Design review of the NUTS Ground Station

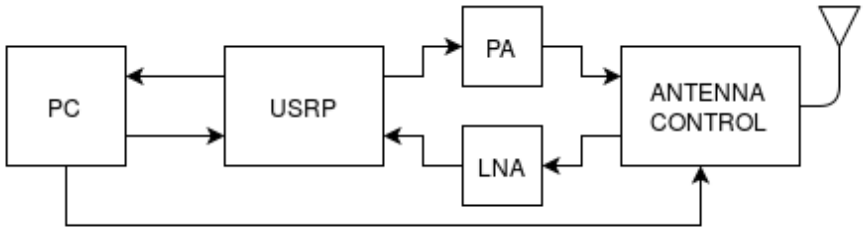
Requirements table

Code	Description
R05-GS-NGH-001	The ground station must send commands to the satellite
R02-GS-CW-001	The ground station must decode the beacon signal
R03-GS-NGH-002	The ground station must process housekeeping data
R04-GS-NGH-003	The ground station must receive payload data from the satellite
R06-GS-NGH-004	The ground station must use FEC to prevent data corruption and loss

System overview

The role of the ground station is to provide communication with the satellite for the duration of the mission. The communtication will take place on two different frequencies, VHF (145.98 MHz) and UHF (437.305 MHz), to give some flexibility with regards to noise and other communication. The data is encoded using the NGHAM packet radio protocol developed by J. Skagmo, LA3JPA.

The RF-frontend consists of an antenna with a PA for uplink and an LNA for downlink. This is connected to an USRP which performs filtering and mixing for basisband processing. The basisband signal processing and encoding/decoding is done by a computer running GNURadio. An example top level design is shown below.

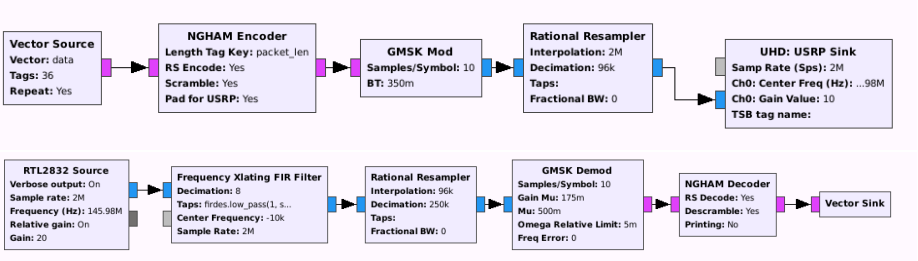


GNU Radio (v3.7.8)

GNU Radio is a free software development toolkit that provides signal processing blocks to implement SDRs and signal processing systems. It communicates with the hardware over ethernet using raw I/Q samples. These samples are processed using module blocks written in either Python or C++, and converted to and from a meaningful bitstream of data.

The blocks used in this system include:

- GMSK Mod/Demod: Converts between I/Q symbols and bits
- NGHAM Encode/Decode: Converts between data bits and encoded data bits, the encoded bits include the data bits as well as CRC bits and Reed-Solomon bits used for Forward Error Correction
- Frequency Xlating FIR Filter: Multi-purpose filter for shifting the signal in the frequency domain, also works as a low pass filter.
- Rational resampler: Changes the sampling rate of the datastream.
- UHD USRP Sink: Hardware driver for USRP
- RTL2832 Source: Hardware driver for RTL-SDR dongle used for testing (Will be replaced with UHD USRP Source)



These figures are screenshots from the GNU Radio Companion, a graphical tool used to generate flowgraphs. The top one shows a simple implementation of the uplink design and the bottom one shows the downlink design.

An advantage to this design is that the coding and modulation blocks can be easily replaced for communicating with other satellites using different protocols.

The vector source and sink would be replaced with other blocks for sending commands and processing received data. UDP may be the best solution for this, as it is already a part of GNU Radio.

USRP

The USRP is a Software Defined Radio, which implies that the usual components of a radio (mixers, filters, amps, etc.) are all implemented in software. The USRP has an FPGA which converts real analog signals to complex baseband signals in the digital domain. These are transferred to the host computer running GNU Radio via an ethernet cable.

RF-Frontend

- PA/LNA see https://www.ntnu.no/wiki/display/nuts/Ground+station
- Antenna
  - circultarly polarized

Gpredict and FLYBY

used for calculating pass times and positions to control the antenna and calculating the doppler shift which must be corrected by the ground station

What is done

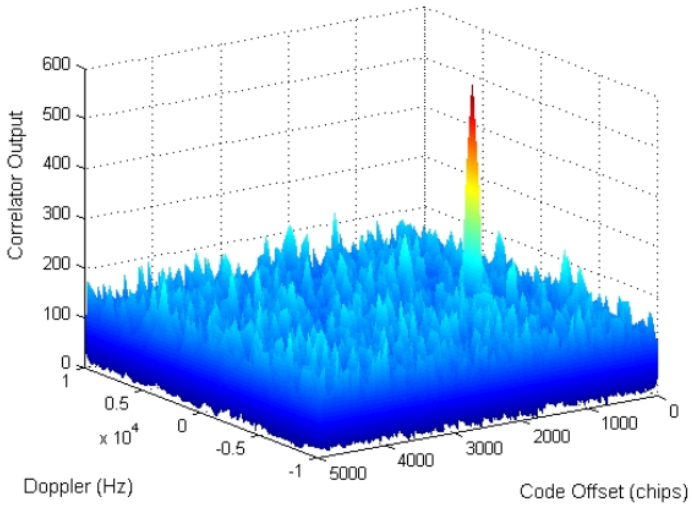
- The NGHAM encoder block is complete and decoder block is almost done (at the time of writing).
- Communication between USRP and the OWL VHF radio module is successful, and messages of different lengths decode correctly. Communicating with UHF radio module should be trivial (?!).

With this the network layer communication between the ground station will be complete. Which contribute to completing all requirements labeled NGH.

TODO

- Finish NGHAM decoder block!
- Handle errors in the non-FEC encoded parts of the packet (preamble, sync word and size tag)
- Find a way to handle doppler shifts

  - currently this is calculated by FLYBY software and HAM radio
  - one possible way is to run the decoder on an interval of frequencies, like a gps receiver does



  - another is to find out how to use the Clock Recovery MM block in a clever way (it is integrated in the GMSK Demod block, but it may not work for large frequency offsets).

- CW signal, useful blocks probably already exist in GNU Radio (Requirements labeled CW).

- Implement a higher level communication protocol for transferring meaningful data between ground station and satellite

Abbreviations

- CW: Continous wave
- FEC: Forward Error Correction
- GS: Ground Station
- I/Q: In-phase/Quadrature

- LNA: Low Noise Amplifier
- NGH/NGHAM: Next Generation Ham
- PA: Power Amplifier
- RF: Radio Frequency
- RS: Reed-Solomon
- RX/TX: Receive/Transmit
- SDR: Software Defined Radio
- UHF: Ultra high frequency
- USRP: Universal Soft Radio Peripheral
- VHF: Very high frequency