Recent technical challenges of upgrading the ROPK radio telescope

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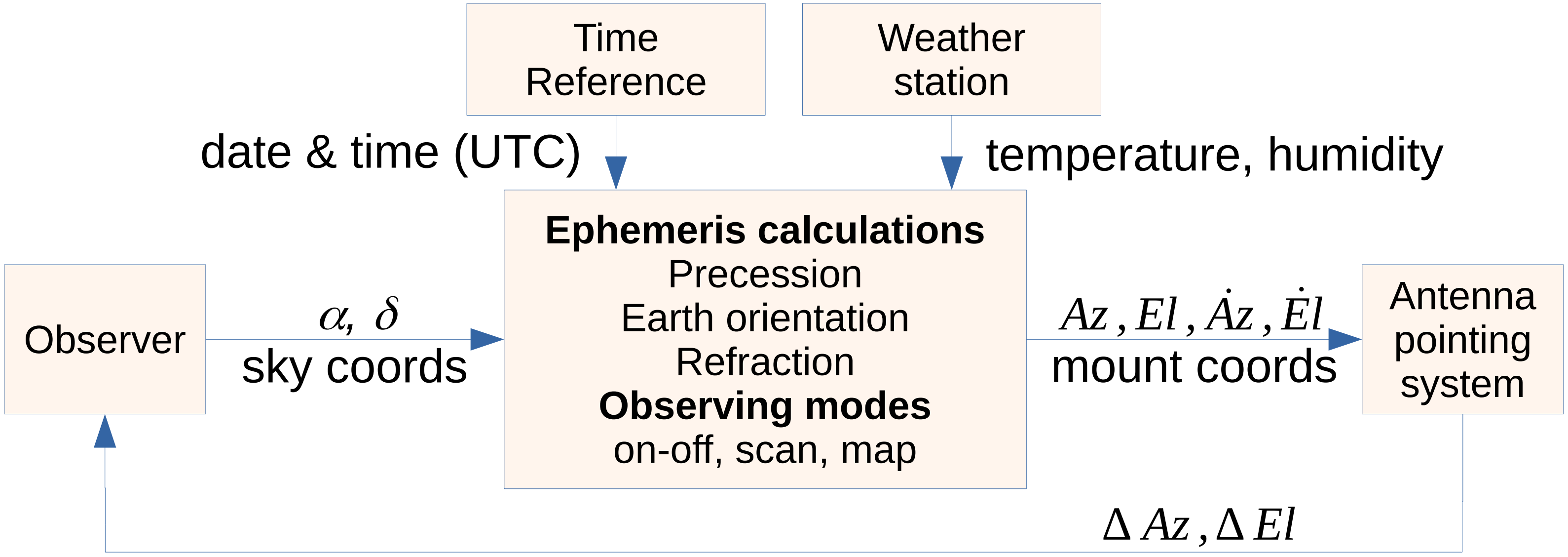
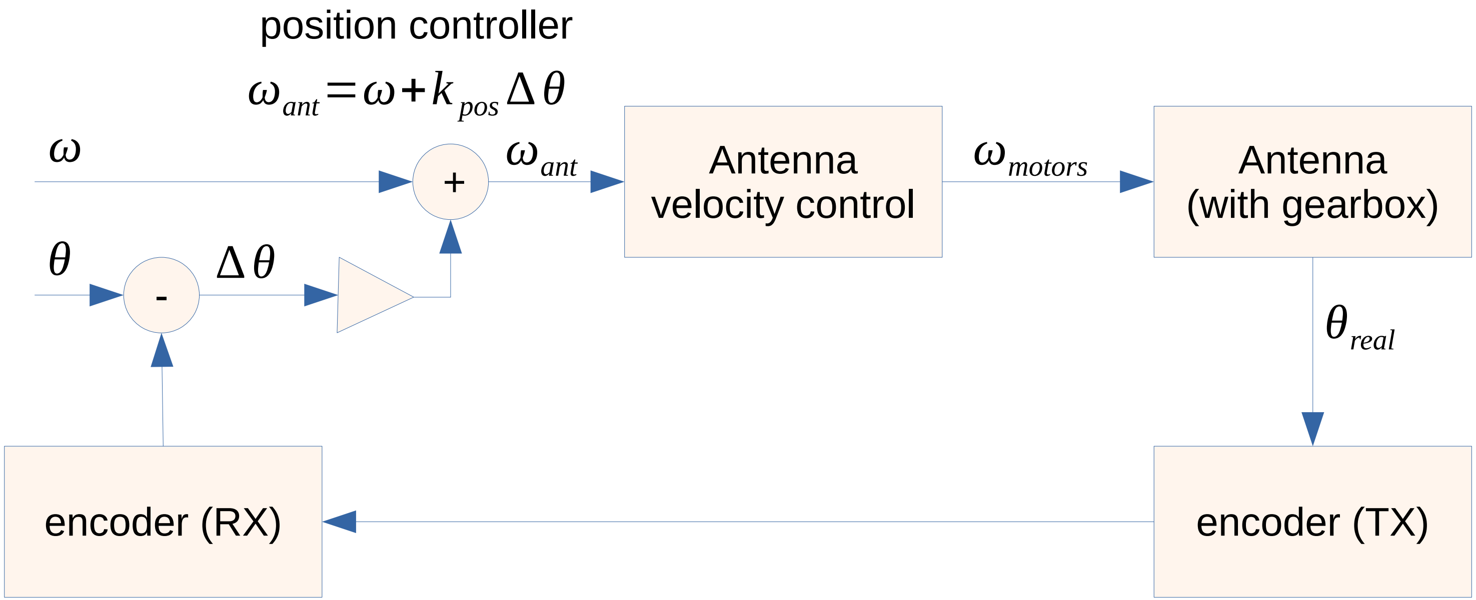
Ephemerids calculations



- Before: formulas & constants from Nautical Almanac
- New: Standards of Fundamental Astronomy routines (IAU)

Antenna pointing system

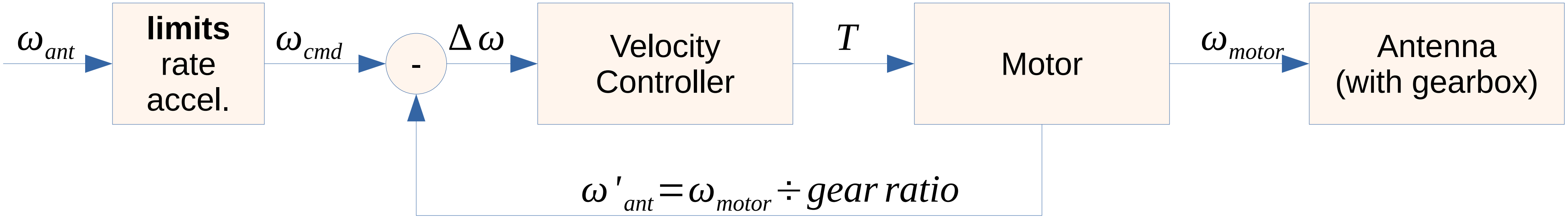


- Before: analog control system, computer in the loop
- New: Dedicated control computer (PLC)

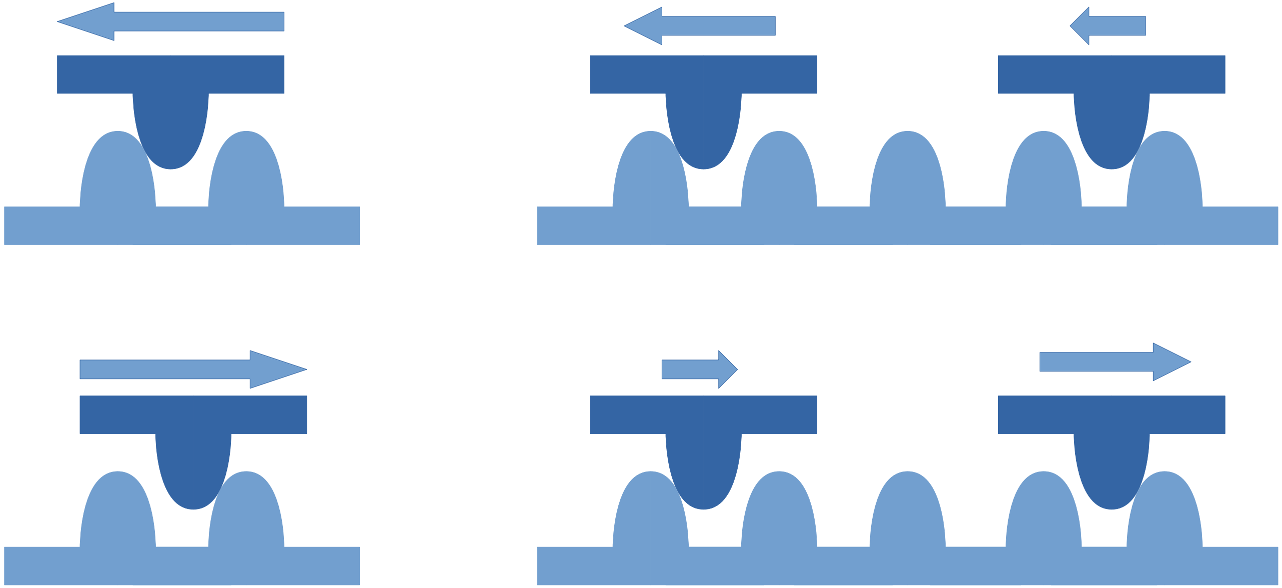
Velocity control

Classic PI controller:

$$T = k_p \Delta\omega + k_{\text{int}} \int \Delta\omega \, dt$$



Torque balance - backlash



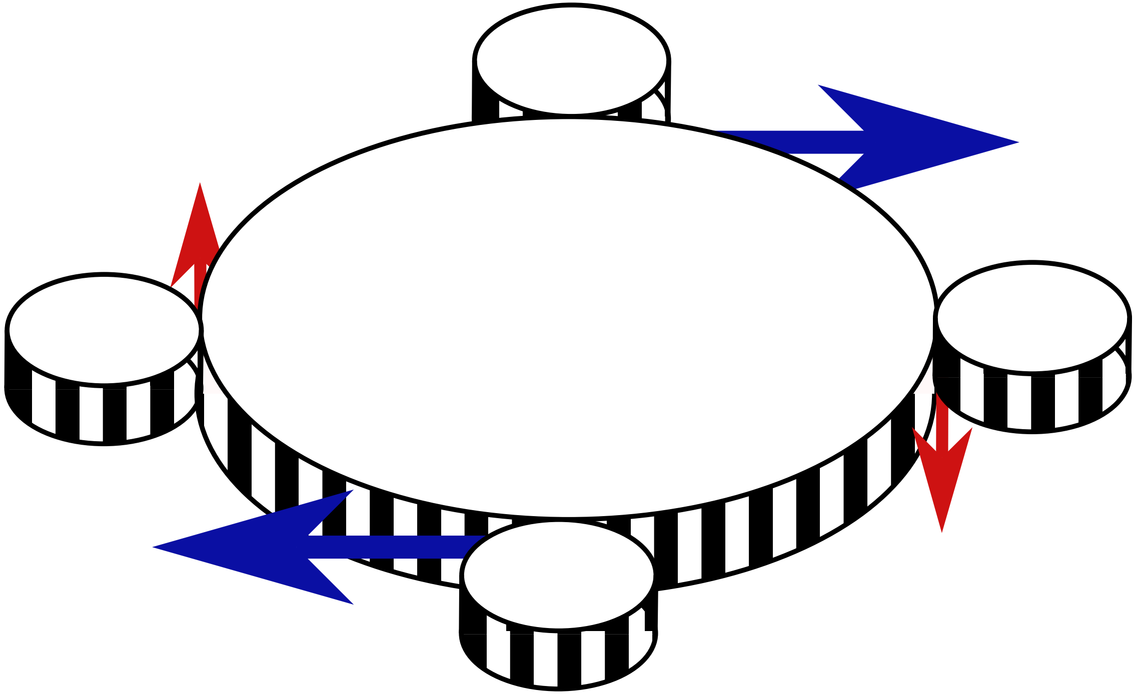
$$T_1 + T_2 = T$$

$$T_1 = \frac{T + \Delta T}{2}$$

$$T_2 = \frac{T - \Delta T}{2}$$

$$\omega_{motor} = \frac{\omega_1 + \omega_2}{2}$$

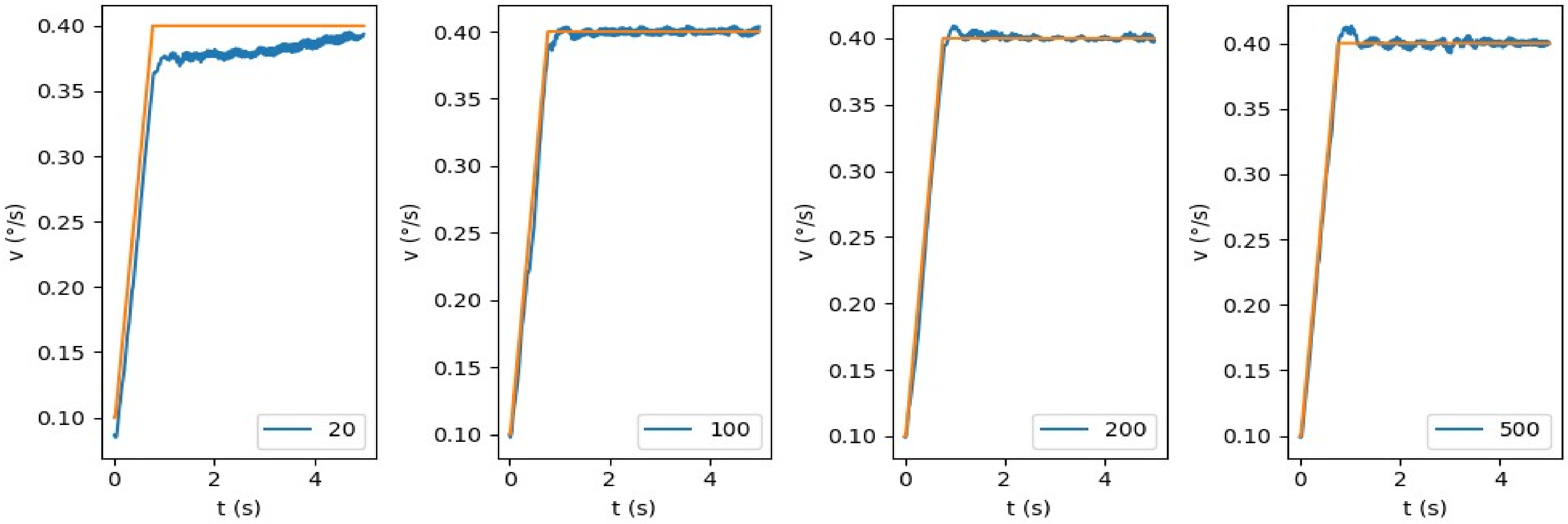
Why four motors?



Velocity gain adjustment

Classic PI controller:

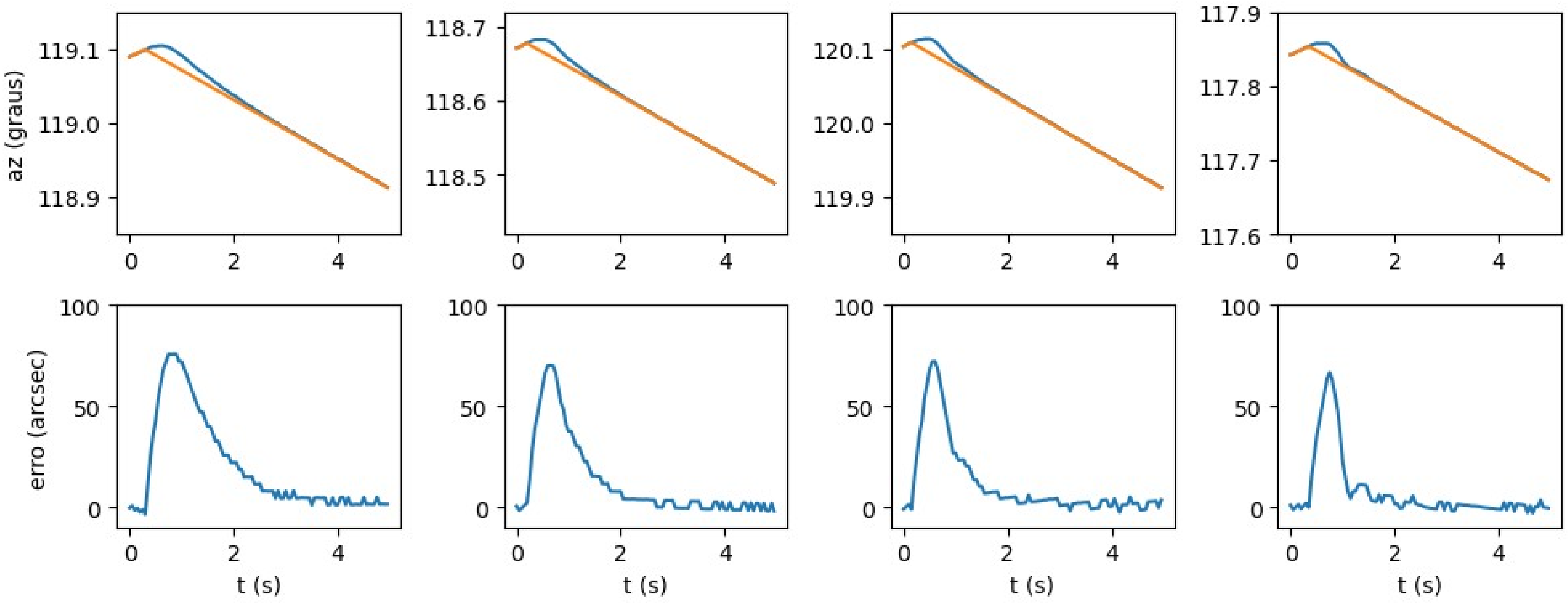
$$T = k_p \Delta\omega + k_{\text{int}} \int \Delta\omega \, dt$$



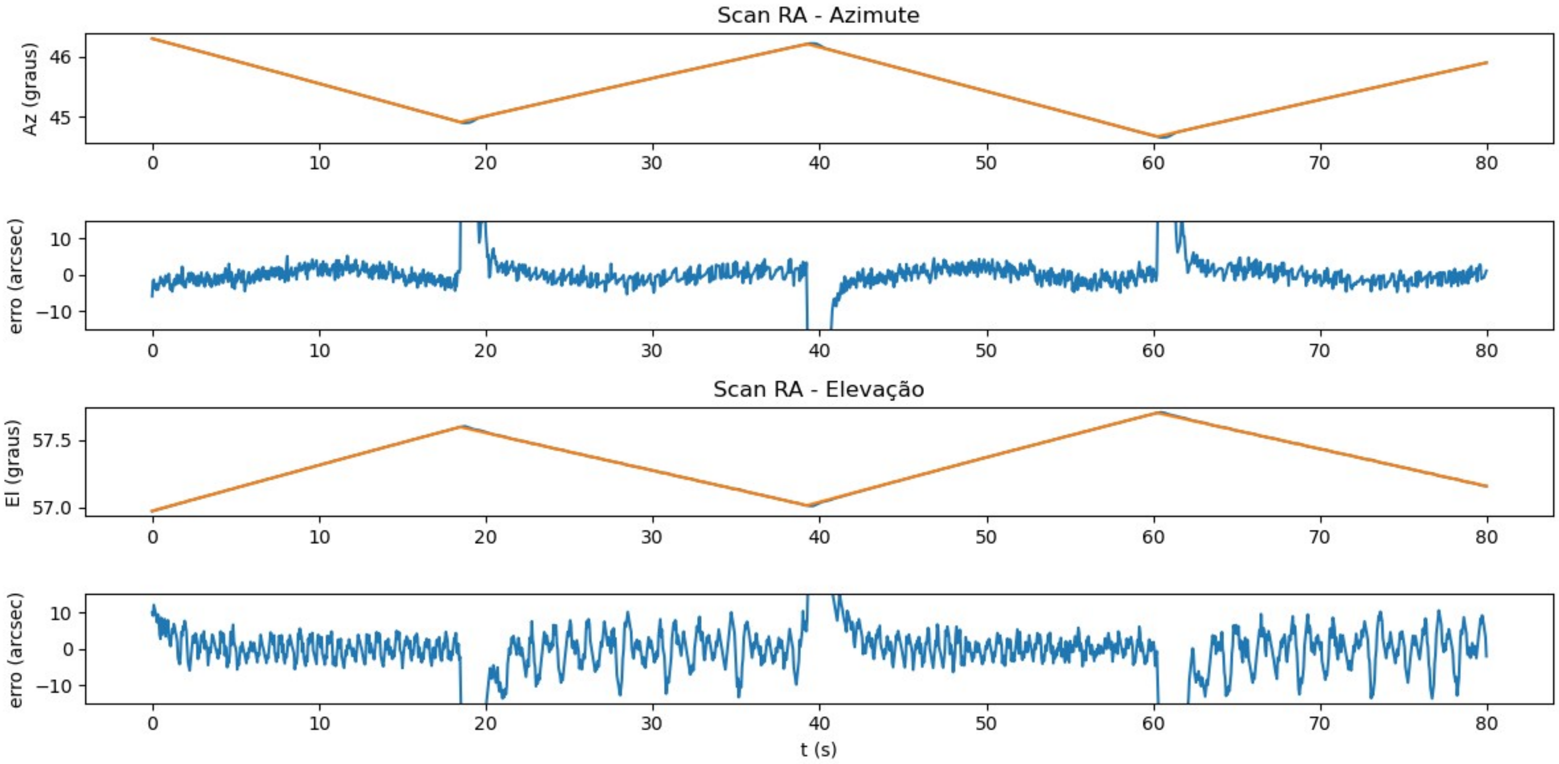
Position gain adjustment

position controller

$$\omega_{ant} = \omega + k_{pos} \Delta\theta$$

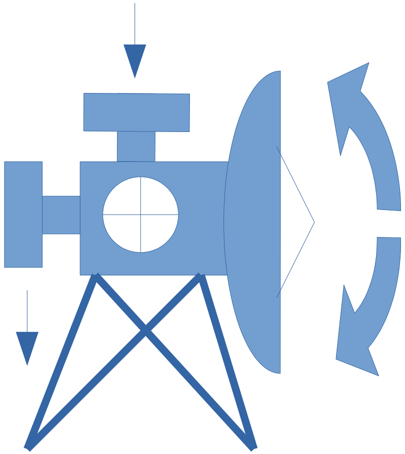
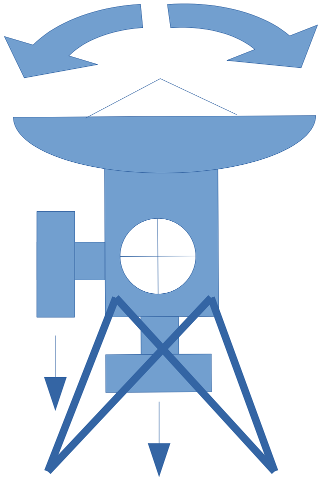


Result



Scan RA - Azimute
Az (graus)
46
45
0
10
20
30
40
50
60
70
80
erro (arcsec)
10
0
−10
Scan RA - Elevação
El (graus)
57.5
57.0
erro (arcsec)
t (s)

Balance

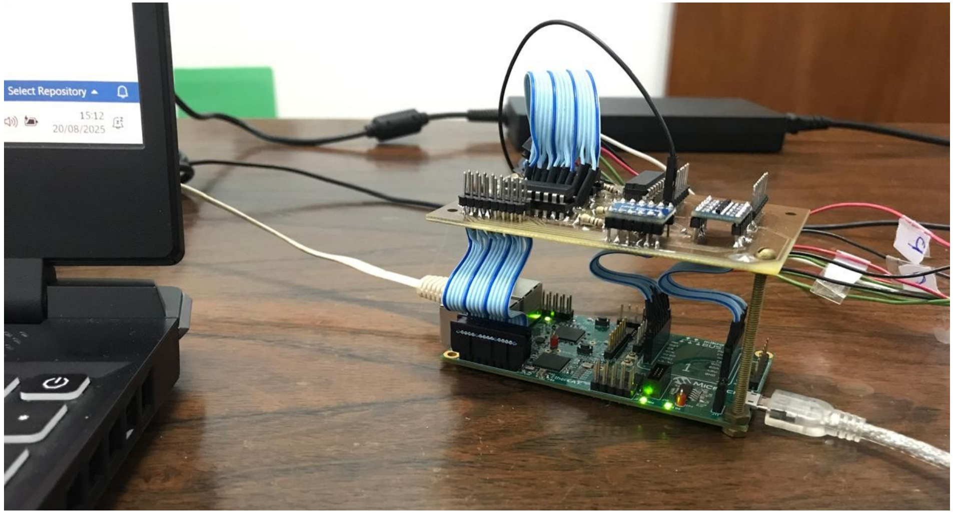
- Put the antenna (near) horizontal
- Measure torque climbing up and down
- Add counterweight to arm until balance achieved
- Repeat with antenna (near) vertical

New antenna pointing system

Encoder receiver interface

Parallel interface
Special purpose industrial computer

Ethercat interface
Direct connection to control system



Weather station

“7 GHz” building

Electric field sensor

Computer

→

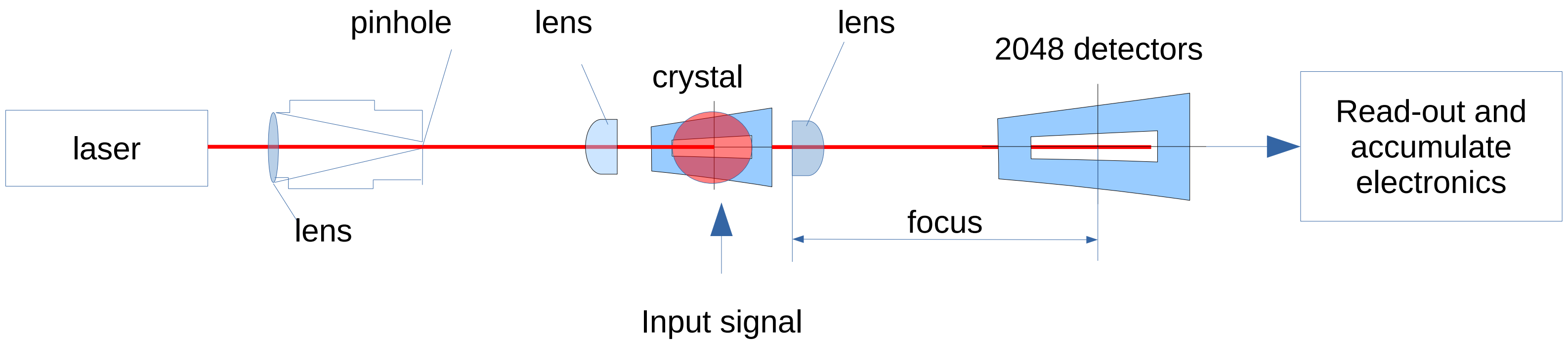
“Radome” building

Antenna Tracking

Computer

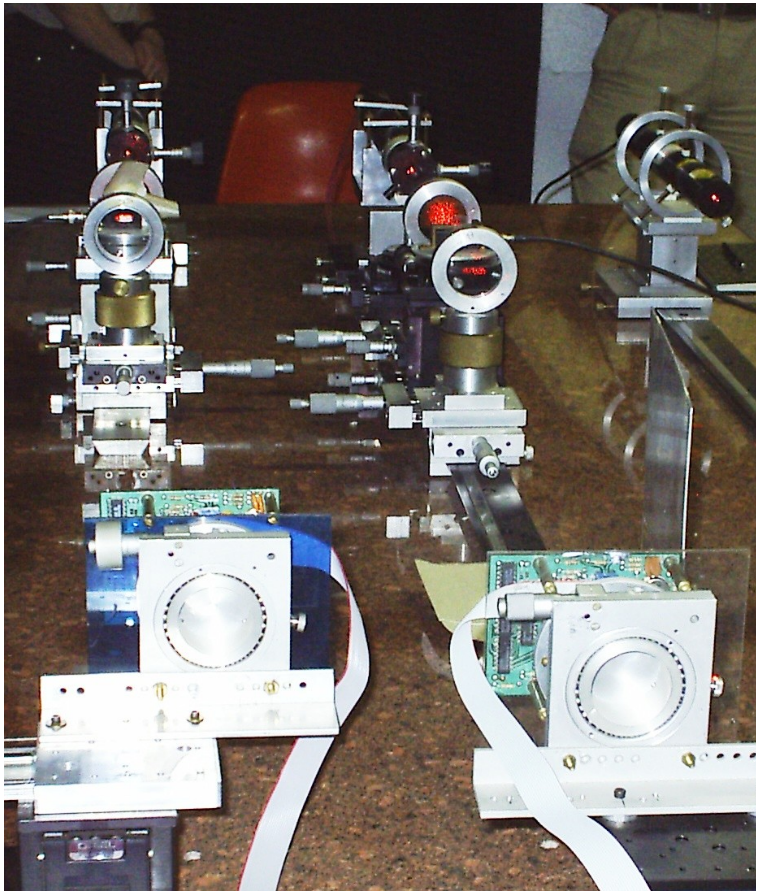
- Old weather station giving noisy results
- Console stores 1 min data, computer retrieves each 5 mins
- Easiest to read independently (Python), shared communication port

Previous Acousto-Optic spectrograph

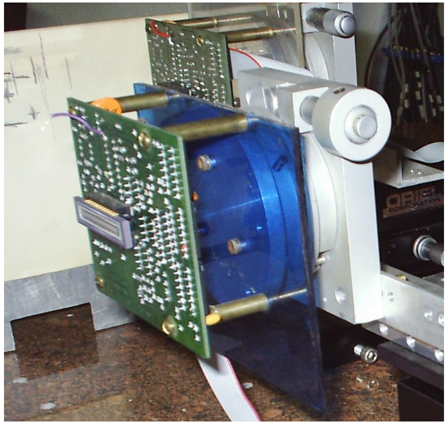


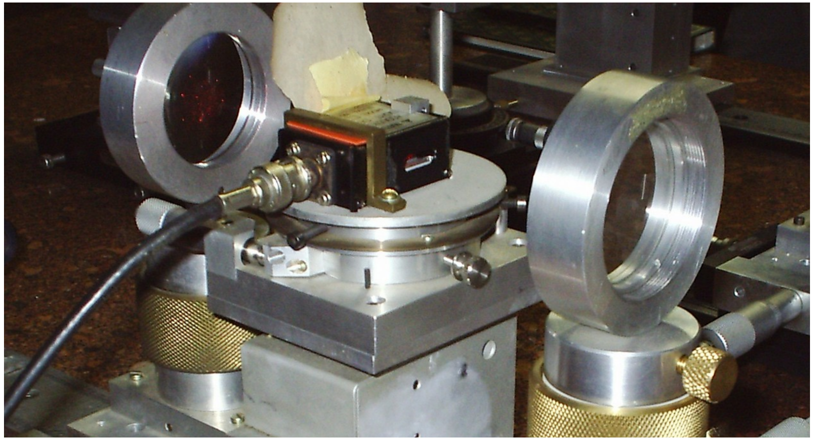
- Goal: spectral analysis of incoming signal
- Input signal induces acoustic waves in piezoelectric crystal
- Input frequency modulates the difraction index, like a grating
- So, laser deflection is frequency dependent (Fourier analysis)
- Resolution and bandwidth is crystal dependent

Old spectrograph

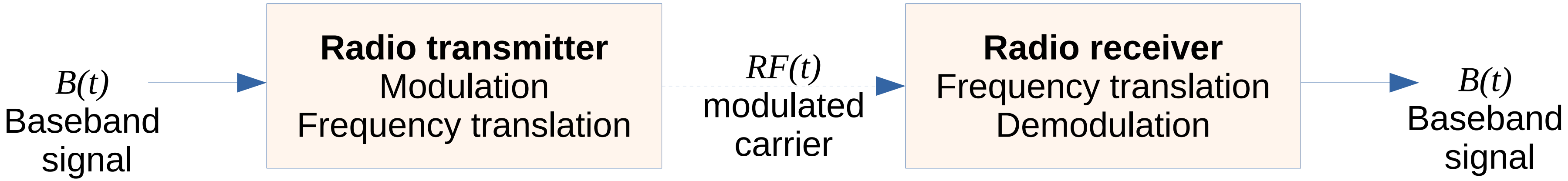


Band: 40 MHz
Channels: 2048
Resol: 70 kHz





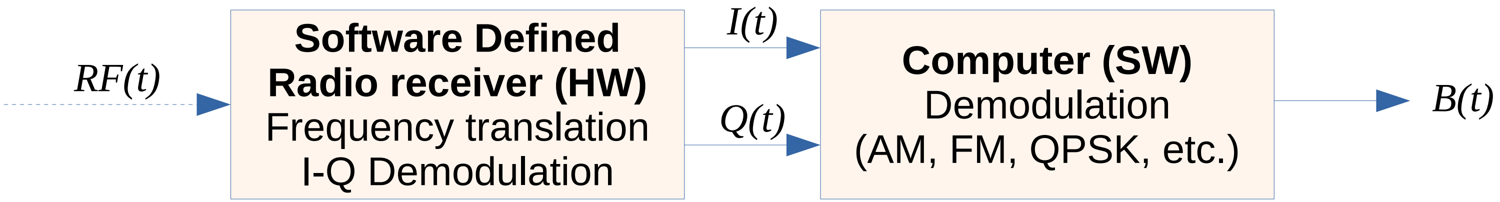
New SDR based spectrograph



$$RF(t) = A(t)\cos(2\pi f_c t + \phi(t)), \text{or}$$

$$RF(t) = I(t)\cos(2\pi f_c t) + Q(t)\sin(2\pi f_c t), \text{or}$$

$$RF(t) = 2\Re(\mathrm{C}(t)e^{2\pi f_c t})$$

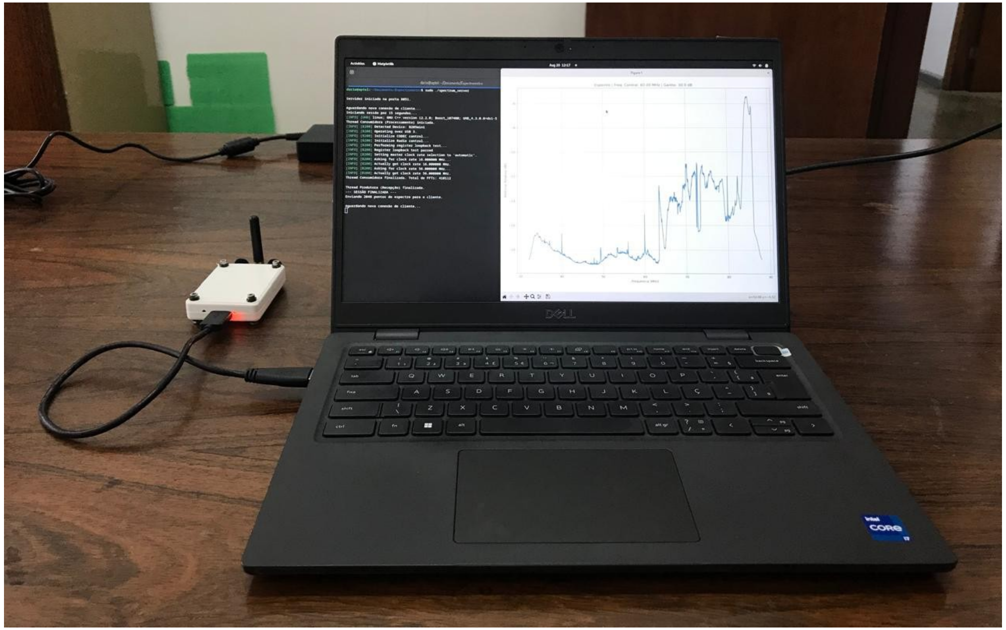


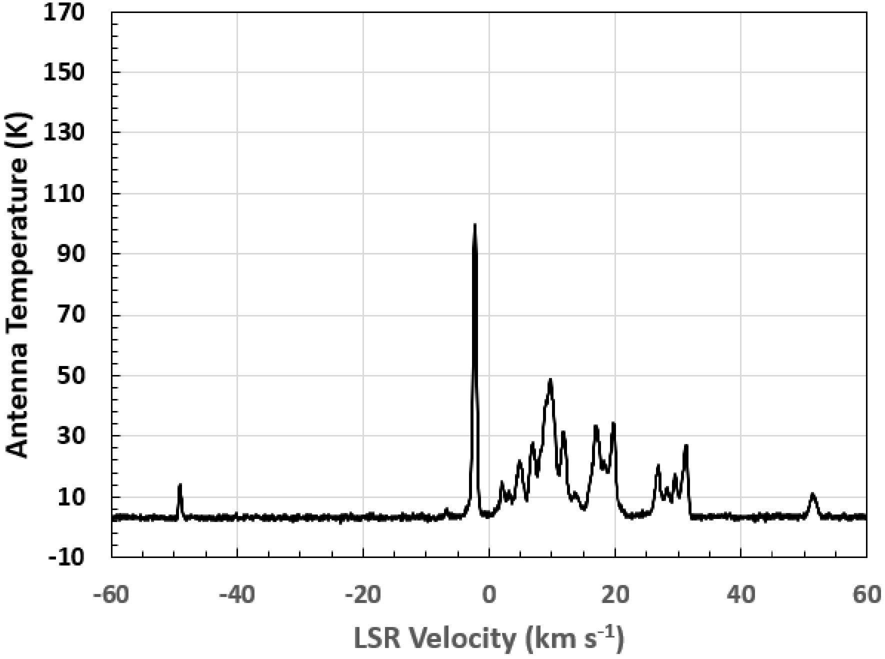
$$\text{For Astronomy}: PSD(f) = \overline{|\mathscr{F}(C(t))|^2}$$

$$\text{where}: C(t) = I(t) + i\,Q(t)$$

New spectrograph

Band: 1 - 56 MHz
Channels: 2048
Resol: 0.5 - 27 KHz





SDR results

- SDR model: Ettus Research B210i mini
- Bandwidth is limited by FFT
- CPU: AMD Ryzen 7 6800H
- GPU: NVIDIA GeForce RTX 3070 Ti
- 1st try in CPU (single thread) + Python (Linux): < 3 MHz
- On Windows: < 14 MHz with threads, 16 MHz with GPU
- On Linux: < 36 MHz with threads
- With NVIDIA GPU: < 42 MHz
- With CPU, in C with threads: 56 MHz

Next challenges

- Refine the pointing model
- Receiver focusing
- New digitizer for dual total-power receiver
- Polarization spectrograph
- Radome replacement
- Surface photogrammetry
- Cryogenics maintenance