MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

CubeSat Payload for Environment Data Collection

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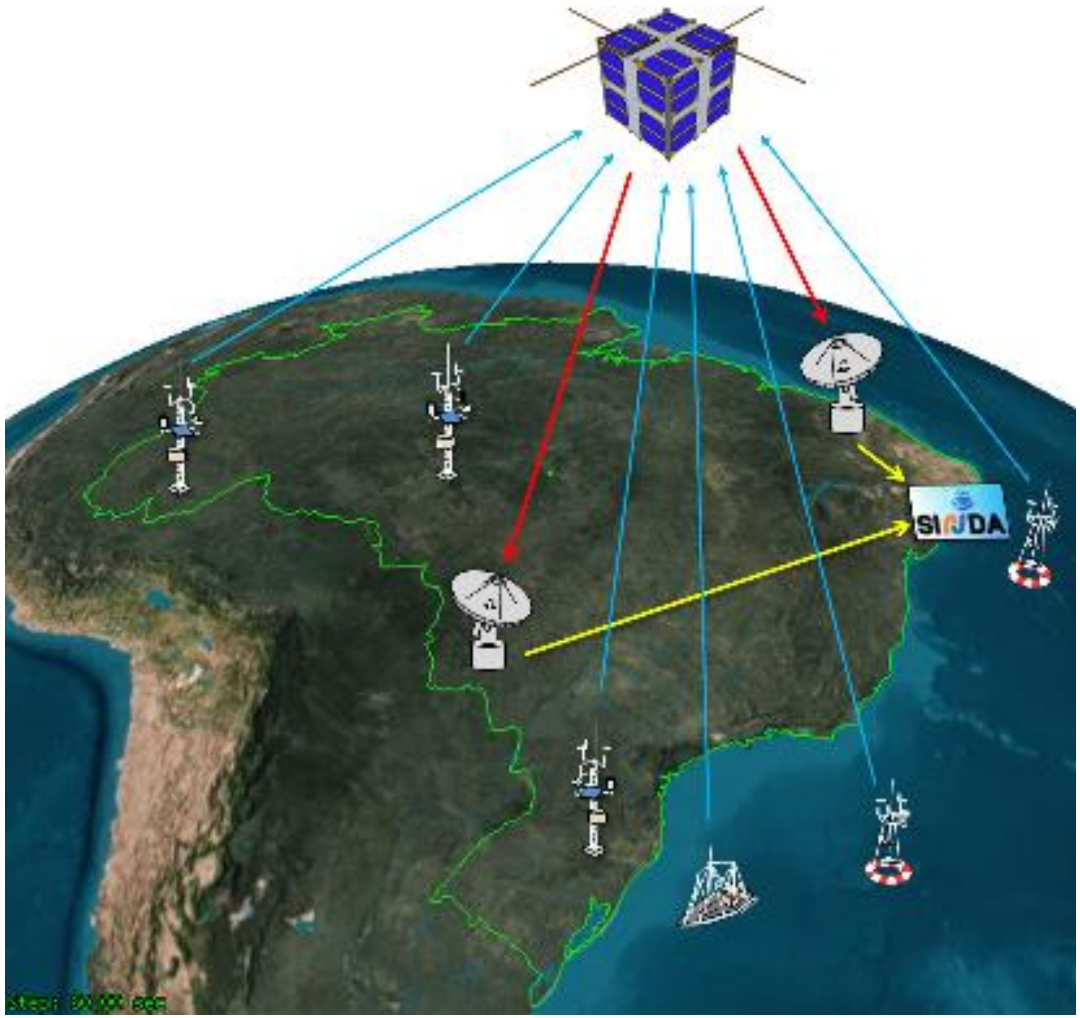
BRASIL GOVERNO FEDERAL

Introduction

- Project Objective
  - Develop a low-power and low-cost CubeSat payload for the Brazilian Data Collection System (BDCS)
- Motivation
  - Existent demand to renew and expand the BDCS constellation;
  - CubeSat low cost and easy development;

BDCS

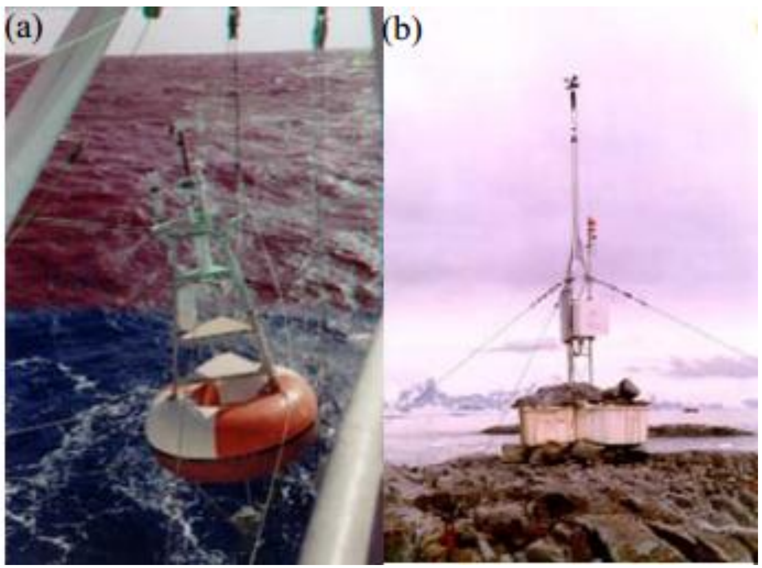
- Data collection and geolocation system based on LEO Satellites (aprox. 750 km). It uses UHF band, and its application is restricted to environmental monitoring and human life-protection.
- Composed of
  - Aprox.600 Data Collection Platform (DCP);
  - Satellites: SCD1 (1993), SCD2 (1998), CBERS-4 (2014);
  - Receive Ground Stations (RGS): Cuiabá e Alcântara;
  - Data Center: Natal;
- Compatible with ARGOS-2
- The system coverage is limited to Brazilian territory;
- **Service provided free of charge**.

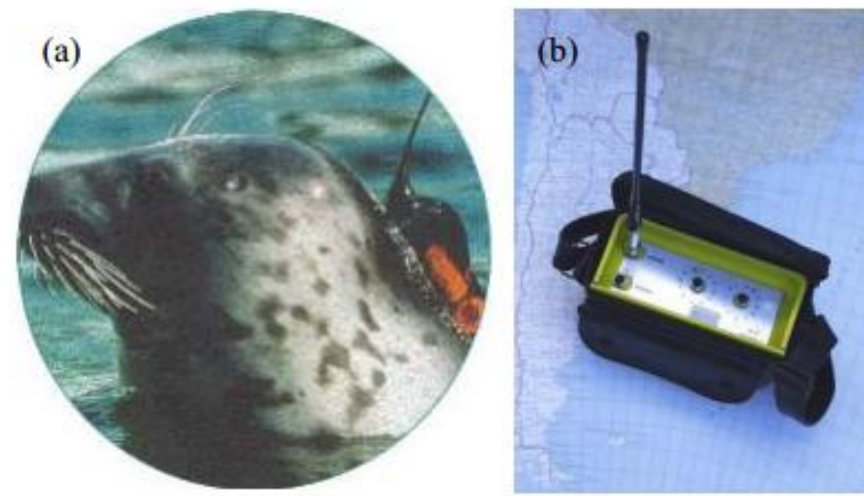


BDCS illustration

Data Collection Platform

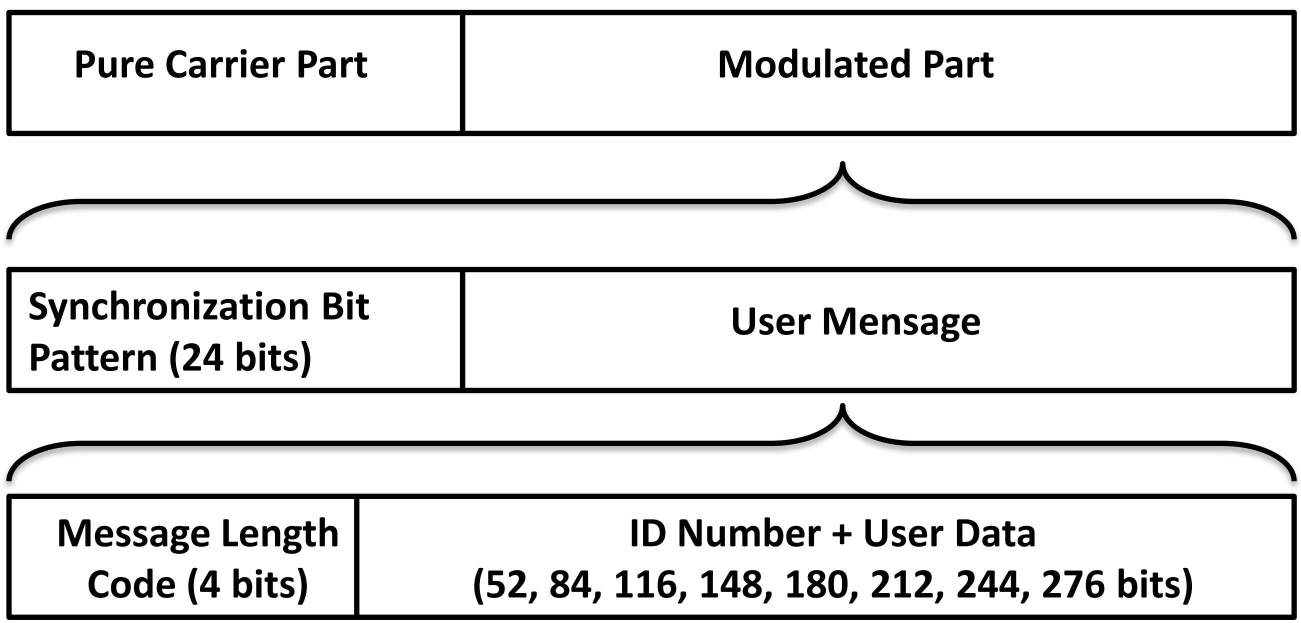
- The system has currently around 600 DCP.





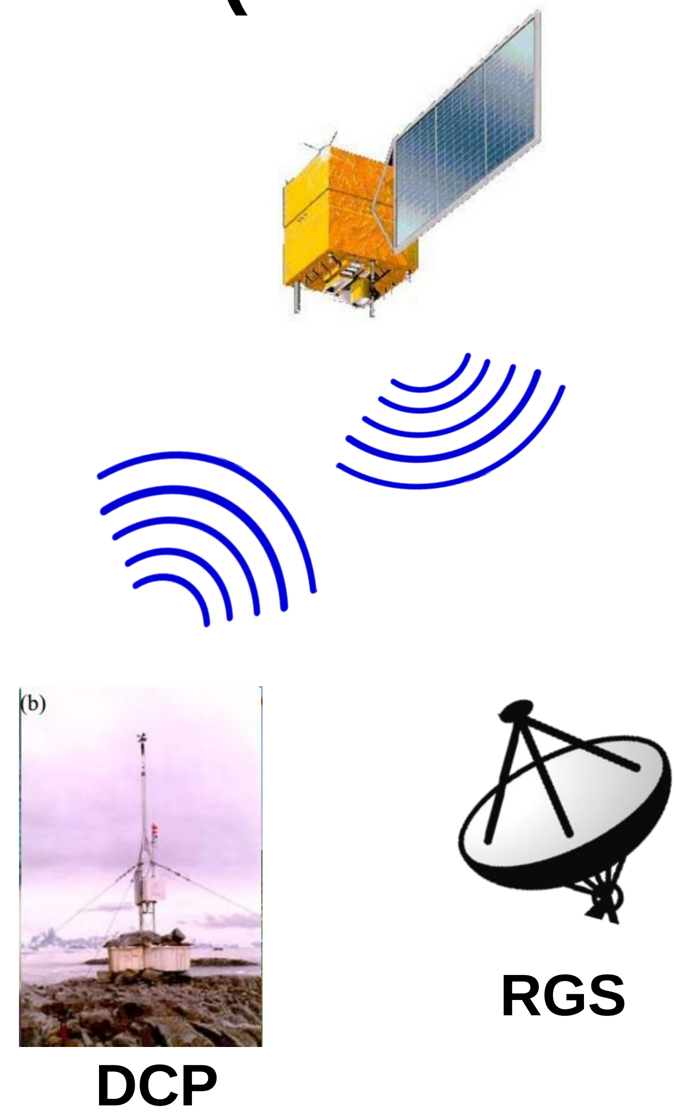
Platform Transmitter Terminal (PTT) Message Format

- Variable length (maximum of 256 bits), 400 bps, Manchester coded, ±π/3-PSK, pure carrier preamble, Fc=401.635MHz ±30kHz, retransmission time >60s



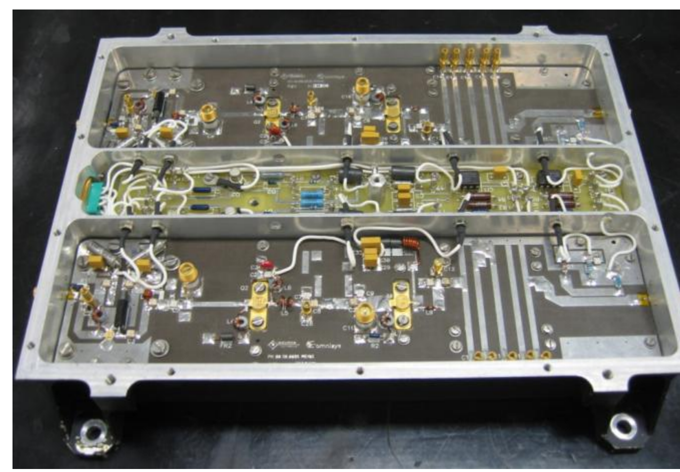
Data Collection Transponder (DCT)

- Retransmission through analog modulation:
  - Limited coverage due to the simultaneous line of sight requirement between PCD-Satellite-RGS;
  - High power consumption;
  - Signal distortion;
- Based on space qualified components
  - High reliability;
  - Very high cost;



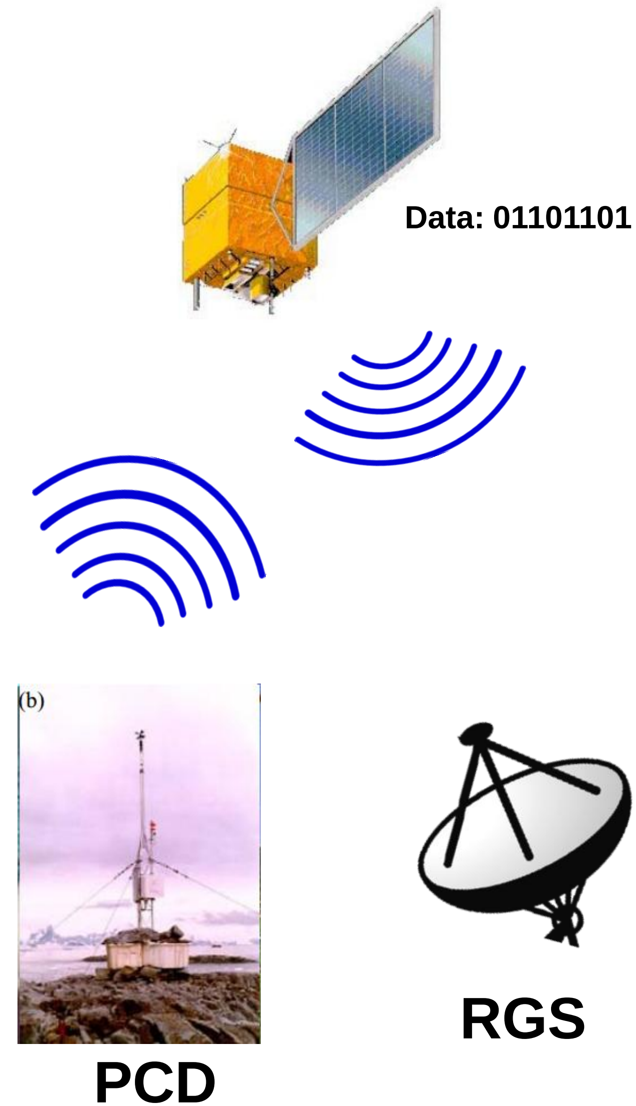
DCT Specification

- Receive frequency: 401.635MHz
- UHF transmitter 3W
- S-Band transmitter 100 mW
- PM Modulation;
- Reliability: 0.968 for 7 years
- Power Supply 16.8 V
- Power Consumption 18.2W (active mode), 4.7W (passive mode)
- Mass <17 Kg
- Manufactured by Omnisys



Environmental Data Collector (EDC)

- On-board Decoding
  - Global coverage;
  - Downlink using the satellite telemetry channel
  - Better performance;
  - Lower mass and power consumption;
- CubeSat compatible;
- Based on COTS:
  - Lower cost;
  - Lower reliability;



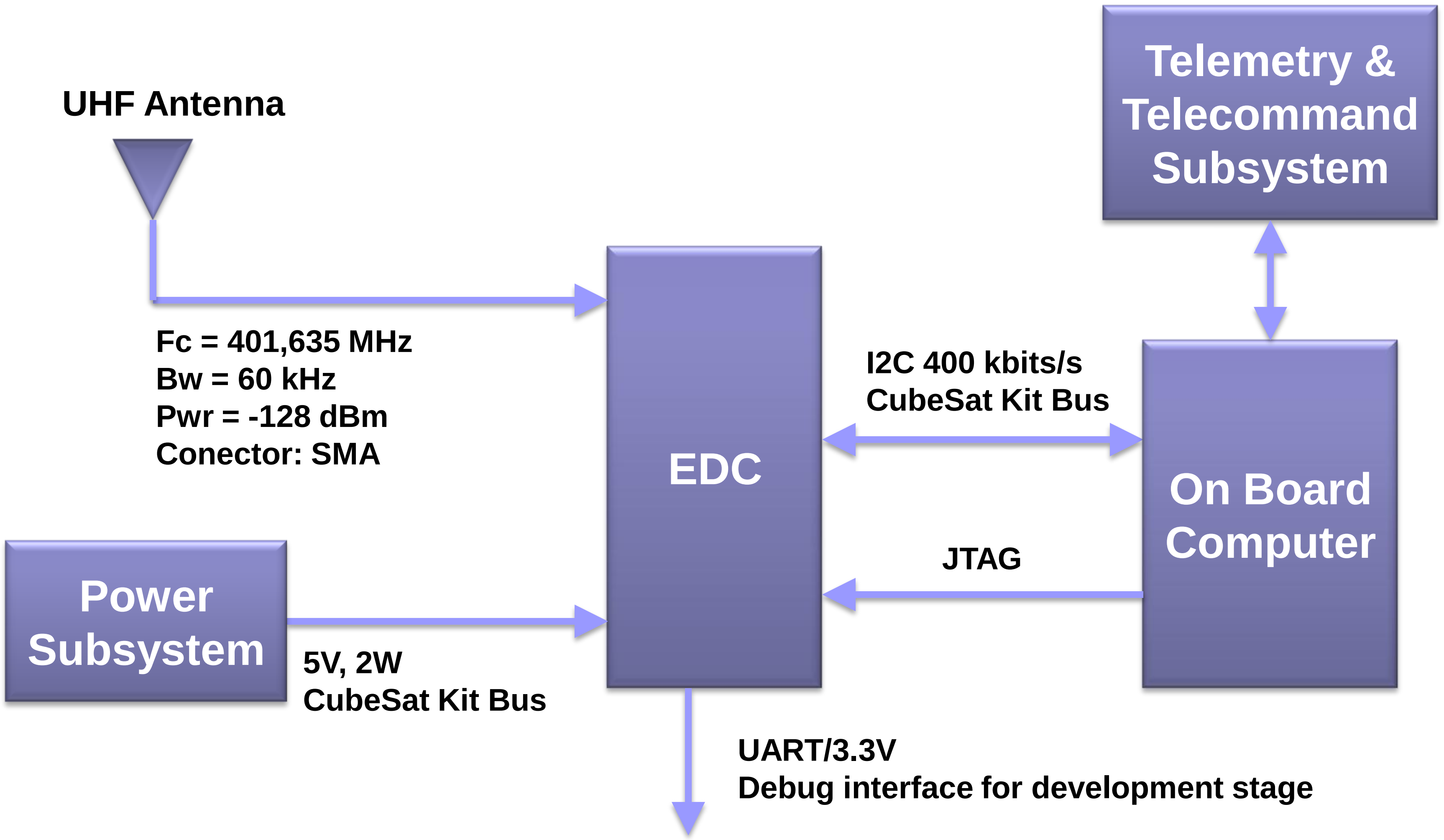
EDC Functional Specification

- Decode BDCS and ARGOS II signals in 401,635 MHz ±30 kHz;
- Decode up to 12 PTTs signals simultaneously;
- Decode sensibility of -132 dBm;
- Attach receive time, frequency, and power information to decoded messages with resolution of <10ms, <0.5Hz and <2dB respectively;
- Provide decoded messages and housekeeping to the OBC.

Electrical and Mechanical Specification

- Power source: 5V; <2W;
- Dimensions: 95,89 mm x 90,17 mm X 30,00 mm;
- Mass: < 250g;

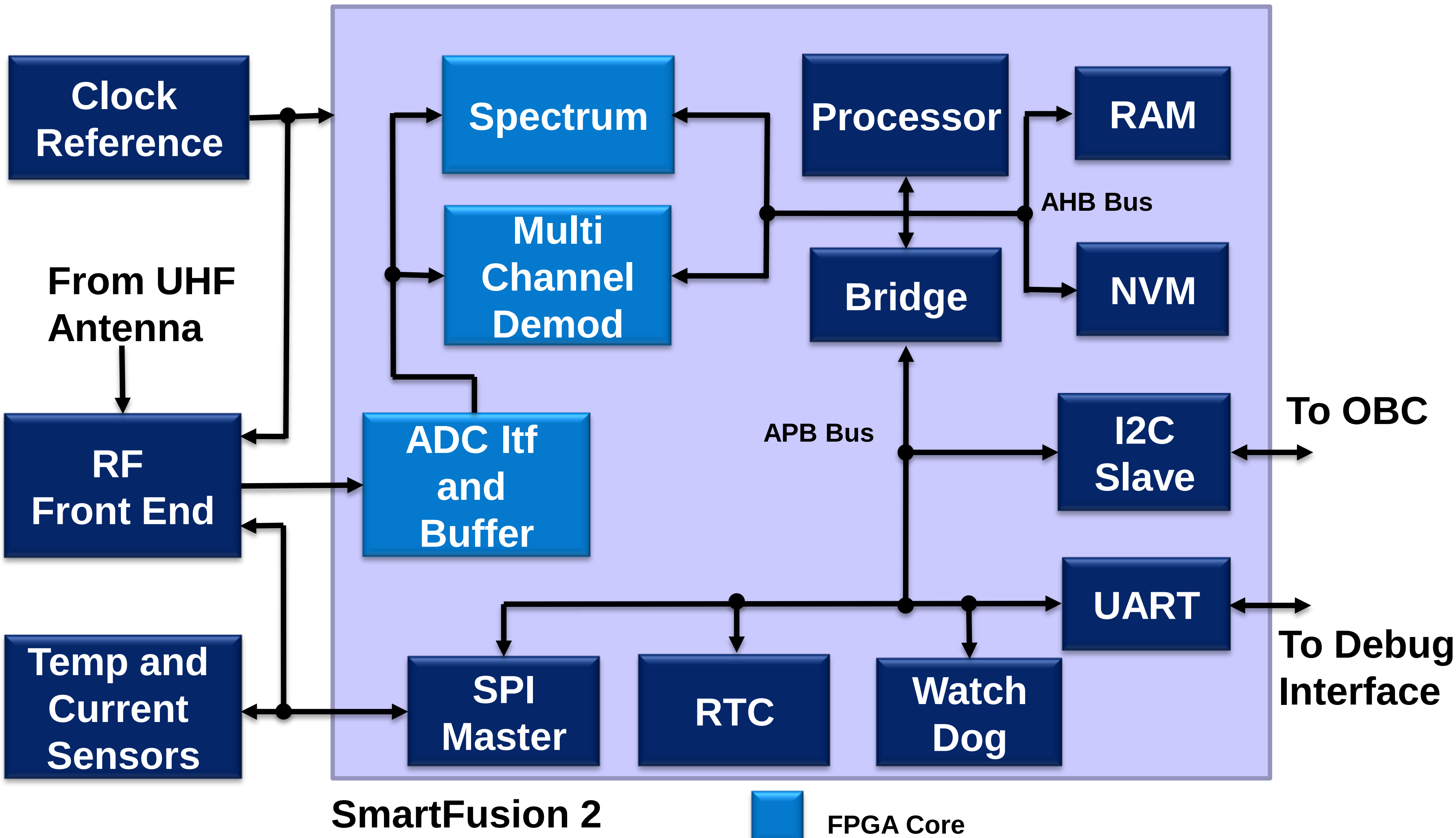
EDC Interface Specification



EDC Architecture

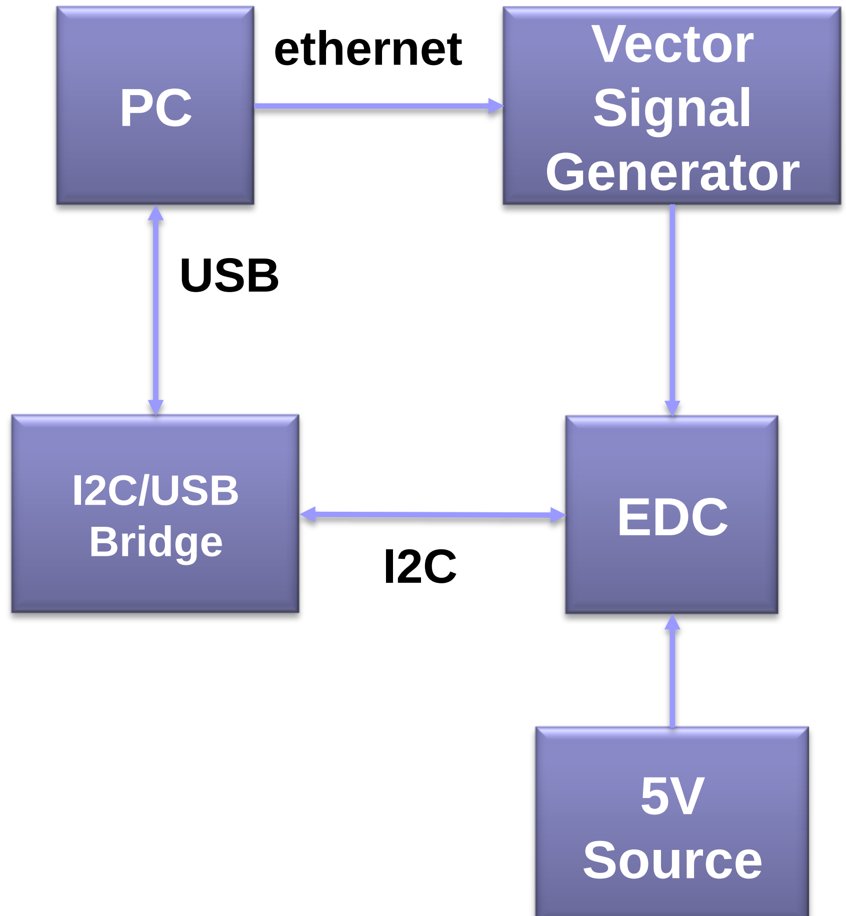
- Microsemi SmartFusion 2
  - Flash Based FPGA
  - Microcontroller Unit
    - Cortex M3 processor;
    - I2C and SPI buffer with Single Event Upset (SEU) protection;
    - Processor cache with SEU protection;
- Software/Hardware partition;
  - FPGA Core:
    - Spectrum sample calculation;
    - Demodulation of PTT signals.
  - Microcontroller:
    - Management of demodulation channels;
    - All signal decoding processing after demodulation;
    - Management of the communication with the OBC;

EDC Architecture

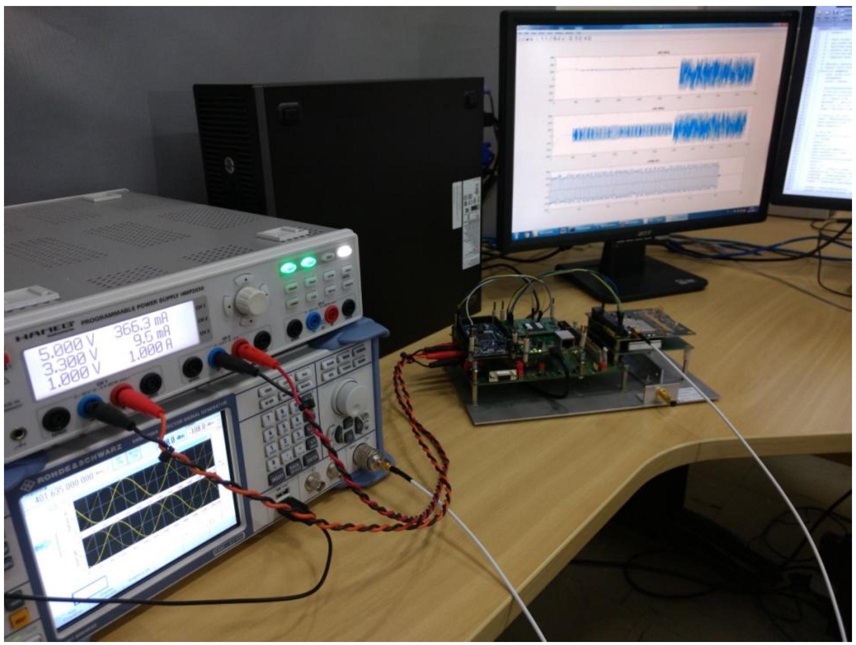


EDC Test System

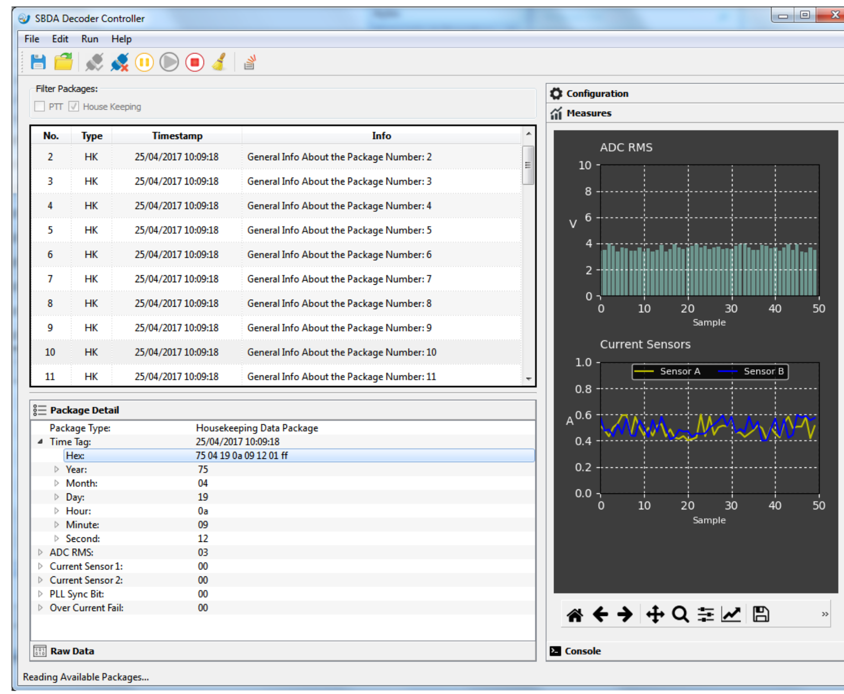
- A PC generates a digital baseband signal containing multiple PTT signals;
- A Vector Signal Generator converts the digital baseband signal into an UHF signal.
- The EDC decodes the UHF signal and provides the decoded messages to the PC through an I2C/USB bridge;
- The PC verifies if messages were properly decoded ;
- The PC also check if housekeeping information were properly generate during the simulation period;



Results

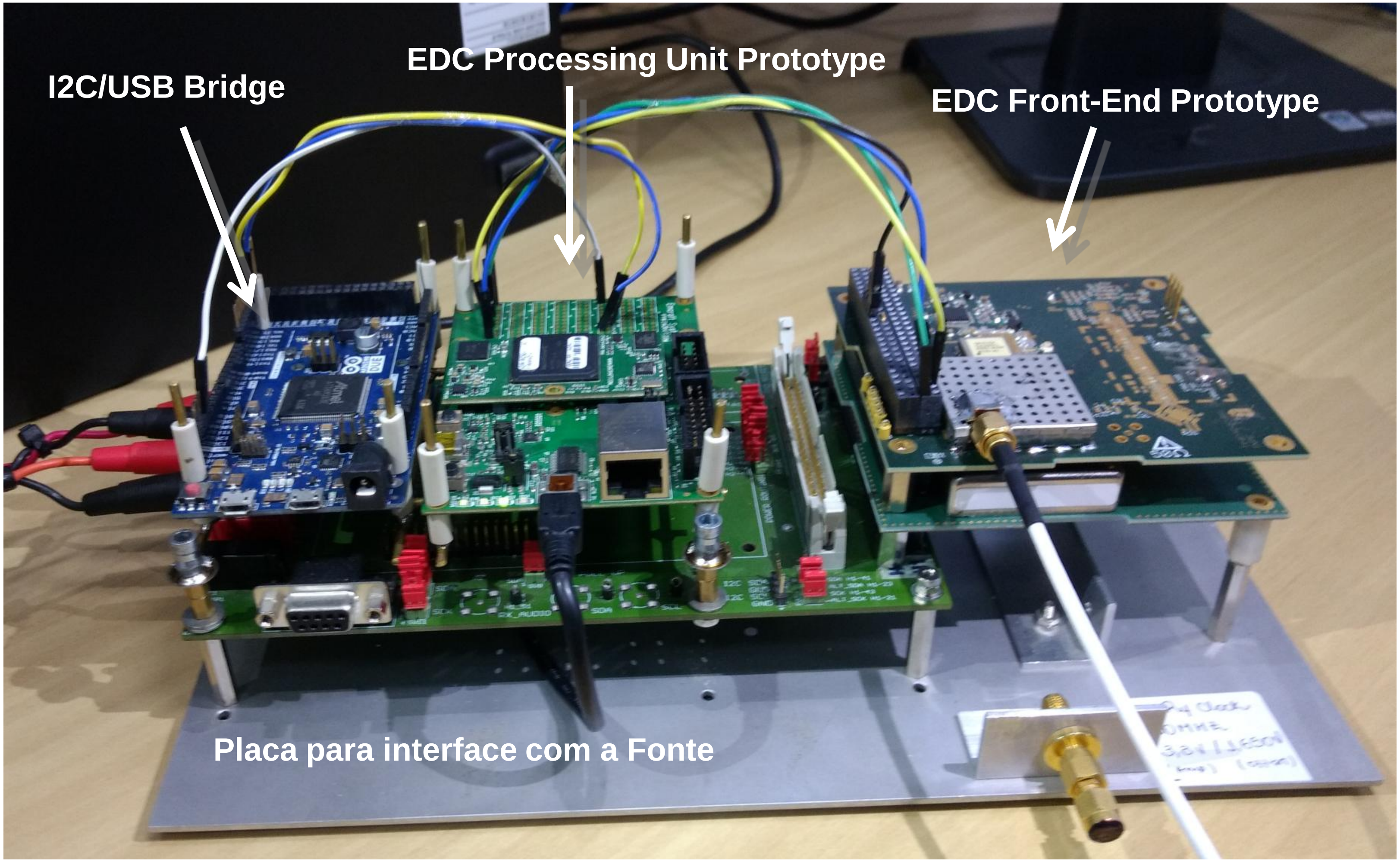


EDC test bench



EDC test software

Results



EDC Prototype

Results

- The prototype has passed functional teste;
- The only functional requirement that was not fulfilled is the time resolution for the received signal time estimation;
  - The embedded RTC of SmartFusion 2 microcontroller has a resolution of 1 second. The required resolution is 10 ms;
  - As consequence EDC usage as geolocation through Doppler effect is not viable.
  - A high resolution RTC will have to be programmed in the FPGA core;

Future Work

- Finish the engineer model (Dez/2018);
- Improve the documentation;
- Perform more testes: mechanical testes, measure power consumption, etc;
- Look for a launch opportunity as an experimental payload;
- Transfer the technology to a company to transform the EDC into a product and promote our aero-space industry;

Conclusions

- A bigger team is needed. Current team is composed by 2 engineer, and 2 undergraduate student;
- We should look for patterns in order to internationalize the system and gather force in the system development;
- A R&D team is required to work on a system-level update to add features as:
  - Improve receiver sensibility,
  - Provide option for high data rate uplink transmission;
  - Downlink communication to DCP;
    - Improve spectrum resource usage;