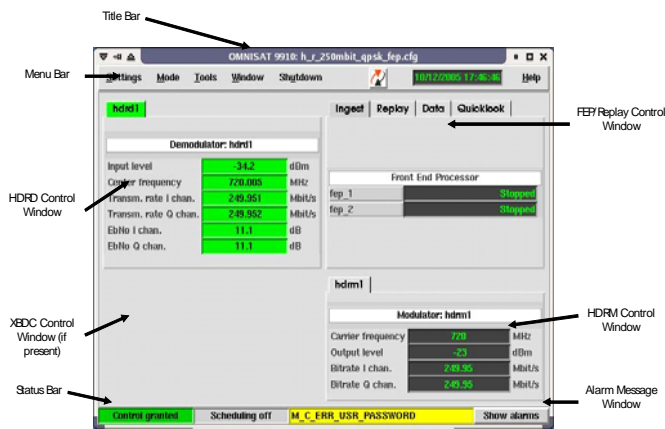


Figure 11 : Graphical User Interface

All Alcatel 9910 OMNISAT functions are operated from the graphical user interface, or GUI, which provides a user-friendly interface to the equipment monitoring and control software. The GUI connects via a socket interface to the monitoring and control software. (See Figure 11) The GUI can run locally on the equipment, or remotely (on following platforms: Linux, Unix, and optionally Windows). Notice that FEP and DRP functions can only be controlled by the GUI when it runs locally on the equipment..

12. SCHEDULING FUNCTION

The scheduling function allows for the complete automation of system operations according to a spacecraft pass schedule over earth station.

13. SOFTWARE AND MISSION CONFIGURATION UPGRADE

A software upgrade and / or mission reconfiguration is possible at customer premises by means of a CDROM, USB or Ethernet interface, without returning the equipment to Alcatel Alenia Space Antwerp.

14. INTEGRATED MEASUREMENT TOOLS

The Alcatel 9910 OMNISAT contains a host of digitally integrated measurement functions. The equipment offers visualisation of all conventional test points on its front-side TFT screen, thus omitting the need for space-consuming external measurement equipment.

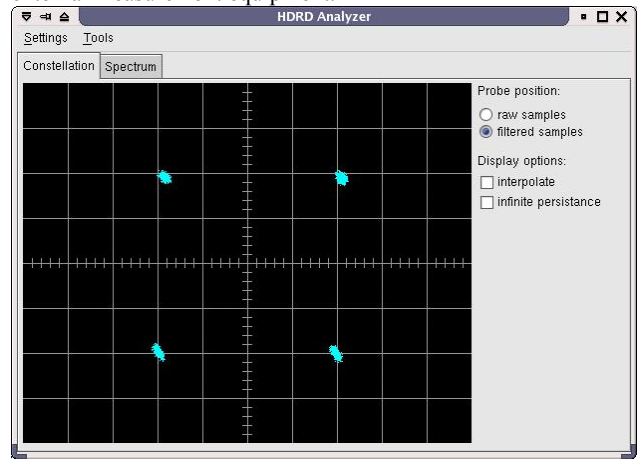


Figure 12: Constellation Analysis Mode

In Constellation Analysis mode, the HDRD Analyzer displays a real-time monitoring of the signal constellation, sampled at the output of the matched filter, at 1 (optimum) sample per symbol.

In other words, in a 'blink of an eye' the experienced operator can derive information from the XY diagram, that summarises a long list of monitor parameters.

In Spectral Analysis Mode, the HDRD Analyzer allows a spectral analysis of the complex base band signal, seen at the demodulator's analogue-to-digital converters input.

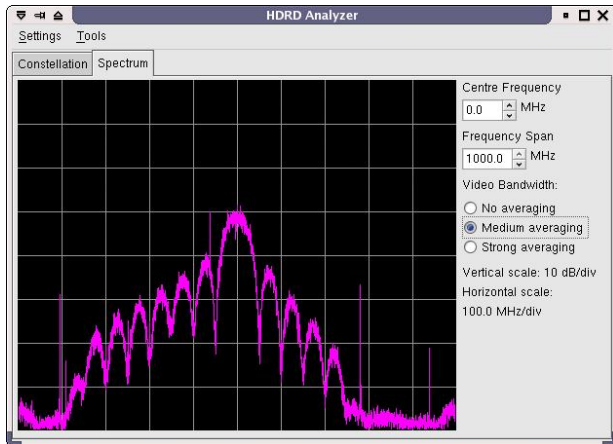


Figure 13: HDRD Analyzer in Spectral Analysis Mode

- Unmanned Aerial Vehicle is a suitable Earth Observation application for the Alcatel 9910 OMNISAT, if used as a compact mono-mission data acquisition system, to receive, demodulate and process the data captured by the UAV's to a first low resolution image (for the optical sensors), or further distribute in real time the raw data packets to a higher level image processor.

The Alcatel 9910 OMNISAT: A new generation product with latest technology.

15. CONCLUSIONS

Thanks to its modular design, the Alcatel 9910 OMNISAT is the ideal receiving equipment for all earth observations stations.

The Alcatel 9910 OMNISAT integrates most signal processing functions into one multi-mission device, supporting unattended operation, thus resulting in:

- Lower integration costs & complexity;
- Lower operation costs;

The Alcatel 9910 OMNISAT is compatible with previous and new generation EO missions;

- Long term investment (for the future).

The Alcatel 9910 OMNISAT is flexible/modular to address several market segments characterised by:

- Pricing range;
- Range of functionalities.

The Alcatel 9910 OMNISAT addresses all EO ground-station operation needs:

- Integration of additional functions in one device;
- Flexibility and ease to support;
- Higher bit rates;
- New demodulation / decoding schemes.

Typical applications of the Alcatel 9910 OMNISAT include:

- All-in one compact solution for small multi-mission, easily deployable Earth observation stations;
- Major building block for the high-end multi-mission, multi-channel Earth Observation stations. With modulation and demodulation schemes for higher information data rates and advanced coding schemes for improved error rate reception;