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MasterThesis

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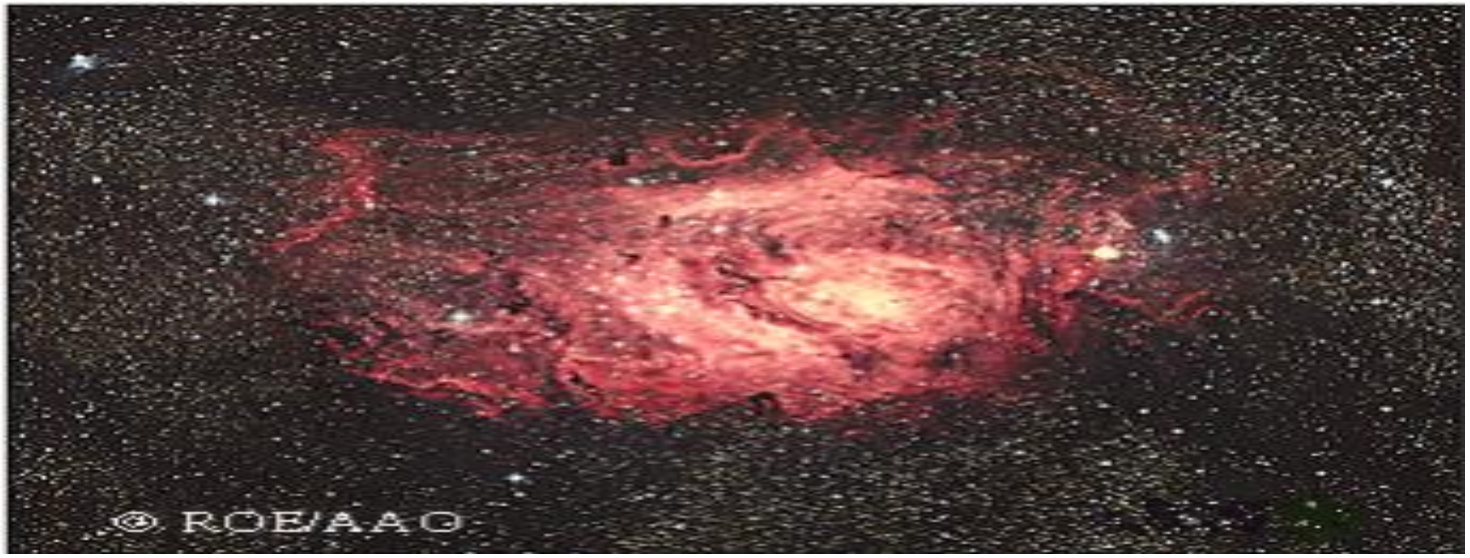
Prototype for a base station for supernova remnant HI line radio wave detector and analyser (SRWDA)

Contents

- Thesis motivation
- Background
  - Radio astronomy and Hydrogen line1 (HL1)
  - Software defined radio(SDR) for detection HL1
- System design
- Hardware
  - Antenna
  - Analog filtering
  - SDR platform for digital processing
- Software
  - Design
  - Implementation
- Measurement
- System import on Mock-up modell

Motivation

- Design and implementation of radio wave (Hydrogen line1) detector and analyser (SRWDA)
- Integration SRWDA with IAP Mockup model

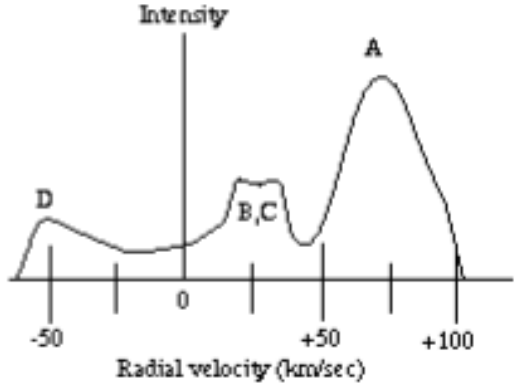


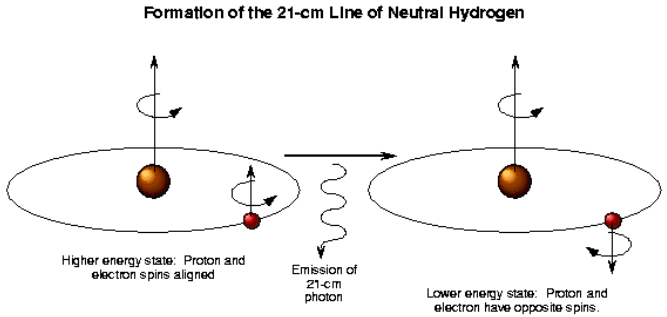
Background

- What Radio Astronomy
  - Radio astronomy studies celestial objects at radio frequencies
  - The discovery of the cosmic microwave background radiation
  - Observation of new classes of objects(quasars, pulsars)
- Astronomical radio source
  - The Sun
  - Supernova remnants
  - Pulsars
  - Primordial black holes
  - ……

Hydrogen line 1 (HL1)

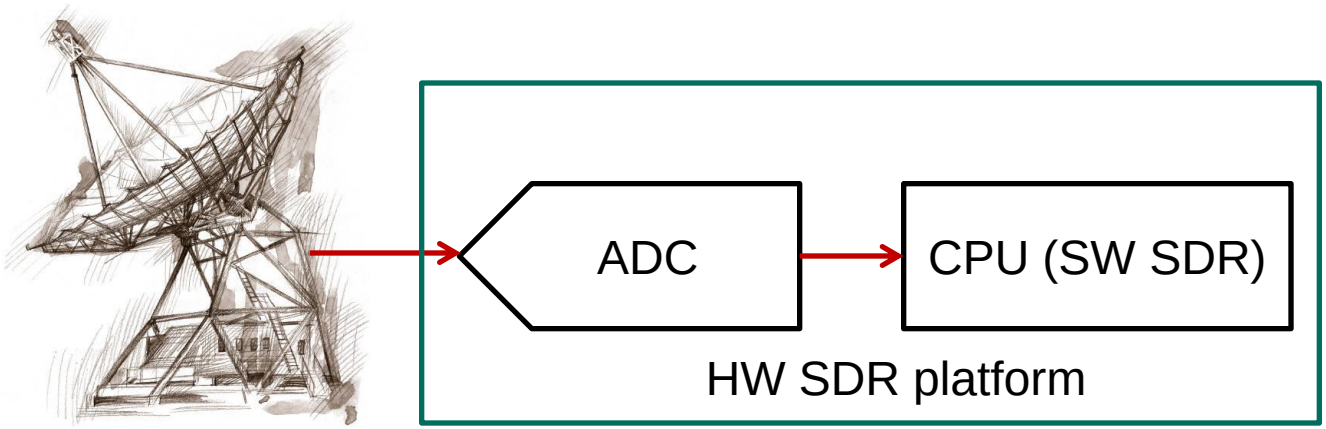
- Electromagnetic radiation spectral line (1420 MHz, 21 cm)
- HL1 is created by a change in the energy state of neutral hydrogen atoms.
- The HL1 provides the best way to map the structure of the Galaxy
- Calculate the mass of galaxies





Software Defined Radio(SDR) for Detection HL

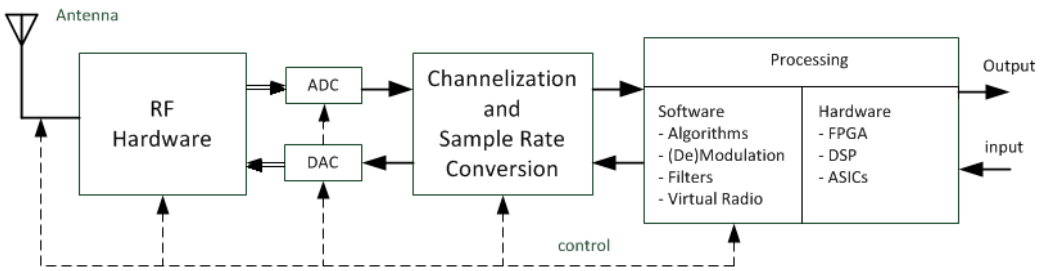
- Idea of SDR: hardware components (e.g. mixers, filters etc.) are implemented by means of software
- Radio telescope for HL can be designed using SDR
- The challenge for detection HL is a weakness of signal



Ideal SDR receiver

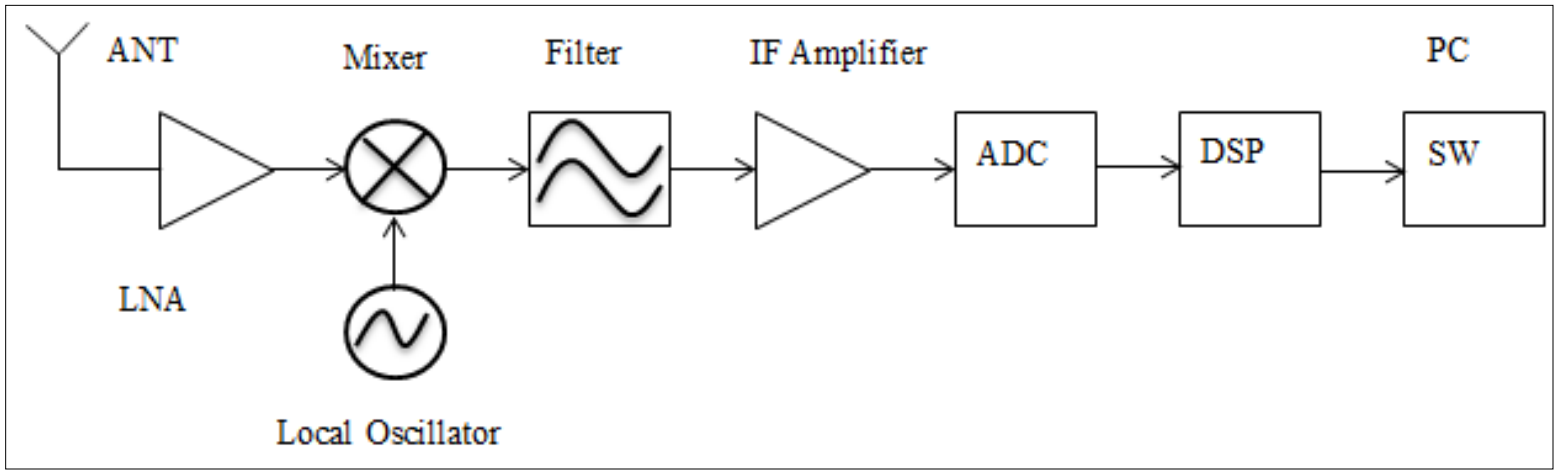
Why SDR?

- Design flexibility
- Reliability
- Upgradability
- Reusability
- Reconfigurability
- Enhanced Functionality
- Lower Cost

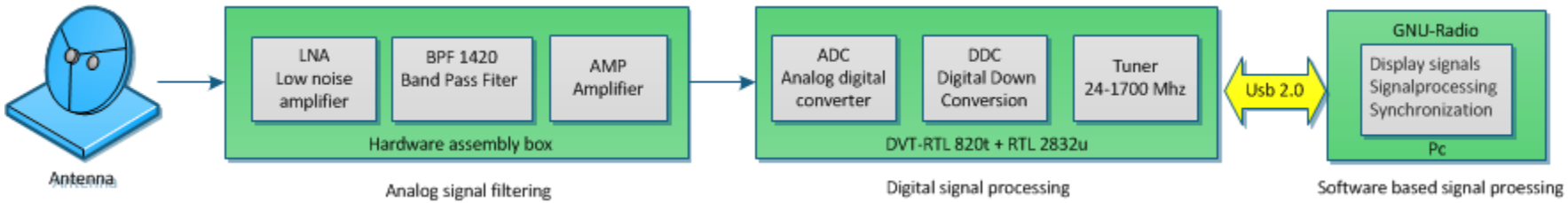


Basic SDR heterodyne receiver architecture

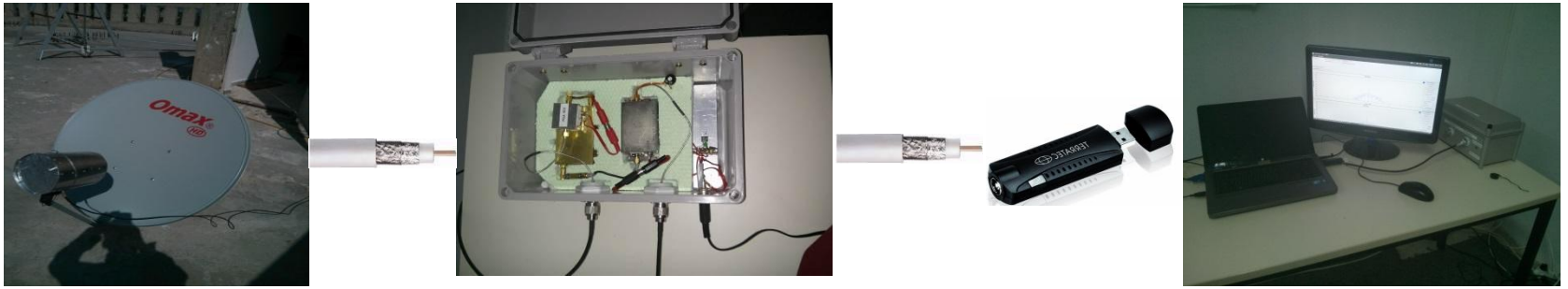
- The most used radio receivers use the architecture of super heterodyne receiver
- Received signal has been converted to a fixed intermediate frequency
- which can be more processed than the original radio carrier frequency.



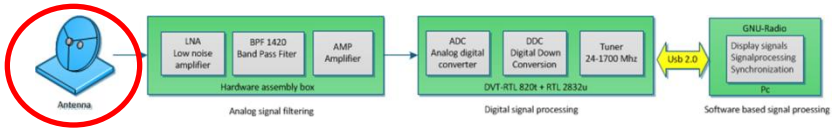
Telescope design



Real system

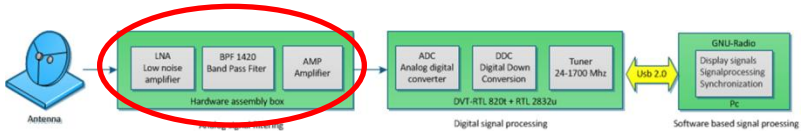


Antenna + Feeder

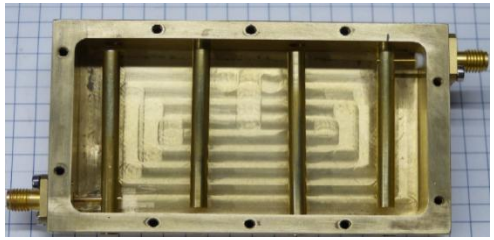


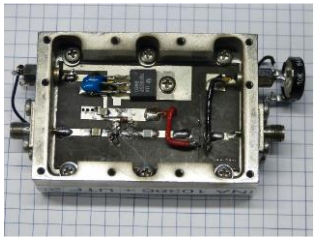
- Parabolic reflector antenna
- Ratio F/D =0.5
  - F : Focal distance. f= 55 cm
  - D : Antenna diameter ie. d= 110 cm
- Feed: dipole or crossdipole
- Feed horn D= 15 cm, L= 20 cm

Analog hardware

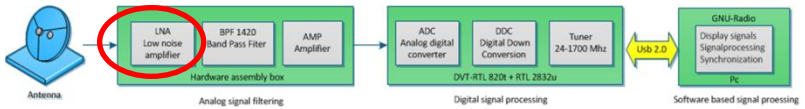


- Low noise amplifier (LNA)
- Band pass filter
- IF main amplifier & Attenuator

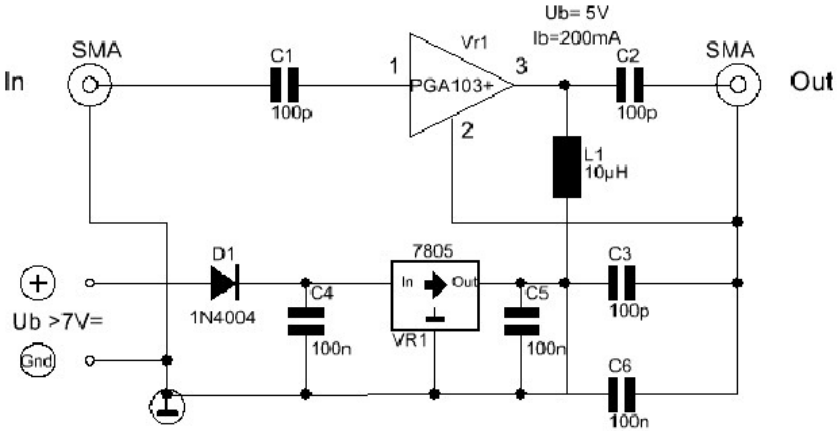




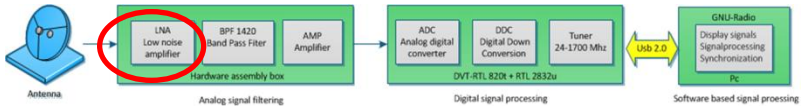
Low noise amplifier (LNA)



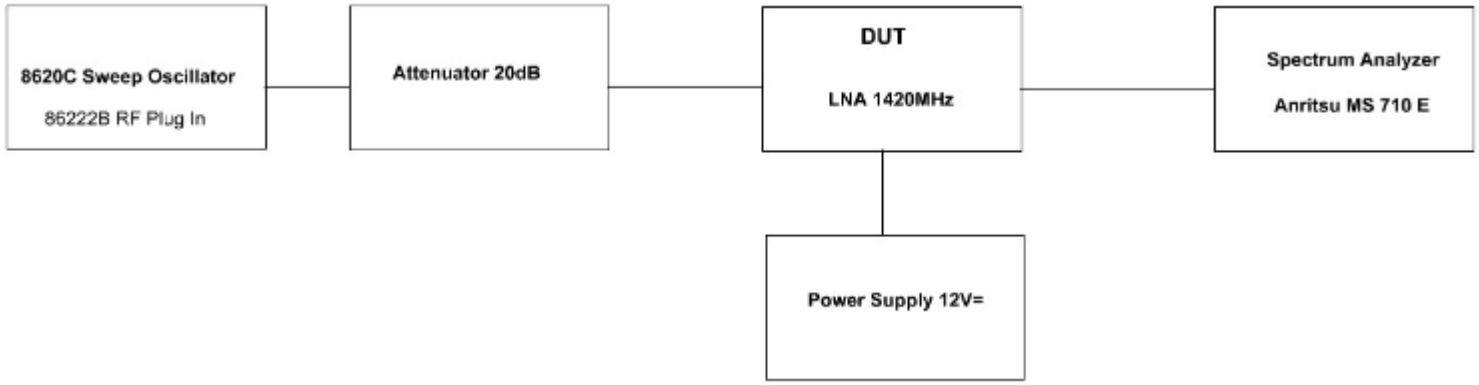
- Low noise amplifier (LNA)
  - Noise figure 12 dB
  - Gain 12 dB at1420 MHz
  - IP1dB, 22.3dBm @2 GHz



Low noise amplifier (LNA)

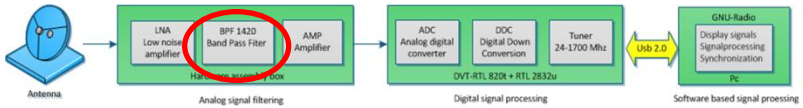


- Test setup for LNA

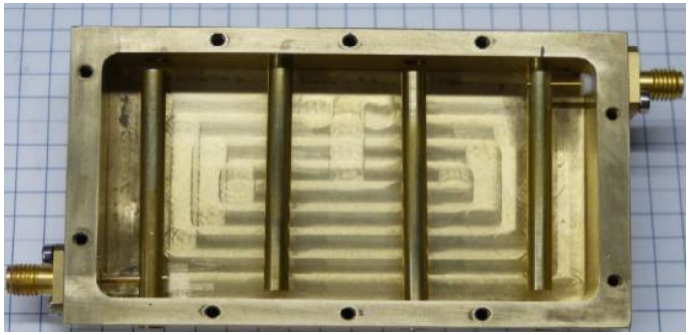


- Frequency response

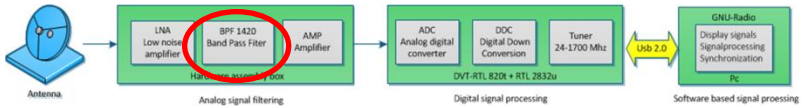
Hydrogen filter 1420 MHz



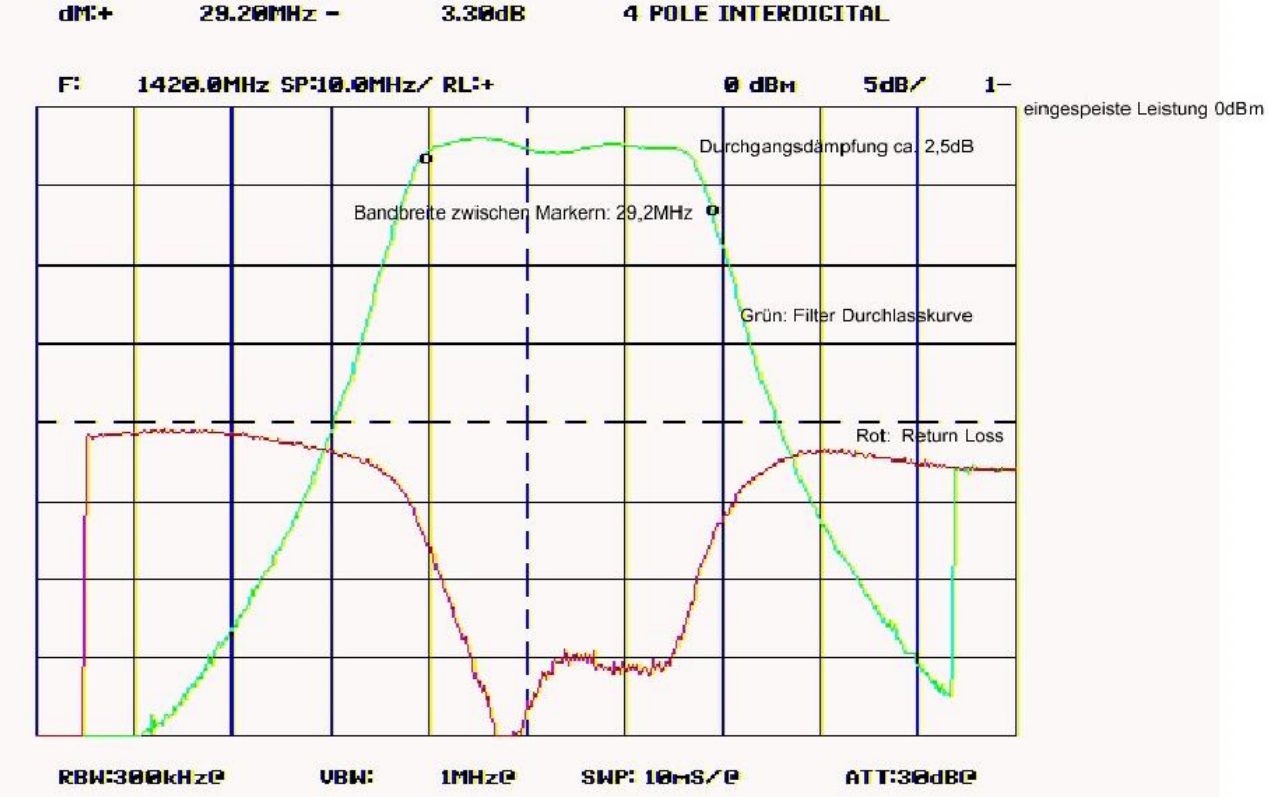
- Interdigital 4 Pole Filter
- frequency domain (3 dB): 1405 to 1437 MHz
- Insertion Loss: 1 dB typ.
- Input / Output impedance: 50 Ohms



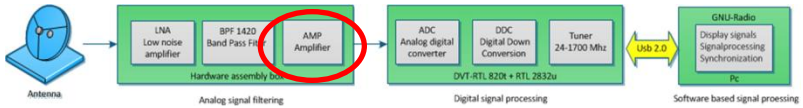
Hydrogen filter 1420 MHz



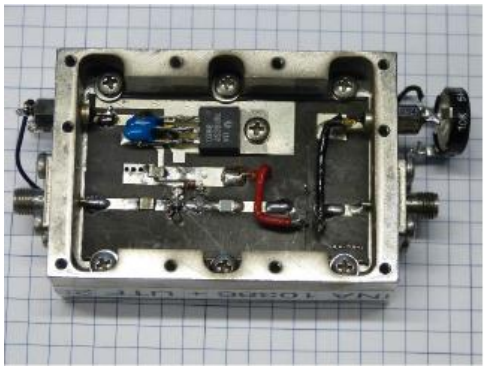
- Frequency response

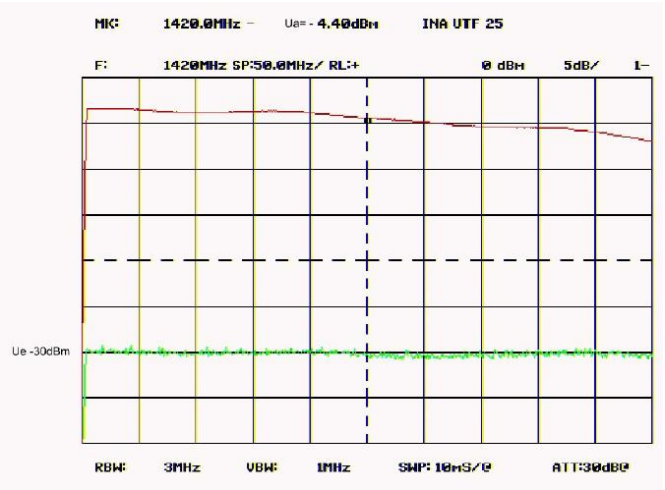


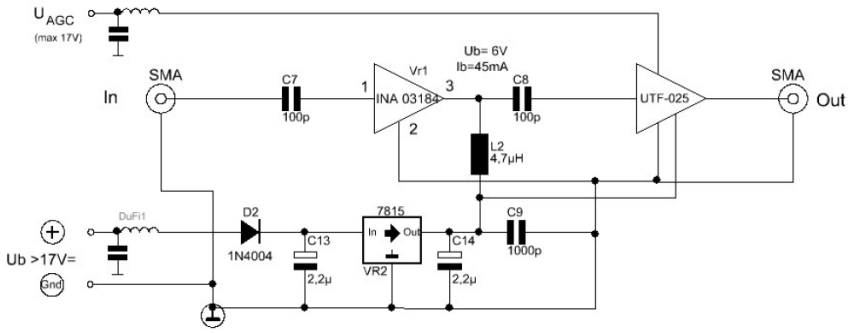
IF Amp



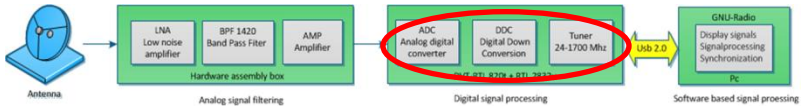
- IF main amplifier & Attenuator
- Bandwidth 10 -1800 MHz
- Gain 26 dB @1.5 GHz







Digital Hardware (SDR Platform)



Criteria for selecting a suitable platform:

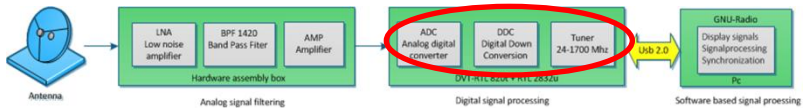
- The frequency range up to 1.70 GHz.
- Suitable for low-cost experimentation
- Reprogramability
- Fully open source platform (hardware, software)
- High resolution
- Sufficient bandwidth

Overview of SDR platform

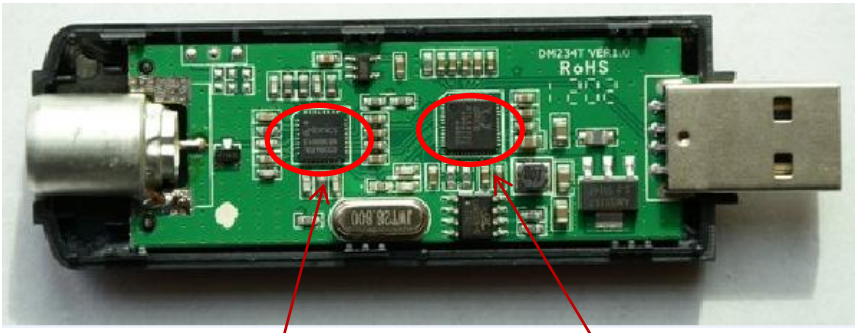
SDR Platform	Hackrf	BladeRF	USRP(B100)	Rtl_SDR(E4000)
Frequency range	30 MHz – 6 GHz	300 MHz – 3.8 GHz	50 MHz –2.2 GHz	52 – 2200 MHz
Bandwidth	20 MHz	28 MHz	16 MHz	3.57MHz
Simple size (ADC-DAC)	8 bit	12 bit	12 bit/14 bit	8 bit
Simple rate (ADC-DAC)	20 Msps	40 Msps	64 Msps/128 Msps	3.2Msps
Transmit?	Yes	Yes	Yes	No
Interface speed	USB 2 (480Mbit)	USB 3(5 gigabit)	USB 2 (480Mbit)	USB (480Mbit)
Open source	Everything (SW+HW)	HDL + Code Schematics	HDL + Code Schematics	Open source
Supported software	Gnu radio	Gnu radio	Gnu-radio/ Matlab	Gnu radio
Price	$300	$420	$675	$20




SDR (RTL2832U-E4000)

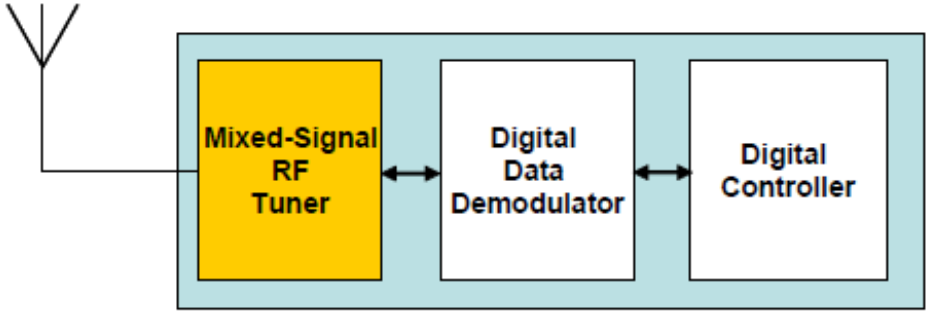


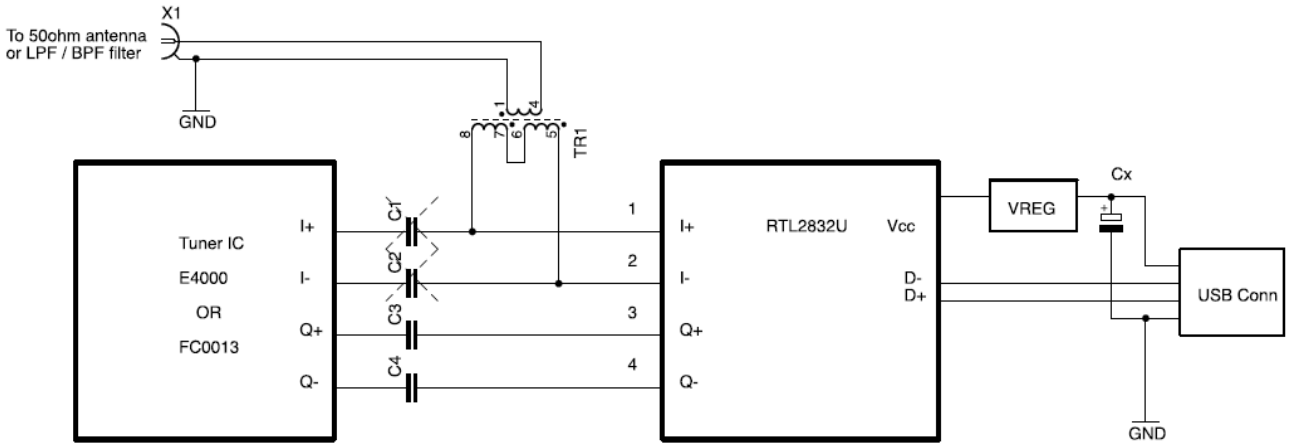
- Filtered signal is down sampled
- Frequency selecting done by The E4000 tunerchip
- Analog to digital converter (RTL2832U)
- Downconversion from IF to BF
- Output is sent to the computer by USB2.0



E4000 RTL2832u

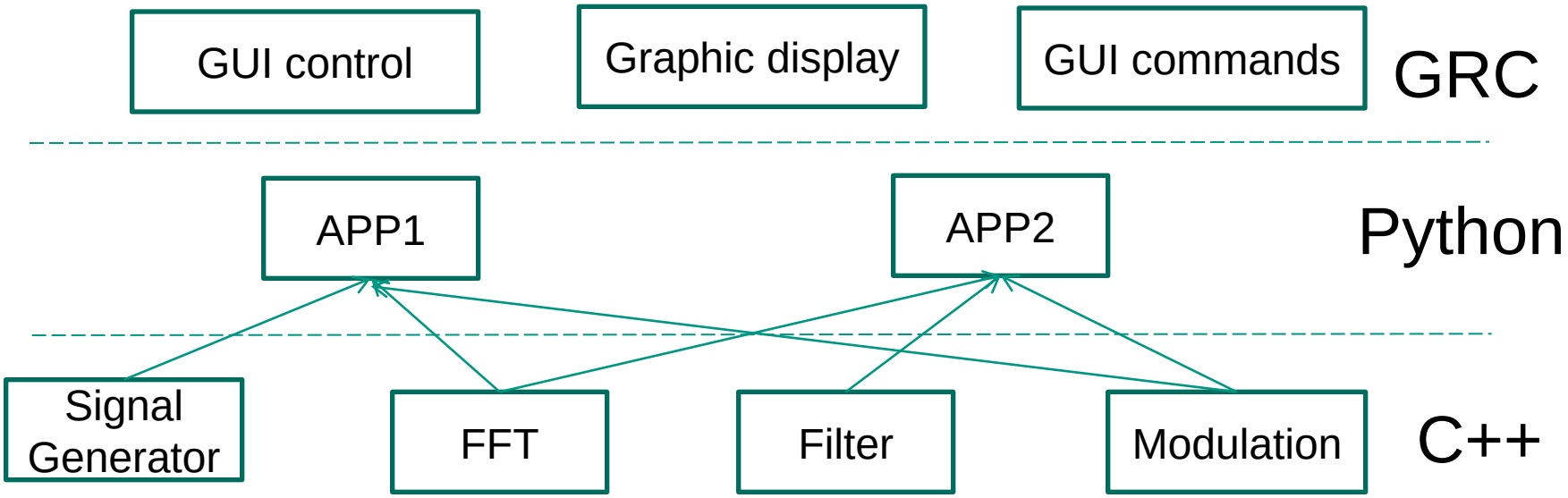
SDR (RTL2832U-E4000)





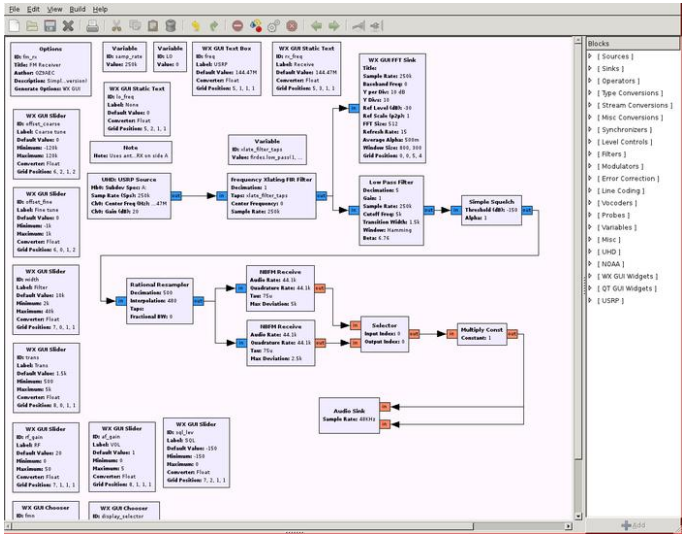
Software Design

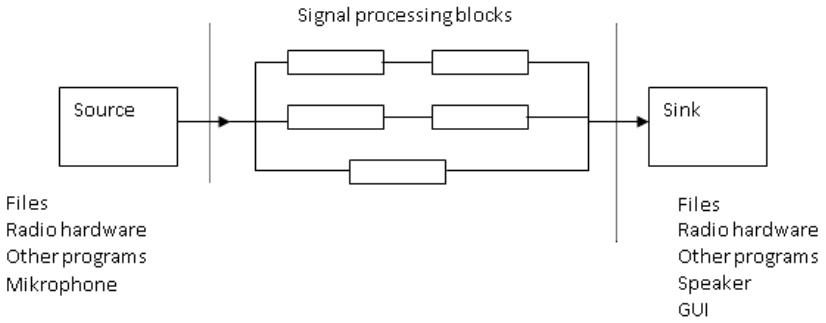
- GNU radio is an open source, Python-based architecture for building SDR projects
- C++ written signal processing blocks and python written connectors
- Available on Linux, Mac OS and Windows



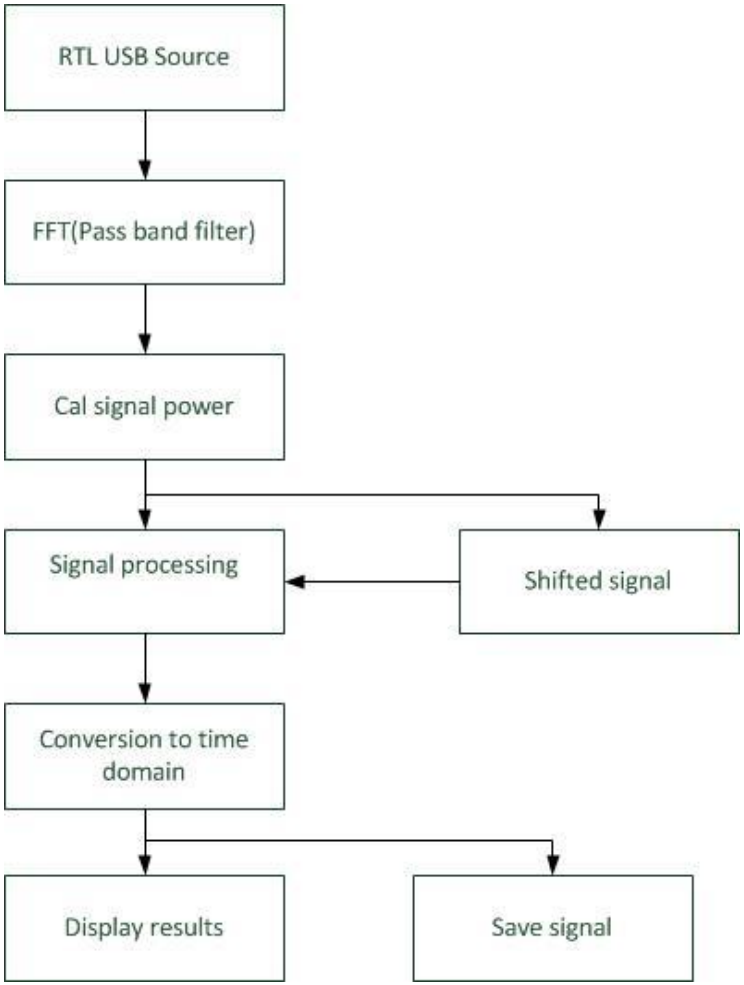
GNU Radio Companion

- A graphical tool that Create signal flow graphs & Generate flow-graph source code



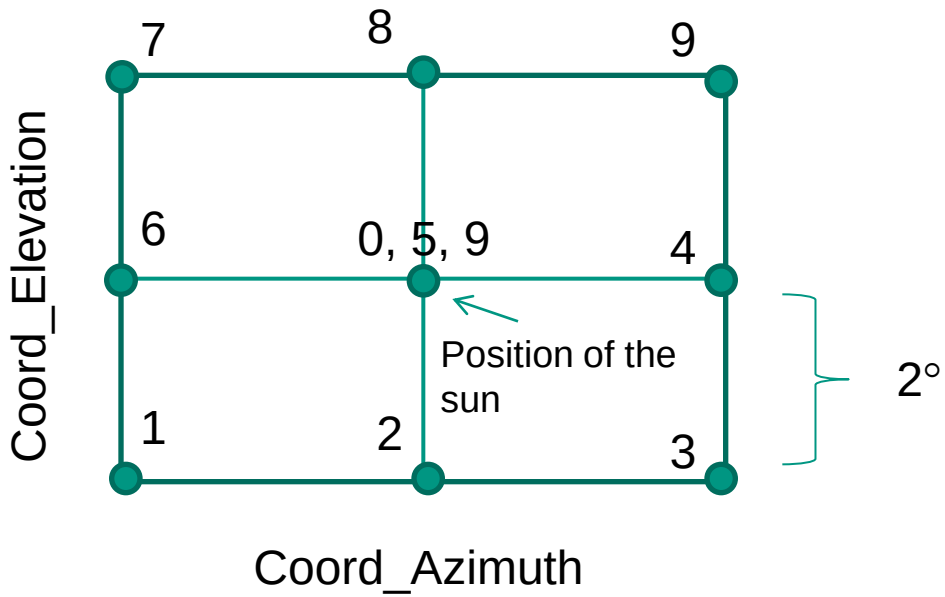


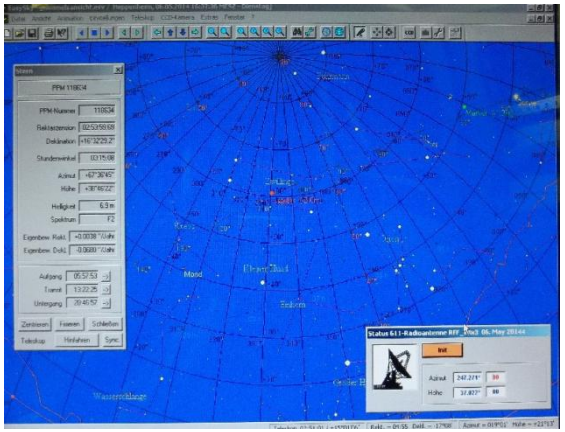
Software Implementation



Software Implementation

- Scan(movement of the antenna) of area of
- Time transmission takes 2 sec between each 2 nodes
- Scanning starts from sun position(Easy Sky) and ends there
- Center of the matrix is tested 3 times

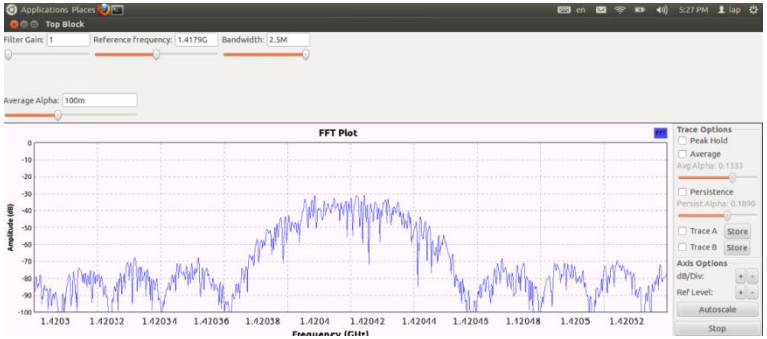




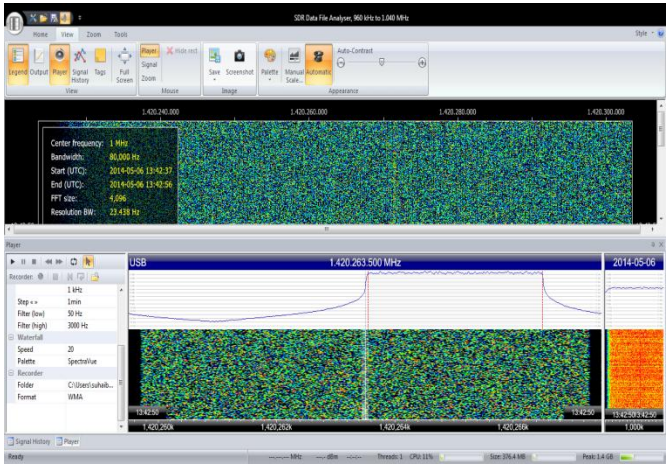
Easy Sky software

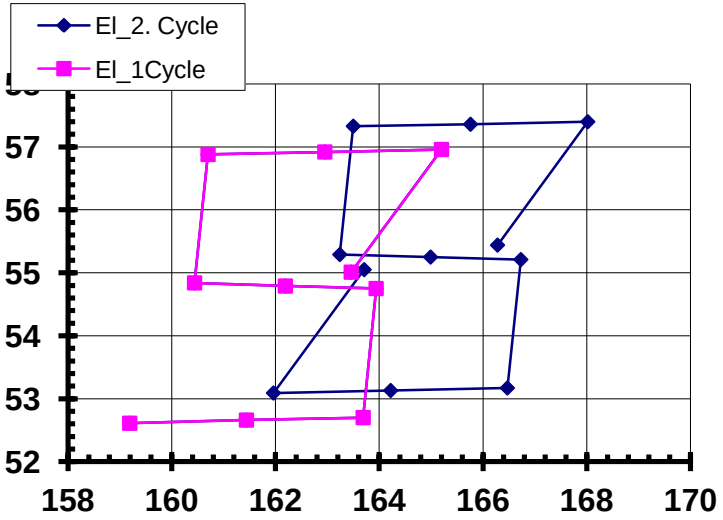
Measurement

- First scenario



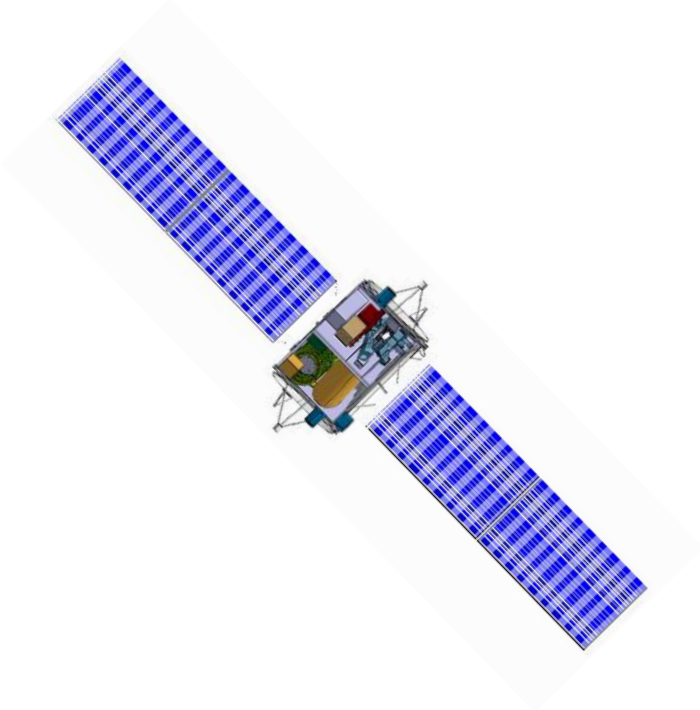
- Second scenario

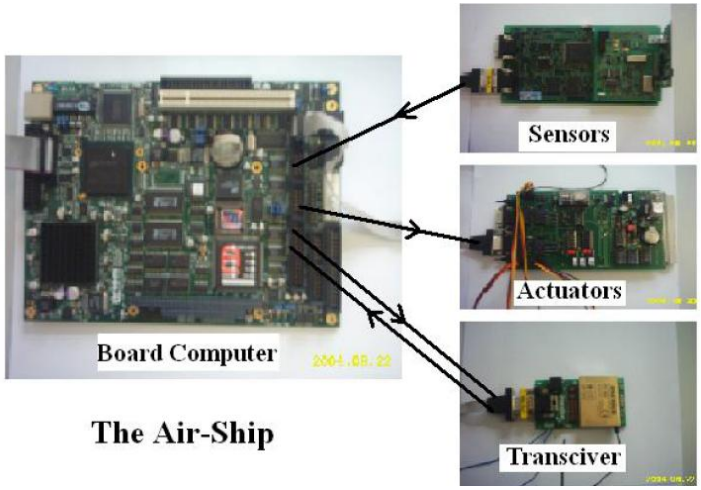




Mock-up model of IAP-satellite (future work)

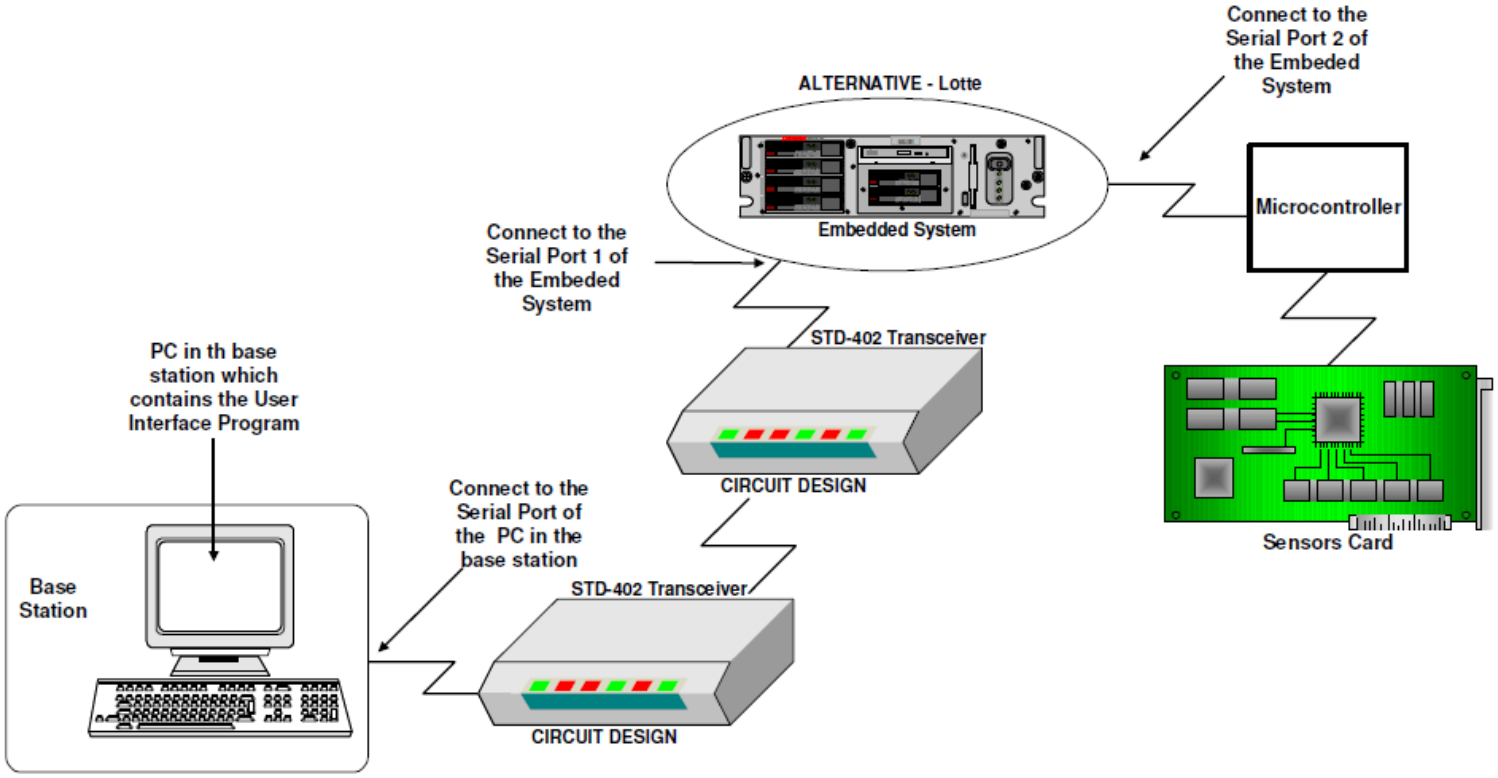
- Mock-up is prototype model of IAP satellite
  - Linux embedded Board computer
  - Sensor card (temperature, camera,…)
  - Transceiver card
  - RTL SDR
  - Antenna





The Air-Ship

Communication system on Mock-up model



Integration receiver model on Mock-up

- Import GnuRadio Model on embedded board
  - Operating system: Linux
  - Generated python_code(GnuRadio) is compiled to C code by compiler
  - C-code will be sent by transceiver to ground station