Implementing a Receiving Chain on a CubeSat-FPGA

A Semester Thesis for the ARIS "SAGE"-Project

Students

Yanick Diggelmann

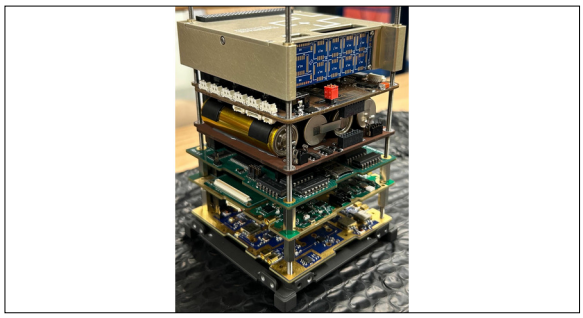
Andrea Studer

Definition of Task: The Swiss Artificial Gravity Experiment (SAGE) is a student-led team with the goal of developing its own 10x10x30 cm CubeSat. The satellite needs a reliable uplink to receive telecommands from earth.
The purpose of this thesis is to design a receiving chain which demodulates data despite the impairments occurring during transmission. The signal processing chain must be implemented on a FPGA on the provided hardware. It must decode the data and deliver a clean output to the on-board computer. The receiving chain must be validated with varying testdata sets. Different frequency error and noise tests must be carried out.

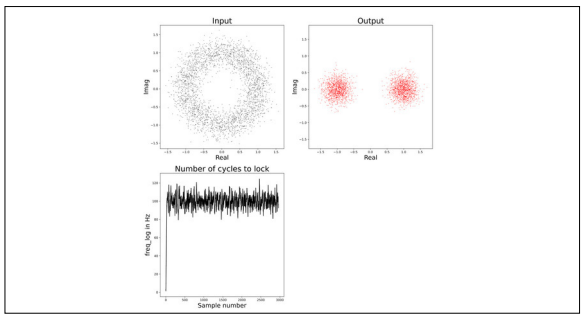
Approach: The receiving chain was designed with respect to a prior thesis from ARIS. Research on the fundamentals of Wireless Communications, Digital Signal Processing and Digital Microelectronics was conducted.
With this knowhow a new design of the receiving chain was created. The Rx chain is divided in two parts: The demodulation part with a decimation filter, root raised cosine filter, a symbol and a frequency synchronization module. And the decoding part with a frame synchronization, a decoding and a descrambling module.
The behavior and function were thoroughly modelled using GNU Radio. The functional blocks were programmed in Python to validate their function and to generate reference data for testing the final implementation in VHDL.

Result: The two filter units were designed including the taps-calculation enabling further use. The symbol synchronization module is complete in Python and will be finalized by the SAGE team.
Implemented in VHDL and therefore final are the three submodules performing the decoding part and the last block of the demodulation part, responsible for frequency error correction. All VHDL blocks were tested on a ZedBoard with the same FPGA as on the satellite. A frequency error of 100 Hz, combined with noise with a Signal-To-Noise-Ratio of 13 dB is corrected successfully.

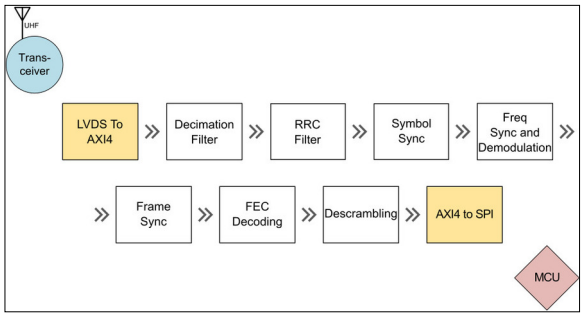
The CubeSat Prototype
ARIS members



Costas Loop: Demodulation modelled in Python
Own presentment



Flowchart of the receiving chain
Own presentment



Advisors
Prof. Dr. Paul Zbinden, Lukas Leuenberger

Subject Area
Microelectronics

Project Partner
ARIS, Akademische Raumfahrt Initiative Schweiz, Dübendorf, ZH