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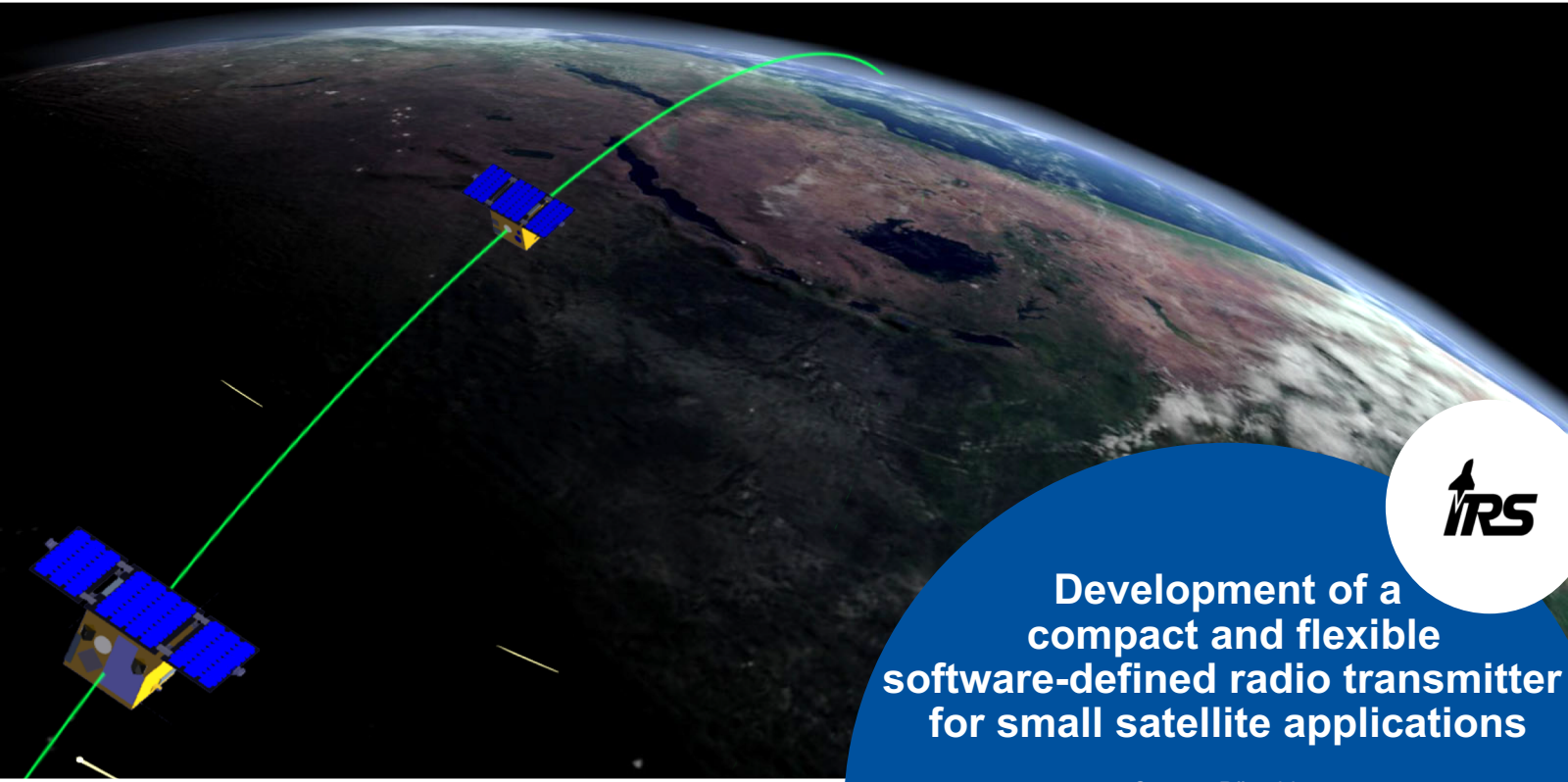

Development of a compact and flexible software-defined radio transmitter for small satellite applications

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Outline

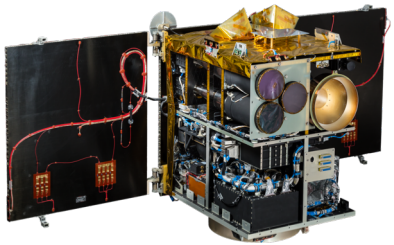
- Motivation
- Implementation Approach
- Current Status
- Conclusions and Outlook

Motivation

Evolution of small satellites

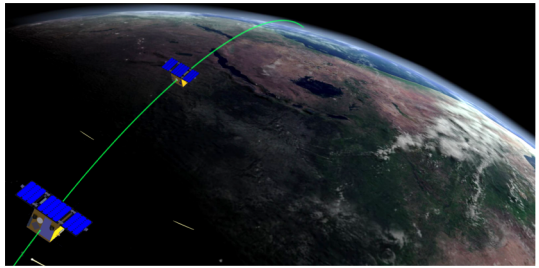
CLASSICAL SMALL SATELLITES

- Low data budget
- Fixed capacity requirement
- Payload data downlink: ham radio S-Band, commercial X-Band, sometimes Ka-Band
- Example: Flying Laptop from IRS



HIGH THROUGHPUT SMALL SATELLITES

- Increasing data budget
- Bandwidth remains equal
- Worst propagation case defines the system
- Limited ressources on small satellites
- Satellite constellations

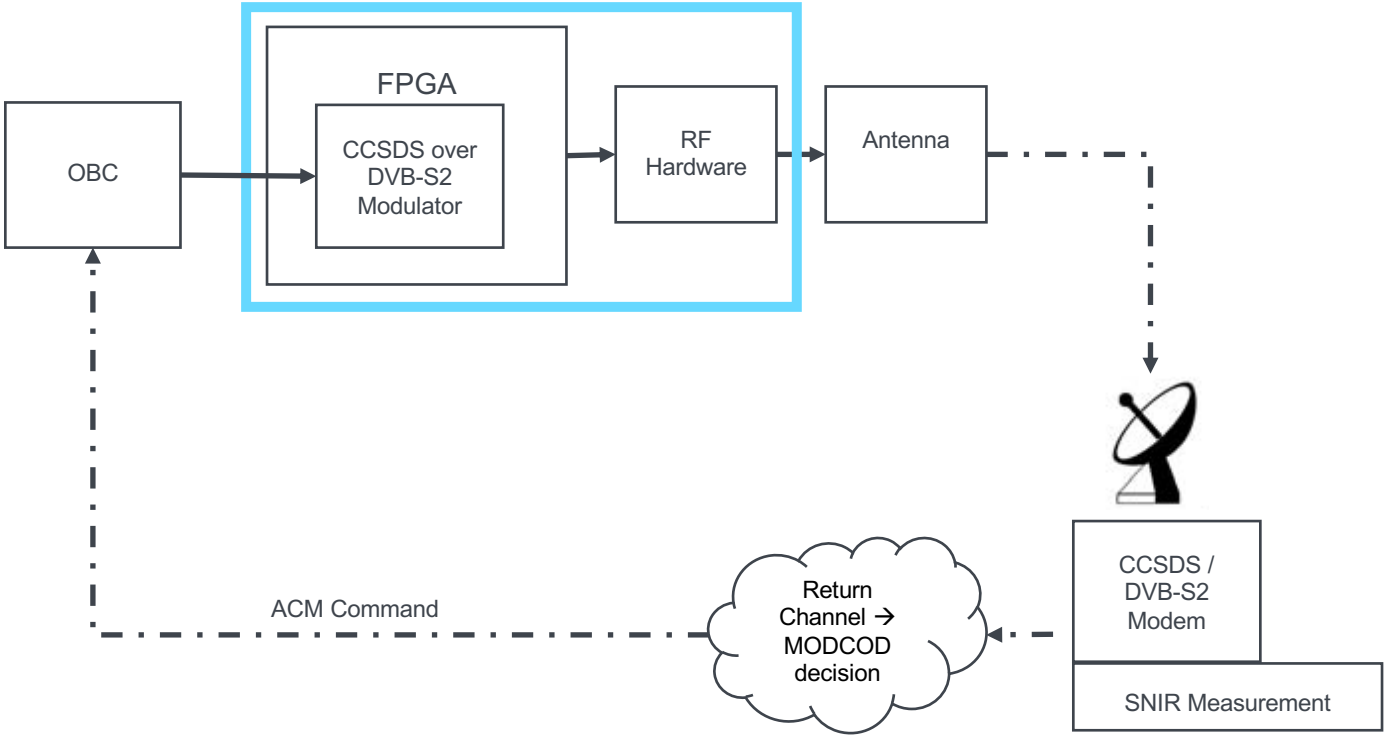


Motivation

Transmission towards more flexible satellite systems

- Approach → Adaptive Software-defined radio
  - Mass-market protocol DVB-S2
  - Modulation and Coding scheme permit operation at 0.7-1.2 dB from the theoretical Shannon-Limit
  - Support CCM, VCM und ACM
    - Essential for regions with strong weather dependence
    - Satellite constellations where the ground station contact window is smaller
  - CCSDS can be implemented over the DVB-S2 protocol stack (CCSDS 131.3-B-1)

Implementation approach



Requirements for the SDR

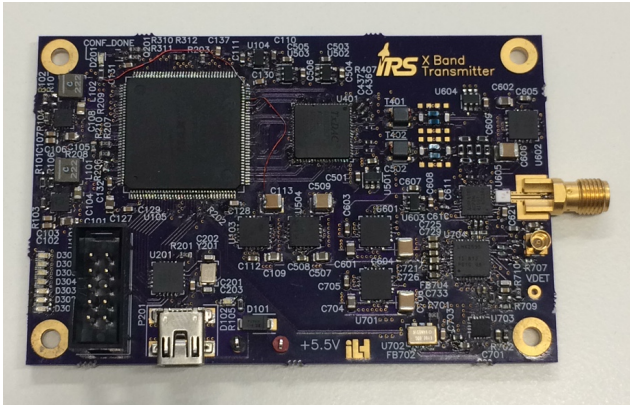
- Development of a compact, low-mass, low-power and low-cost transmitter for future satellite missions

- Reliable transmission of the payload data
- Frequency band: flexible but focus on ham radio X-Band (10.45 – 10.5 GHz)
- Data rate: flexible from 0.5 bis 150 Mbps. Nominal 50 Mbps
- Power consumption: ca. 10-15 W
- CCSDS-compatible
- DVB-S2 ACM
- FPGA for digital signal processing
- Use of COTS components

Current status

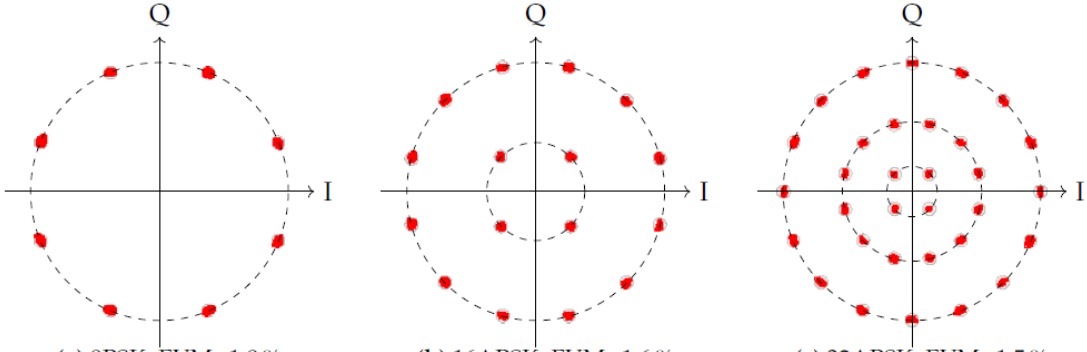
RF-Frontend

- First functional prototype
  - PCB without amplifier
    - Power consumption: ca. 8,5 W
    - RF-Output power: ca. 0 dBm
  - Different modulation schemes tested succesfully (realistic EVM values)
  - Carrier frequency at 10,475 GHz with an adjustable bandwidth up to max. 49 MHz
  - Possibility to adjust the frequency between 6 GHz and 23 GHz
  - Dimensions: 56 x 85 mm



Current status

EVM-values



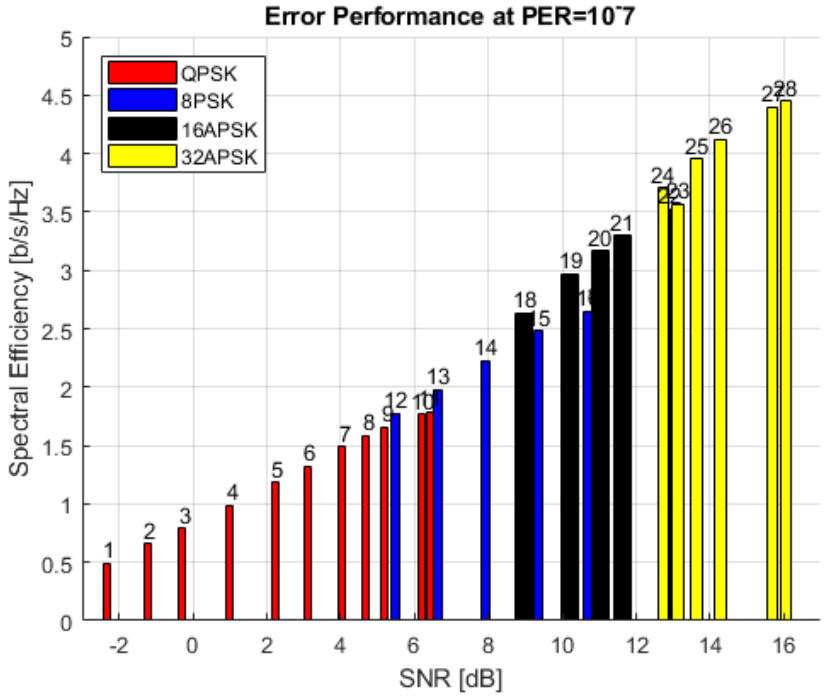
(a) 8PSK, EVM=1,8 %

(b) 16APSK, EVM=1,6 %

(c) 32APSK, EVM=1,5 %

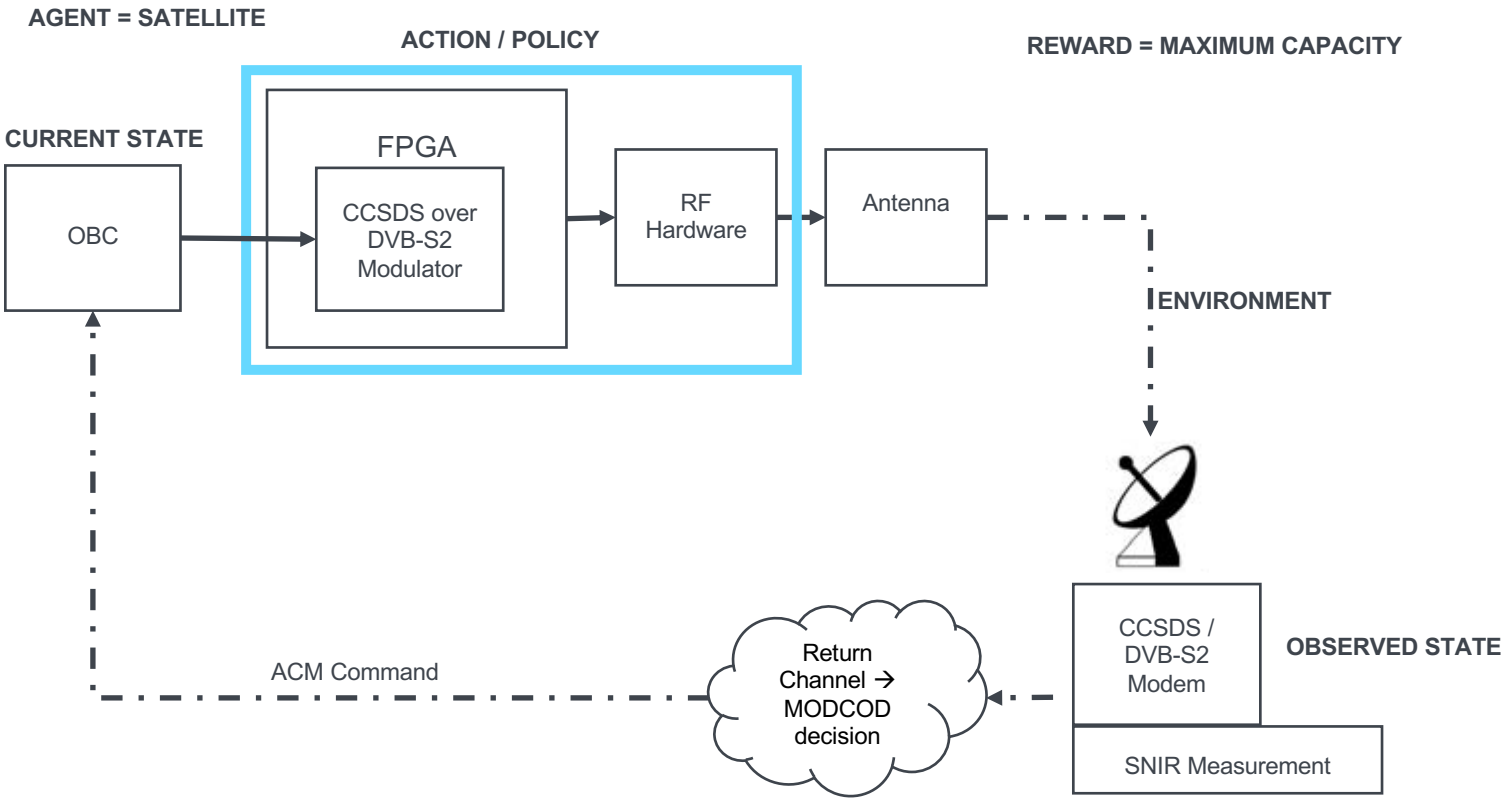
Current status

MODCOD selection



Current status

MODCOD selection



Conclusions and Outlook

- Development of an adaptive Software-Defined Radio Transmitter
  - Functional prototype
  - Adaption of CCSDS over DVB-S2
    - HF-Frontend is already fully compatible
    - Only FPGA SW-development needed

- Outlook
  - Implementation of the needed FPGA-Software
  - Investigation of radiation mitigation techniques
  - Redundancy concepts
  - Investigation of different algorithms for MODCOD selection

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Vielen Dank!

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SDR 3D-Model

- A: Switching regulators for 3.3 V and 3.8 V
- B: Altera MAX10 FPGA
- C: JTAG-Interface for FPGA
- D: LEDs
- E: USB-Interface
- F: Clock generation and distribution
- G: DAC
- H: Antialiasing-Filter
- I: Attenuator
- J: Mixer/Up-converter
- K: DAC for controlling the output power
- L: PLL