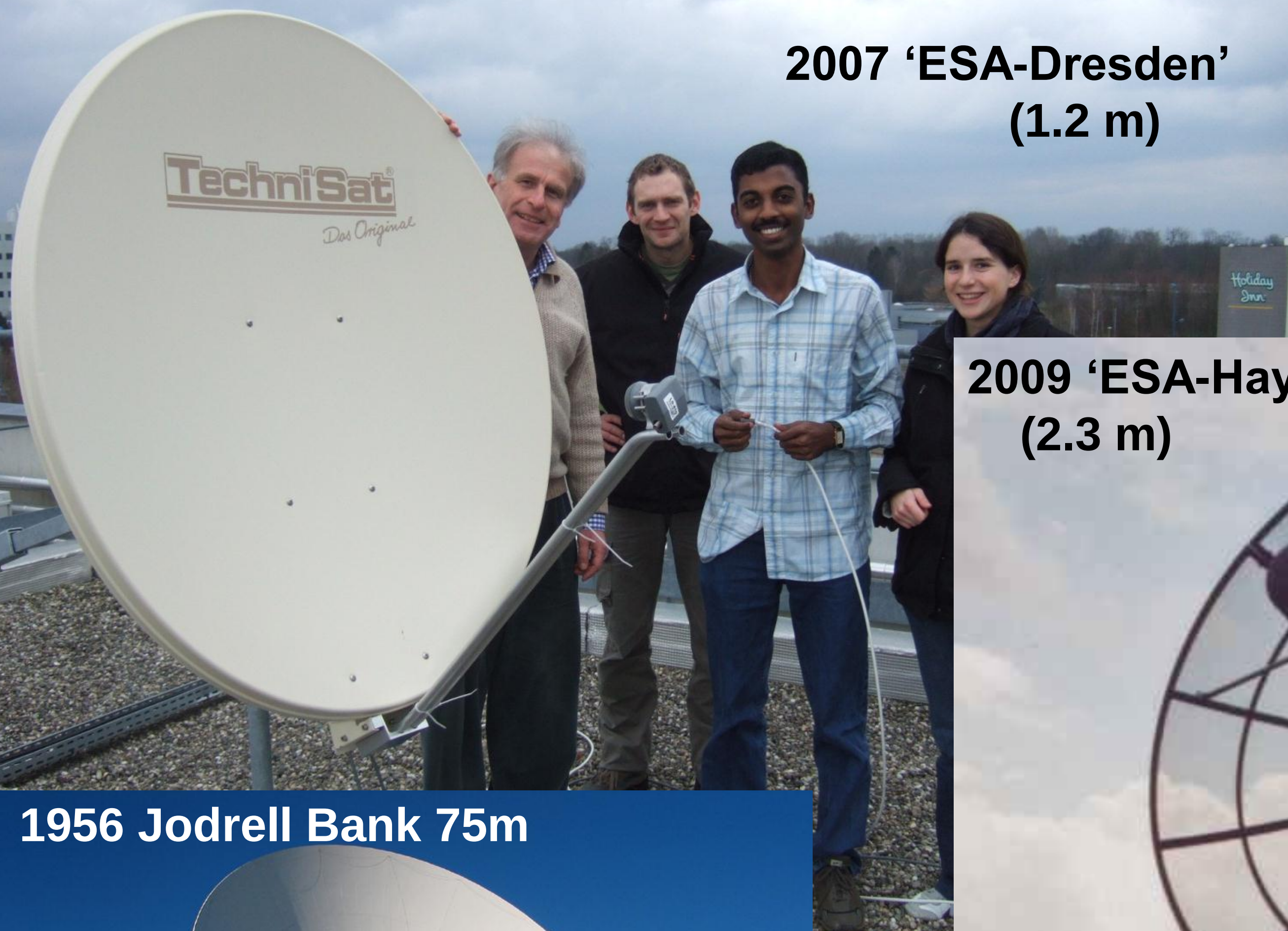
Introduction to Radioastronomy:

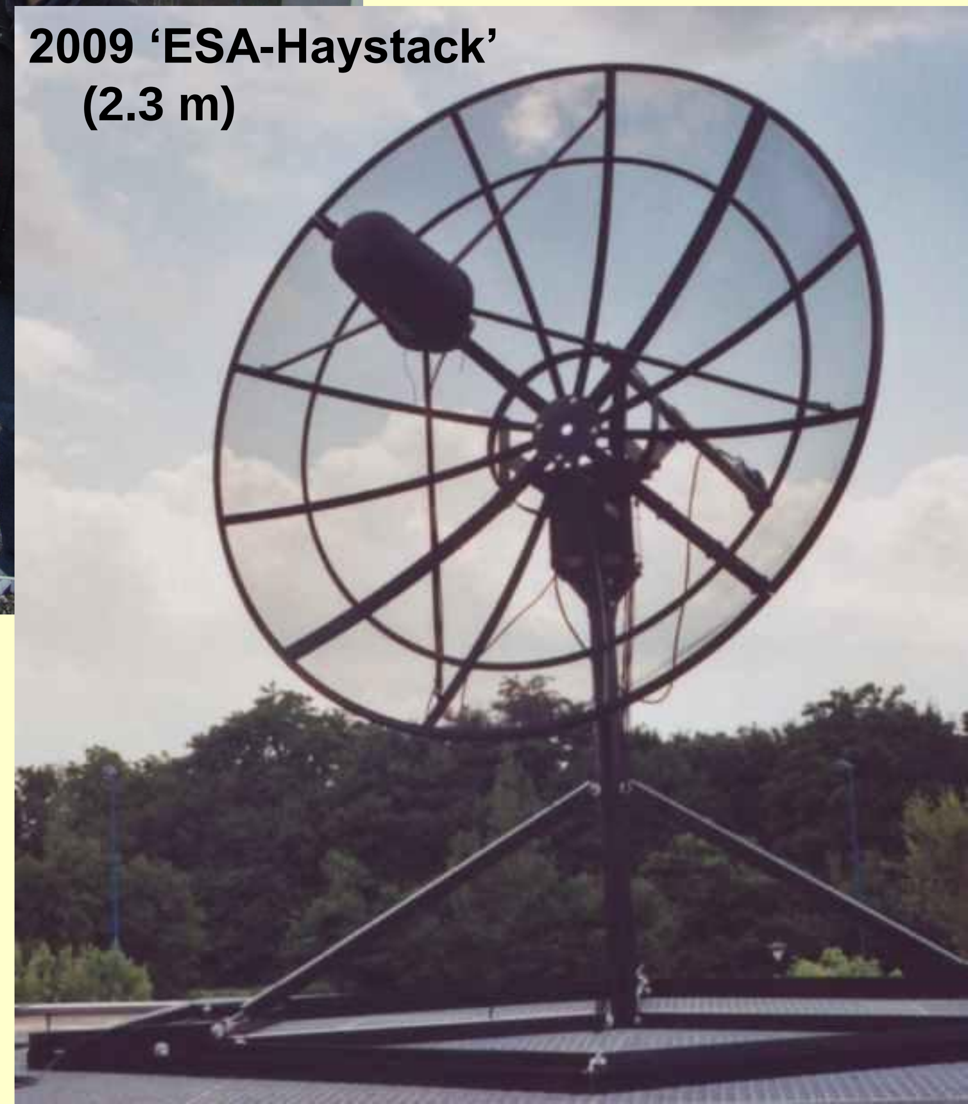
The radio telescopes at ISU

Observatoire astronomique
de Strasbourg

J.Köppen joachim.koppen@astro.unistra.fr

http://astro.u-strasbg.fr/~koppen/JKHome.html

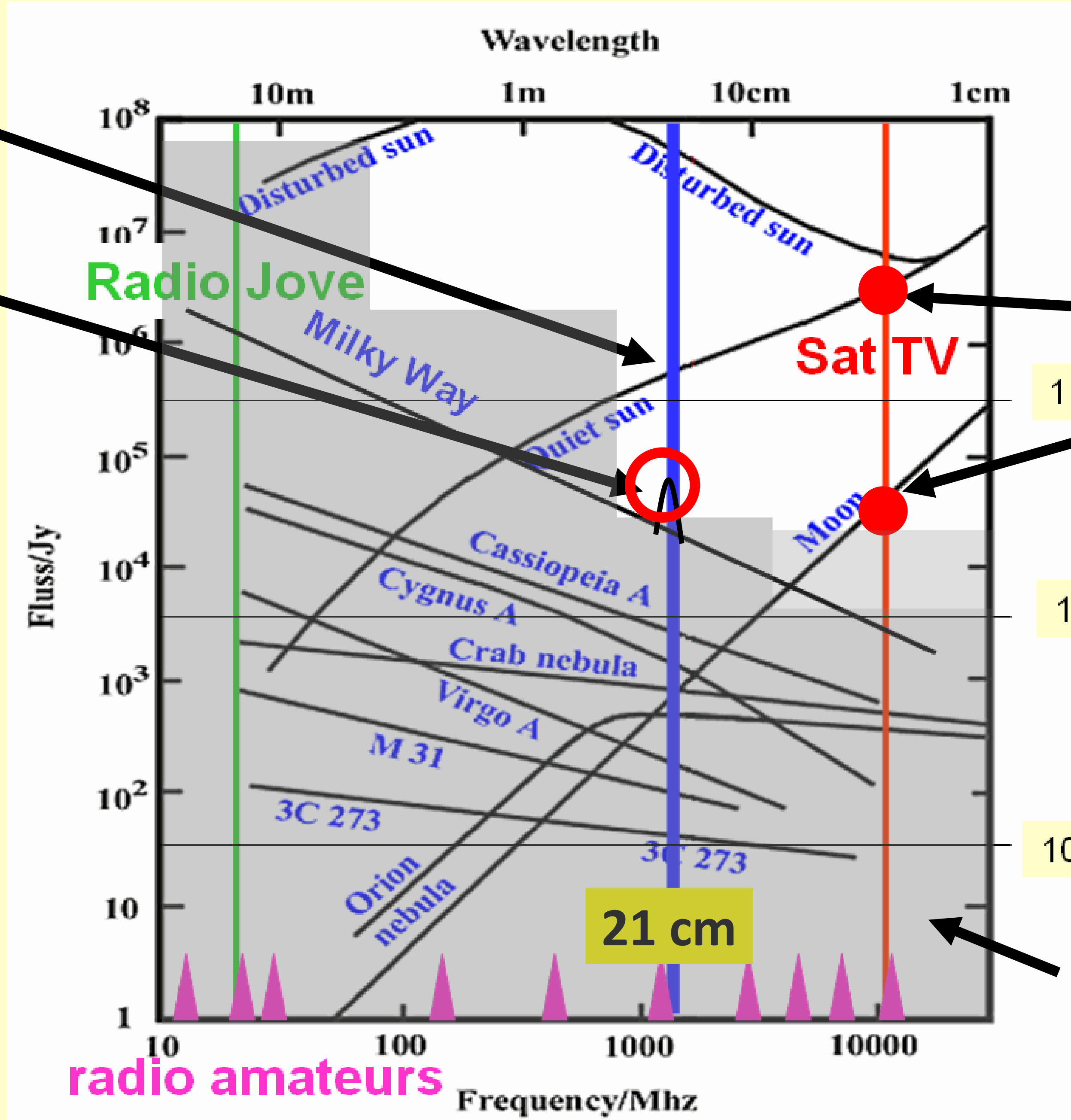

2007 ‘ESA-Dresden’
(1.2 m)
TechniSat
Das Original
Holiday Inn


2009 ‘ESA-Haystack’
(2.3 m)


1956 Jodrell Bank 75m

What we can observe

Haystack



Dresden

GENSO

Local noise @ ISU

ISU's two Radiotelescopes

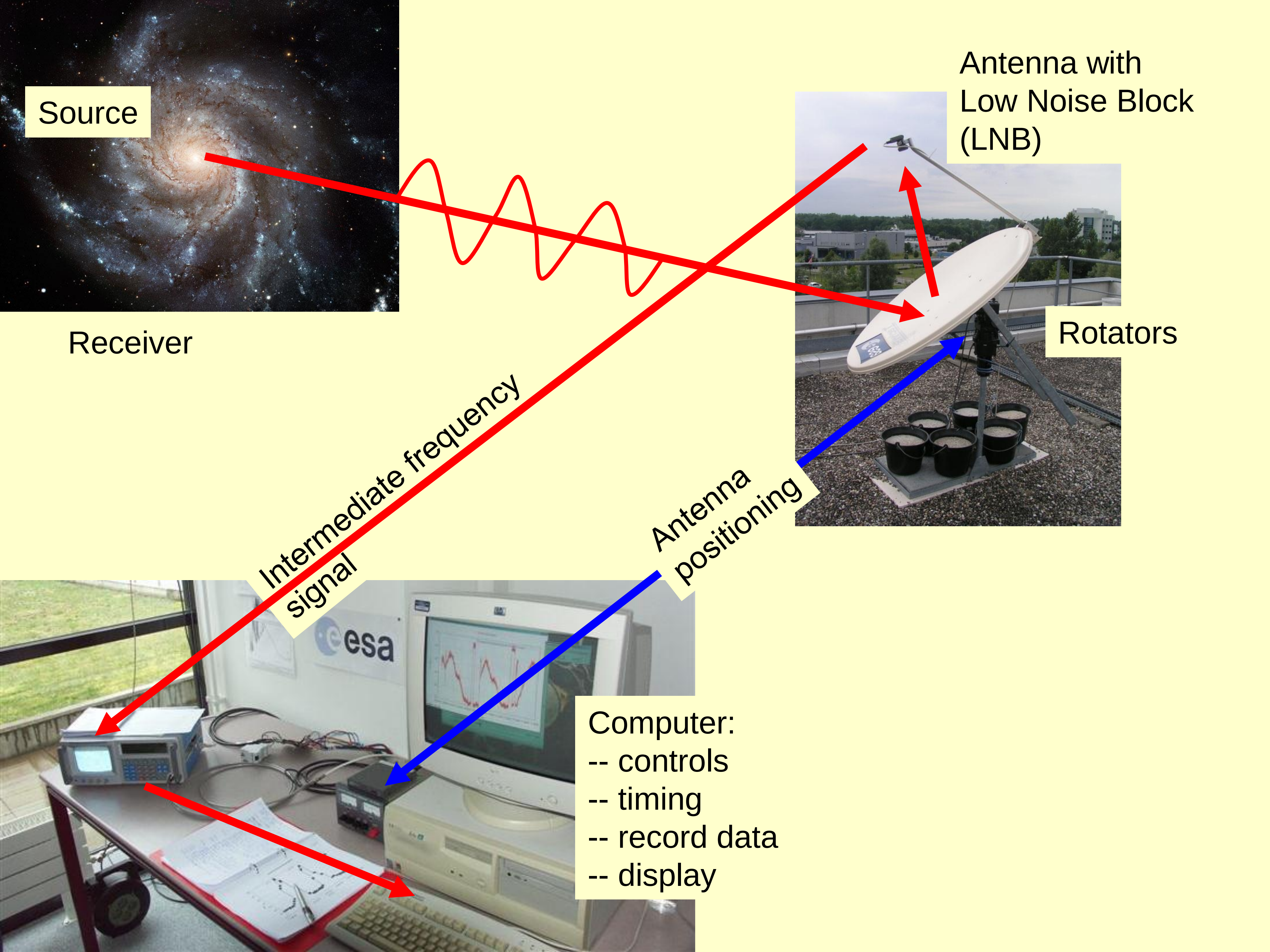
	ESA-Dresden	**ESA-Haystack**
Frequency	**10 ... 12 GHz (continuum)**	**1.420 GHz (HI line)**
Wavelength	**3 cm**	**21 cm**
Dish diameter	**1.2 m**	**2.3 m**
HPBW (ang.resolution)	**1.5°**	**6°**
Time for full solar scan	**30 min**	2 hrs (!)
Suitable objects	**Sun, Moon**, (TV satellites)	Sun, **Milky Way**
We measure	**absolute fluxes (give temperatures, Radiometer)**	**spectra, radial velocities of H gas clouds (Spectrometer)**
Positional accuracy and stability	**±1° (at best!)**	**±0.5°**
operation	**manual**	Manual & **Batch**

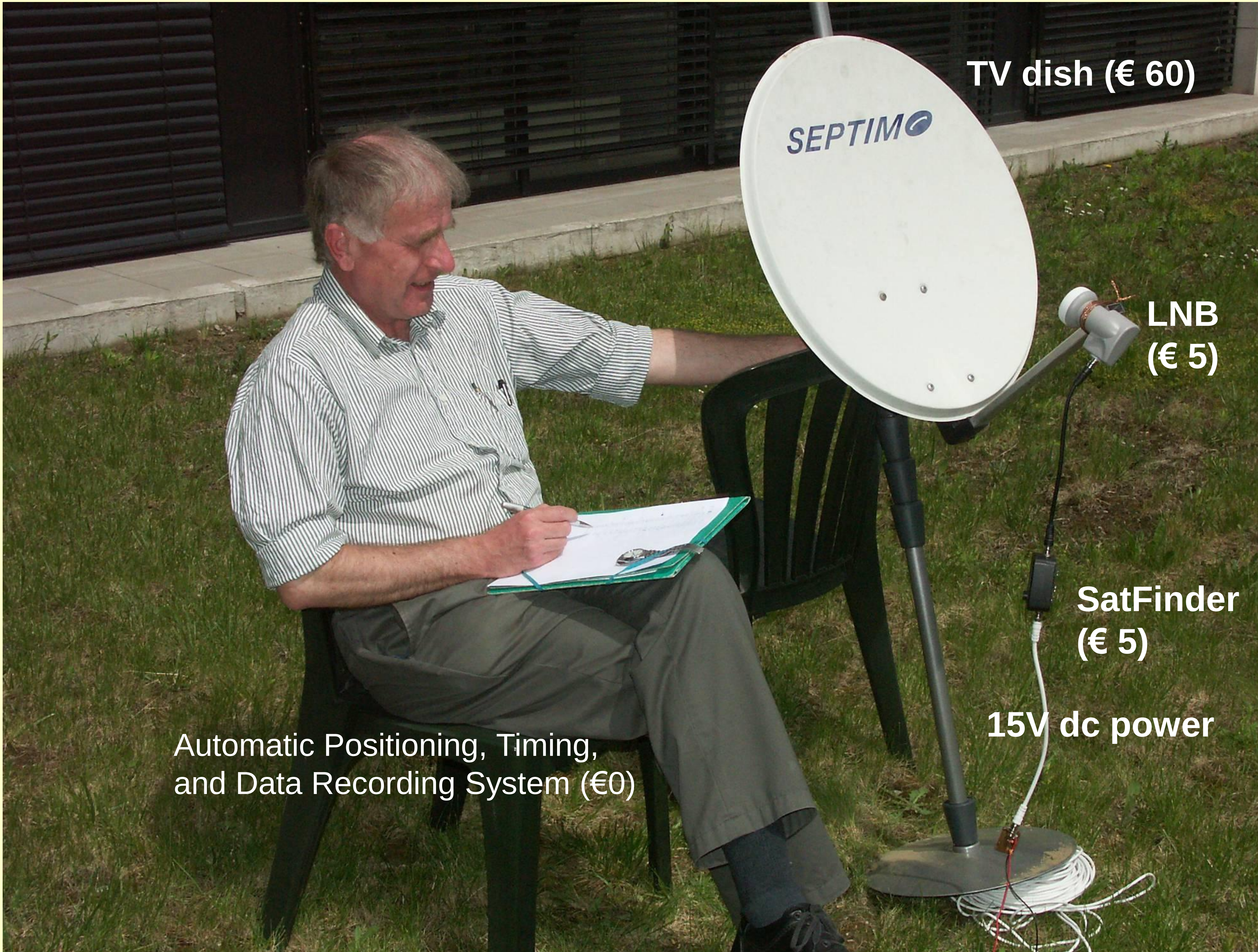
The ESA-Dresden Telescope

- Frequency 10..12 GHz (wavelength 3 cm)
- Radiometer
- 1.2 m diameter satellite TV antenna

- Sun, Moon, (TV satellites)

- http://astro.u-strasbg.fr/~koppen/10GHz/

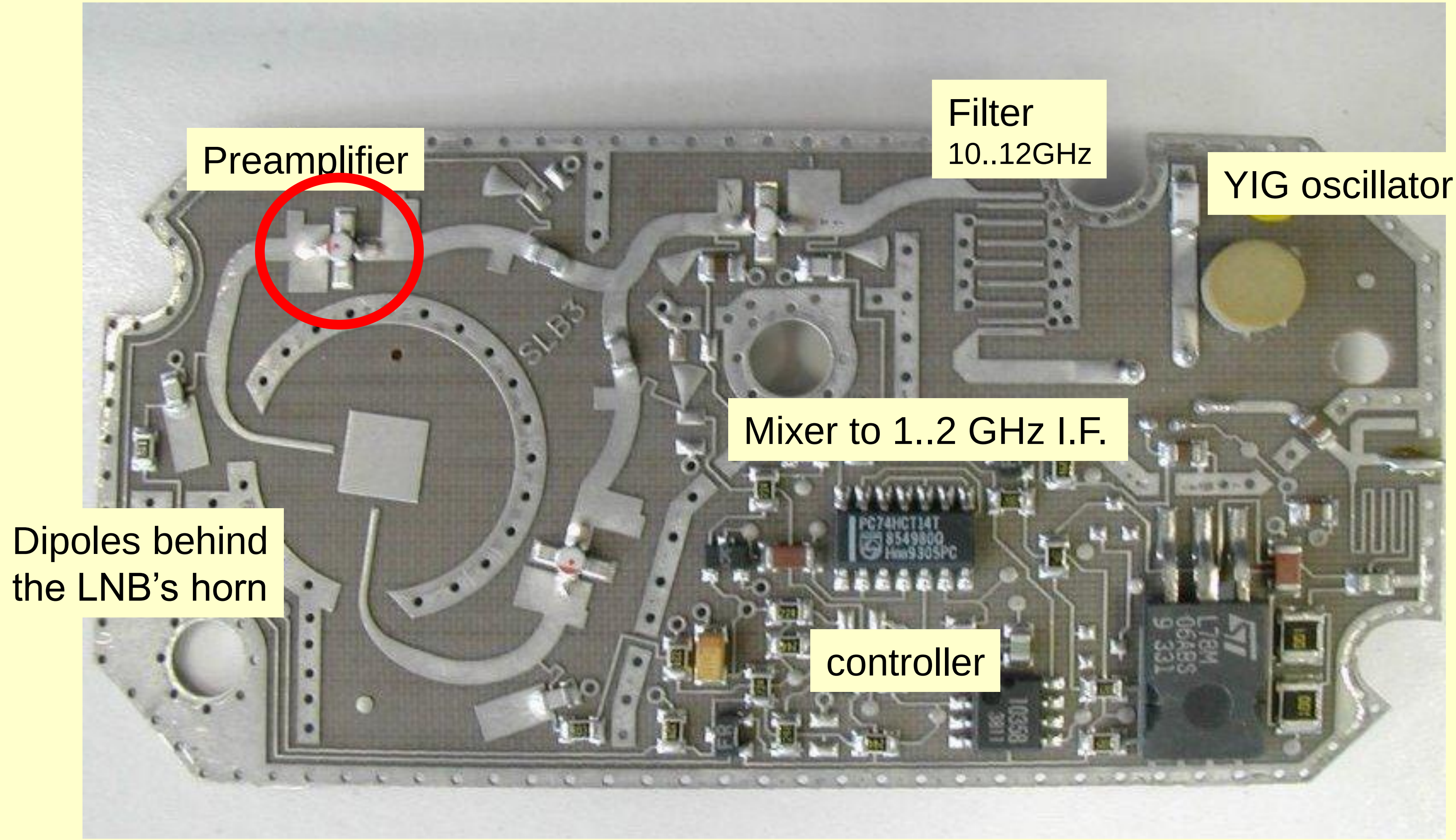

Source
Antenna with
Low Noise Block
(LNB)
Receiver
Rotators
Intermediate frequency
signal
Antenna
positioning
Computer:
-- controls
-- timing
-- record data
-- display


TV dish (€ 60)
SEPTIMO
LNB
(€ 5)
SatFinder
(€ 5)
15V dc power
Automatic Positioning, Timing,
and Data Recording System (€0)

On the roof

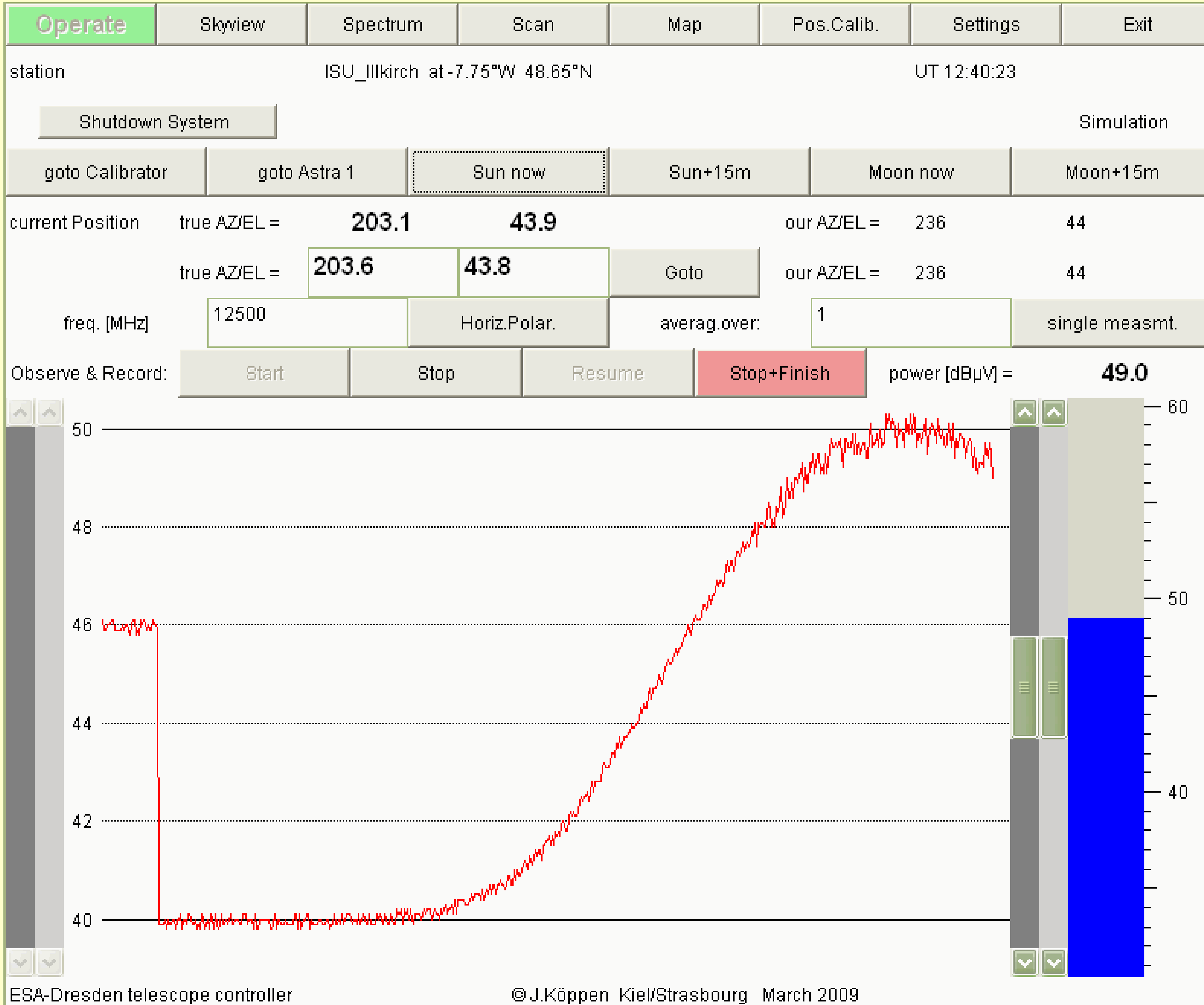
- 1.2m offset parabolic reflector
- Rotators for azimuth and elevation
- Low noise block (LNB):
  - Small horn antenna catches radio wave
  - Dipole senses radio wave, converts it into electrical signal
  - Preamplifier boosts signal (makes the background noise)
  - This 11 GHz signal is converted (mixed) to lower intermediate frequency (I.F., 1..2 GHz)
- Coaxial cable to observatory room

Inside a SatTV LNB



In the Observatory room

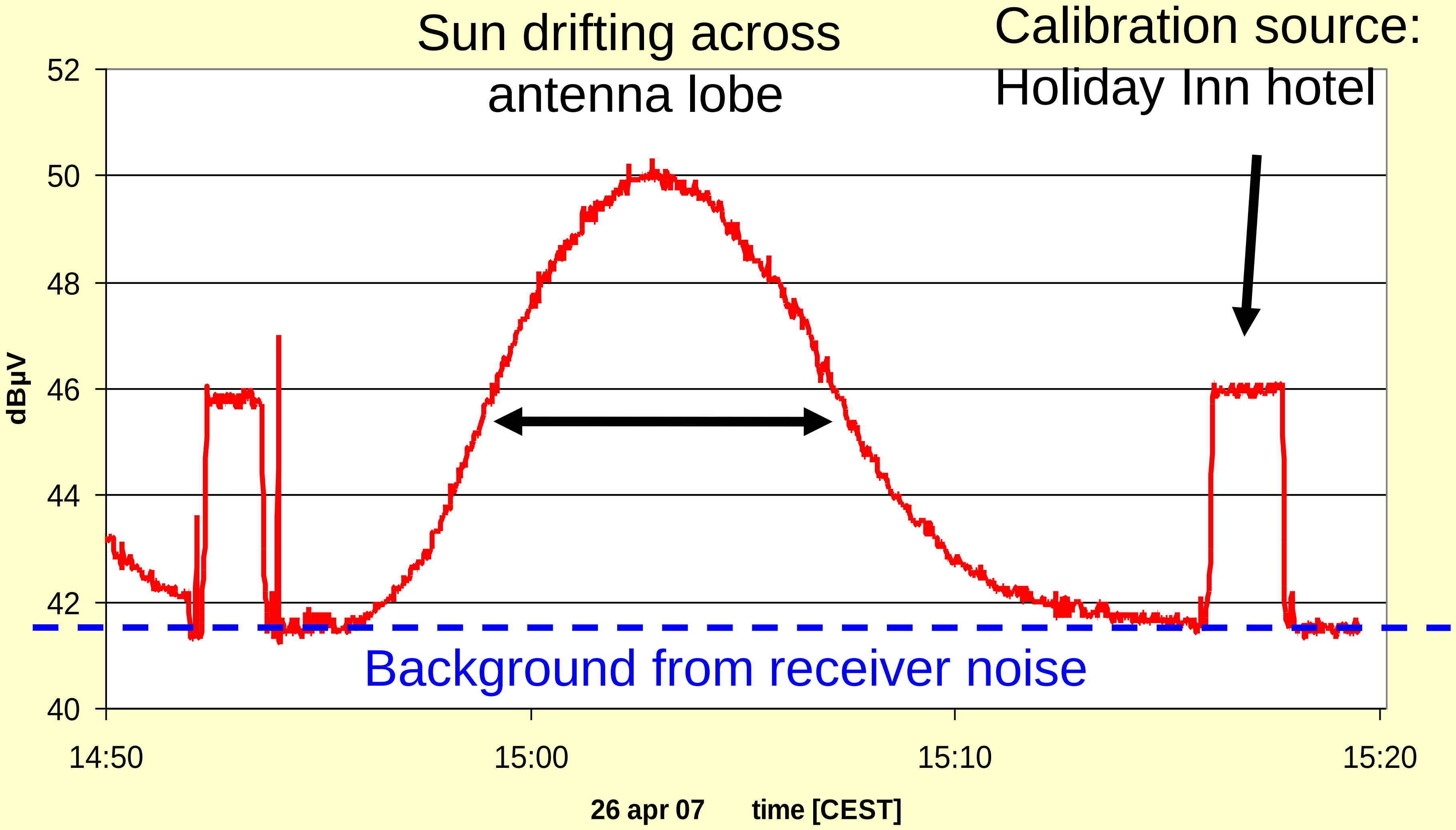
- Receiver measures strength of I.F. signal
  - in μV at its input terminal
  - one measurement every 2 sec
  - data are passed to computer for storage and display
- Rotator controller with computer interface
- Computer software provides graphical interface to user:
  - Controls: position, frequency, start/stop measuring …
  - Display: current position, measured data, …
  - predict Sun and Moon position


Operate
Skyview
Spectrum
Scan
Map
Pos.Calib.
Settings
Exit
station
ISU_Illkirch at -7.75°W 48.65°N
UT 12:40:23
Shutdown System
Simulation
goto Calibrator
goto Astra 1
Sun now
Sun+15m
Moon now
Moon+15m
current Position
true AZ/EL =
203.1
43.9
our AZ/EL =
236
44
true AZ/EL =
203.6
43.8
Goto
our AZ/EL =
236
44
freq. [MHz]
12500
Horiz.Polar.
averag.over:
1
single measmt.
Observe & Record:
Start
Stop
Resume
Stop+Finish
power [dBμV] =
49.0
50
48
46
44
42
40
60
50
40
ESA-Dresden telescope controller
© J.Köppen Kiel/Strasbourg March 2009

How to measure the surface temperatures of Sun and Moon

- Observe the passage of the sun through the antenna beam (we utilize the Earth's rotation!):
  - Maximum gives radio flux from the sun
  - The profile gives the width of antenna beam, needed to determine the beam filling factor
- Flux from calibrator source = source of known temperature = the ground (290 K)
- Observe empty sky = determine background noise (mainly from the front end (LNB) of the receiver system)

An example: the raw data



Preview of analysis

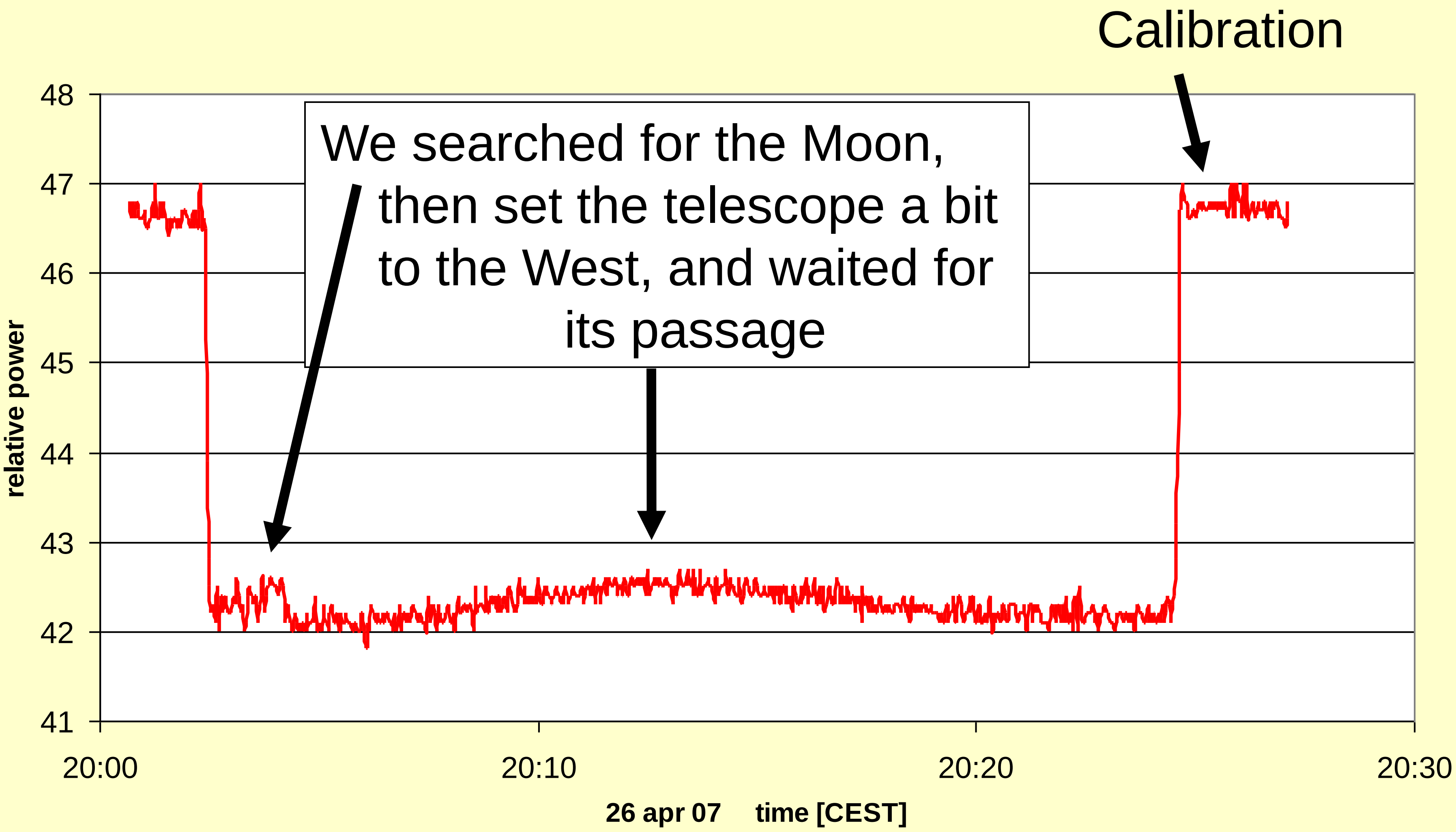
- reduce and calibrate the measured power

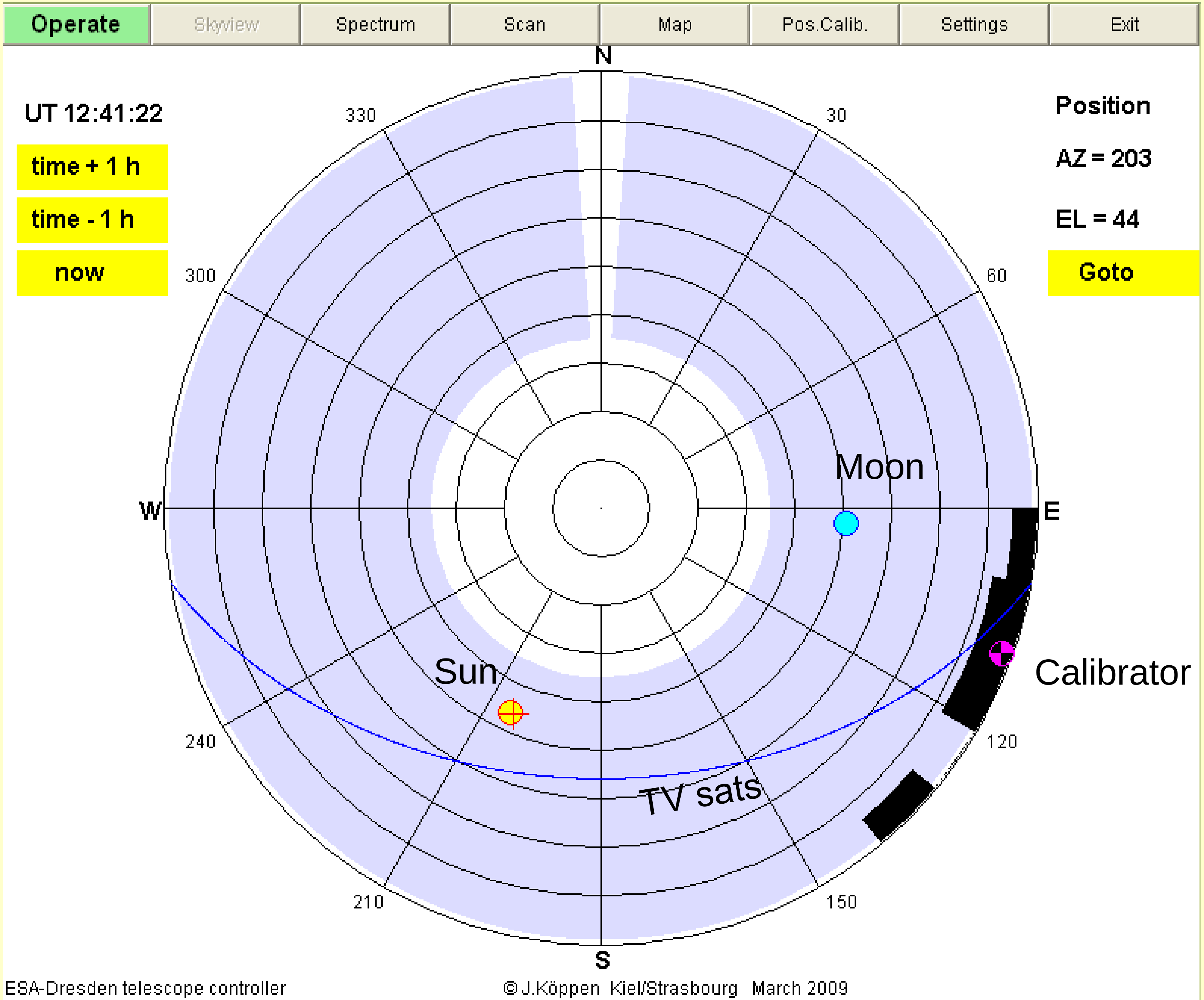
$$T_{Ant} = (P_{Sun} - P_{Sky})/(P_{Cal} - P_{Sky}) * 290\ K$$

- the Sun does not fill the antenna beam: angular diameter $D_{Sun} = 0.5° < HPBW$!

$$T_{Surf} = T_{Ant} * (HPBW/D_{Sun})^2$$

The same thing for the Moon is somewhat more delicate




Operate
Skyview
Spectrum
Scan
Map
Pos.Calib.
Settings
Exit
UT 12:41:22
time + 1 h
time - 1 h
now
Position
AZ = 203
EL = 44
Goto
N
S
E
W
30
60
120
150
210
240
300
330
Moon
Sun
Calibrator
TV sats
ESA-Dresden telescope controller
© J.Köppen Kiel/Strasbourg March 2009

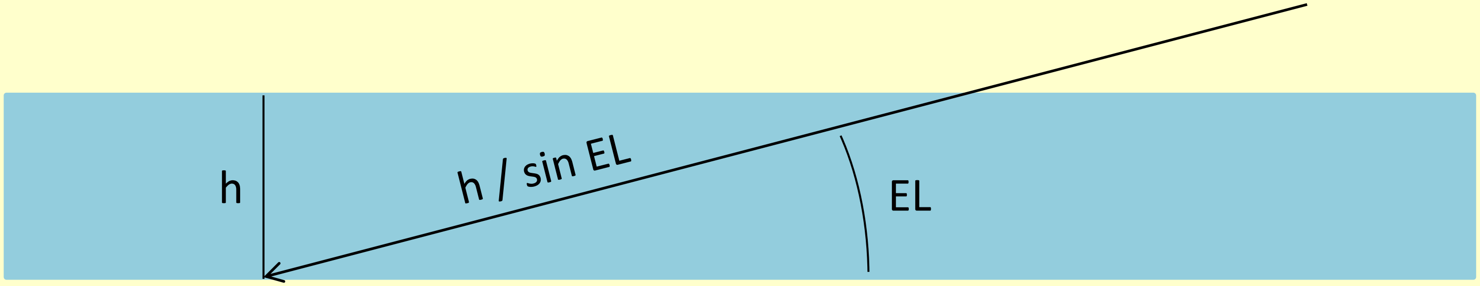
Drift scans of the Sun

- A half-scan is easy at any time:
  - **goto Calibrator**, measure for 2 min
  - **Sun now** , **Goto**
  - find best position manually
  - (perhaps move a tiny bit to the West (right))
  - let the Sun drift across the beam
  - When signal becomes low and constant, you have the sky, then **goto Calibrator** (2 min)
- A full scan is best done near lunch-time

However: the background …

… is the sum of

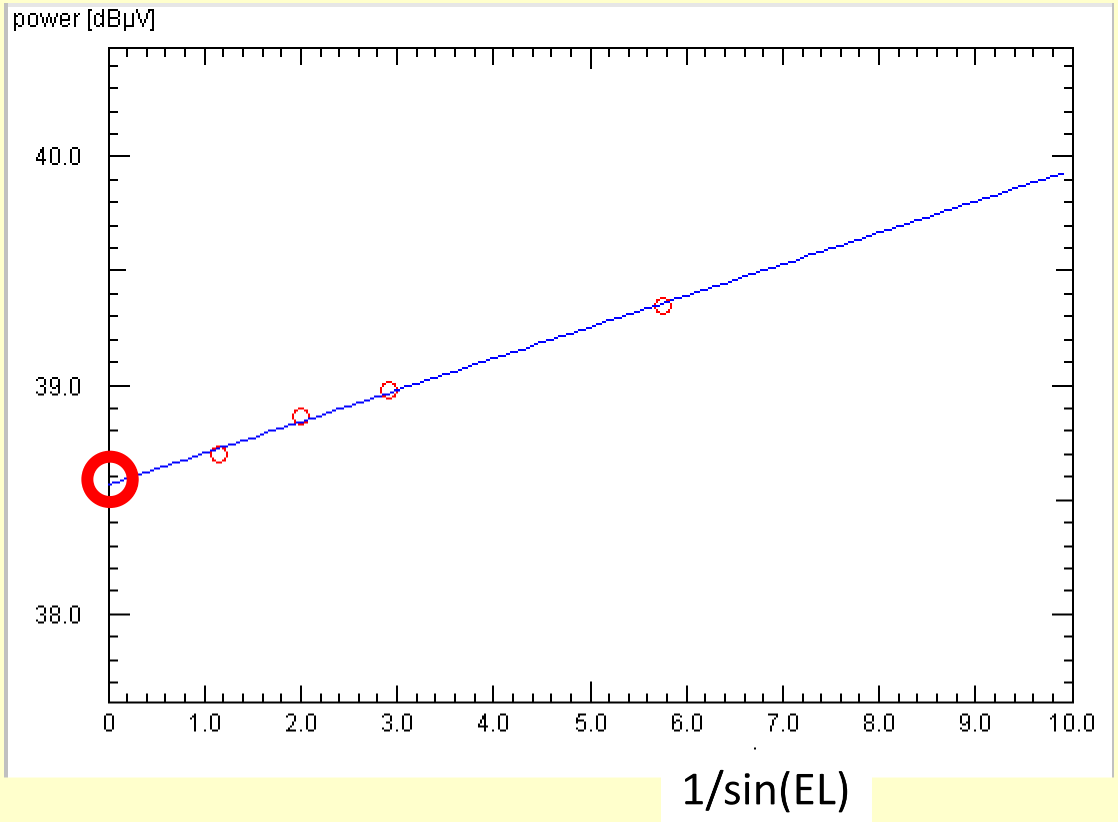
- the receiver noise, which is constant at all positions
- and the sky noise, which increases with lower elevation angle as we look through a longer path through the atmosphere:



- $P_{backgrd}(EL) = P_{RX} + P_{sky} / \sin(EL)$

How to do it

- Measure sky noise at several elevations (needs extra time ☹ 10 min at 10°, 20°, 30°, 60°)
- Fit the data with the above relation, to get P_{RX}



… and apply it

$$T_{Ant} = (P_{Sun} - P_{Backgrd}(EL))/(P_{Cal} - P_{RX}) * 290\ K$$

when we observe the sun, the background noise is from receiver **and** the sky at that elevation EL

but when we look at the calibrator, the background is only receiver noise!

Simulation with the Trainer applet

http://astro.u-strasbg.fr/~koppen/10GHz/applets/trainer/

- In contrast to the real telescope, the simulator's positioning is perfect: use **sun+15min** to lay in wait for the sun
- Data are obtained by grabbing the text from the **Output** screen

Reality: Bag of Tricks I

- The positioning system was never designed to point at such small sources … but we can do it!
- ➔ find the best position manually ➔ we must be present during observations
- **Stop** measuring, receiver outputs signal more often! … then **Resume**
- it’s best done with the controller keys

Bag of Tricks II

- Run ‘RadioAstro’ to establish port communication:
  - Open ...
  - The current position numbers should appear
  - Close ...
  - Exit the program

- Run ‘ESA-Dresden’ software
  - Start

Bag of Tricks III

- In principle, the electronics needs about 2 hours to warm up to equilibrium temperature
- During that time, there will be drifts in the displayed position (5° in Az) and the measured power levels (0.3 dB) … don't worry!
- If you keep that in mind, you can observe without waiting ☺!