DIY Astronomy

Radio Astronomy at 12GHz

The Treavor & Phil Factor

Doug Holland

1. The Treavor Factor -

Treavor says - Can a satellite TV dish be used for radio astronomy?

Rule of thumb – When someone tells you something cannot be done, someone else is probably already doing it -

SARA – the Society of Amateur Radio Astronomers

Under projects

The itty bitty radio telescope

2. The Phil Factor -

During a trip to MOD Pizza, I mentioned that you can measure the temperature of the Moon with a radio telescope

Phil says – So why haven't you done that project?

Why haven't I done that project?.?

Why haven't I done that project?.?

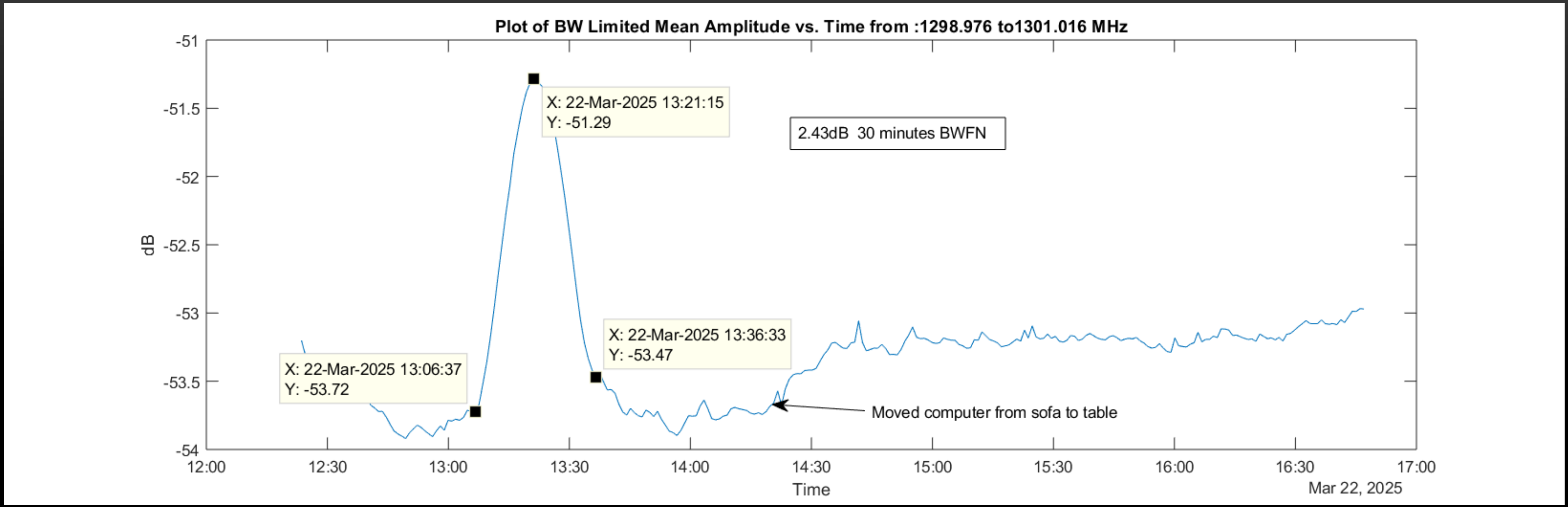
=> Combining the Treavor and Phil Factors <=

WE WILL ATTEMPT TO USE A SATELLITE TV DISH ANTENNA TO MEASURE THE TEMPERATURE OF THE MOON

despicableme.wikia.com

First question – Can a satellite dish be used to detect celestial objects?

How about try something really bright, like the Sun



Answer – YES! A satellite dish can detect the Sun!

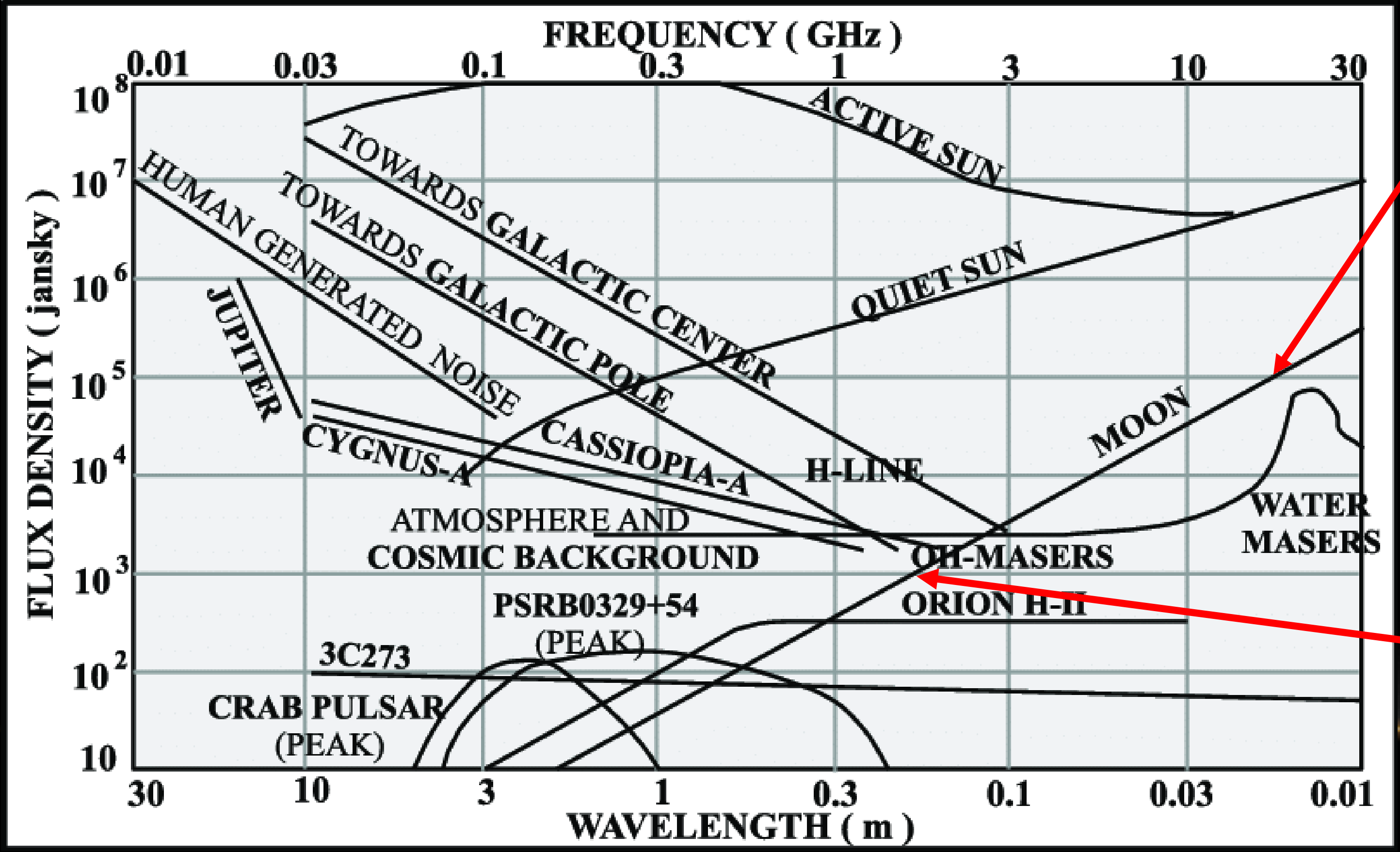
One challenge -

Date of measurement 3/22. Spring Equinox was 3/20.

Anyone got an idea why this could cause a problem?

Second question – Is there any chance a satellite dish could detect the Moon?

1. What frequencies do these detect?
   - From Internet search: 12.2 to 12.7GHz
2. Can we detect the Moon at these frequencies?



Approx. 2.36cm (12.7GHz)

!! Moon is about 100x brighter at 12.7GHz than 1.4GHz !!

Approx. 21cm (1.4GHz)
Previous frequency area

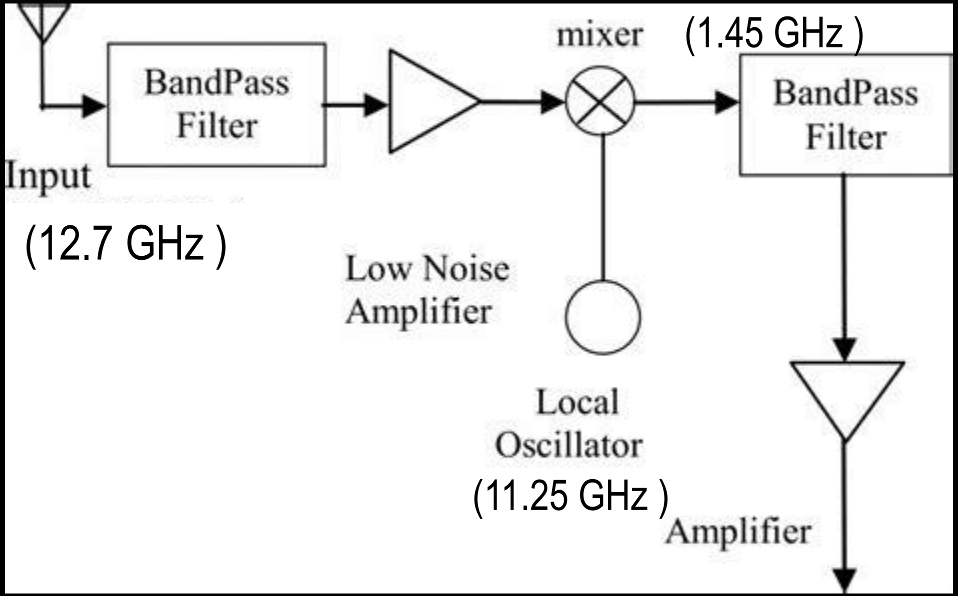
Radio Astronomy and Super-Synthesis: a Survey (Researchgate.net)

Third question – Can we use a Software Defined Radio (SDR) for our receiver?

- Freq range of RTL-SDR: 500KHz to 1766MHz
- Freq range of Airspy Mini: 24 to 1700MHz

Signal 12GHz

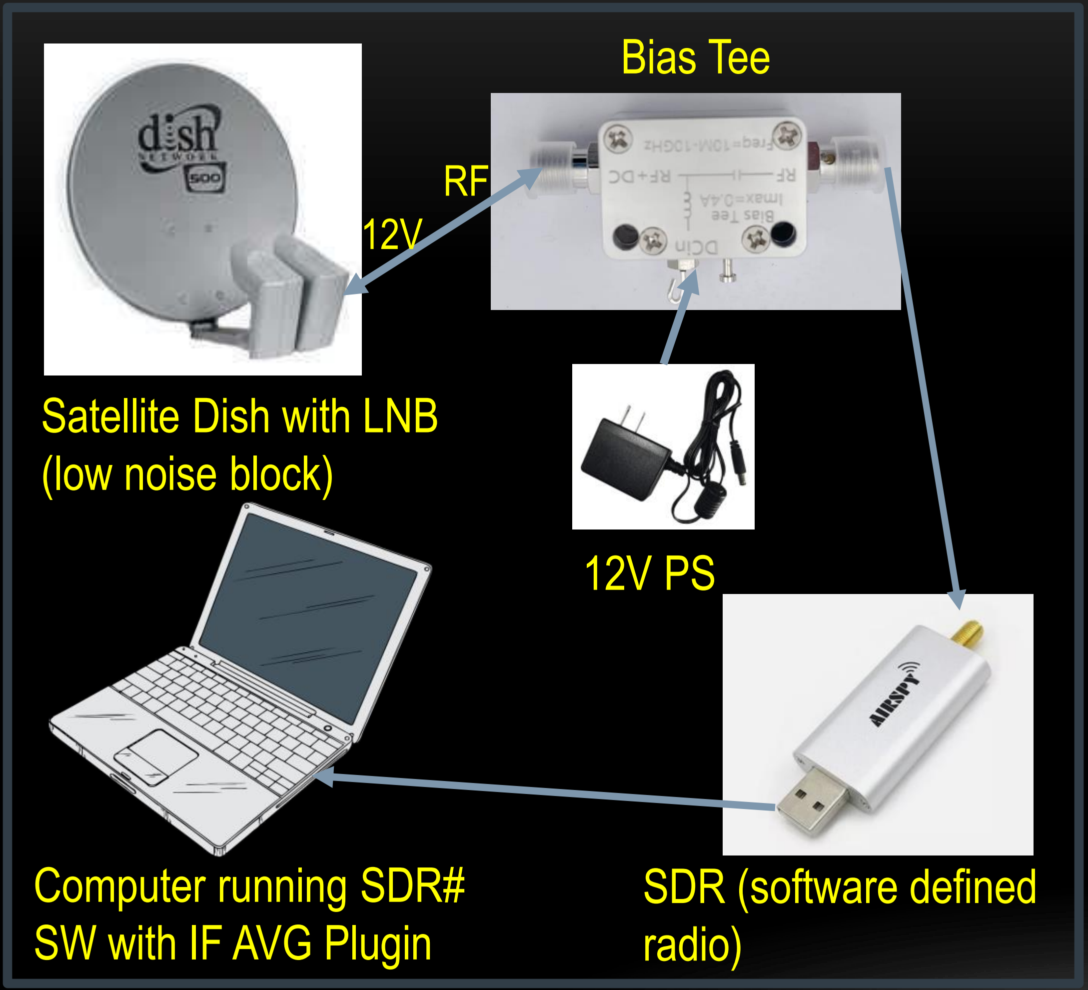
Low Noise Block (LNB)



wiringdigital.com

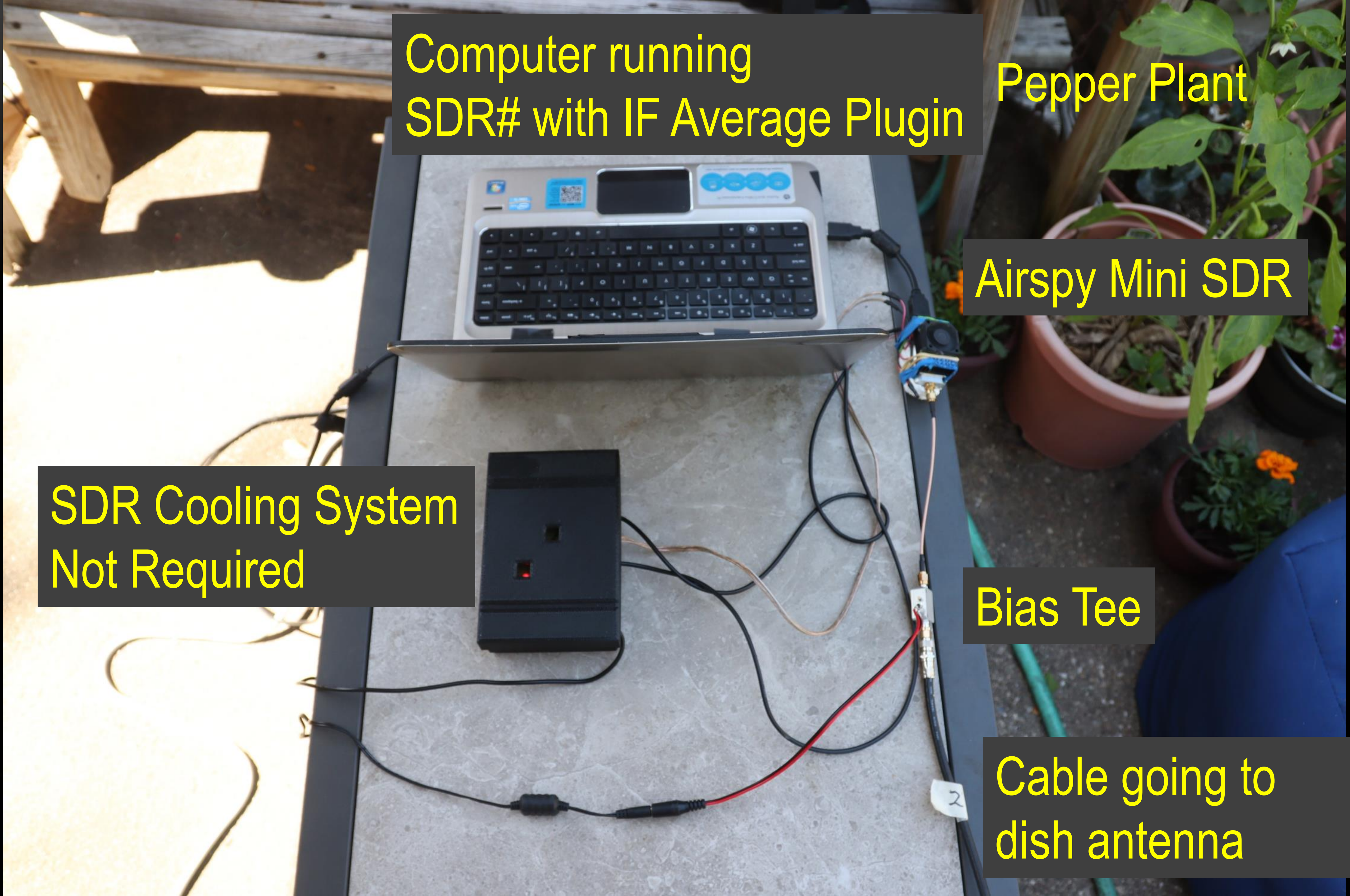
12.7GHz – 11.25GHz = 1.45GHz (1450MHz) => within range of SDR => YES !!

Fourth question – How do you power the LNB (12V) without blowing up SDR?



Signal Path

Aliexpress: Bias Tee / DC Block – routes power to LNB but not to SDR



Computer running
SDR# with IF Average Plugin
Pepper Plant
Airspy Mini SDR
SDR Cooling System
Not Required
Bias Tee
Cable going to
dish antenna

Fifth question – How do you know where antenna is pointing?

- Shape is not a parabola: odd oval shape instead, offset feed antenna (LNB)

- *There is a plate on the bottom*

??? Any chance that the angle of the plate corresponds with direction of the antenna beam ???

!!! Turns out that it does => meaning that a protractor with weight on string can be used to set Declination !!!

=> Use compass to align antenna North / South along local meridian

Making the Measurement, Requirements

- Need to determine location of Moon
  - DEC changes every day
    - Find for that day's transit (when it crosses over local meridian – the line in the sky, overhead from North to South)
  - Use Planetarium Software: Kstars, The Sky, Stellarium, etc.

- Need to find usable frequency
  - Satellite interference experienced from 12.45 to 12.65GHz
  - Used 12.7GHz (1450MHz SDR) for measurement

Moon Temperature Measuring Configuration (with cat)

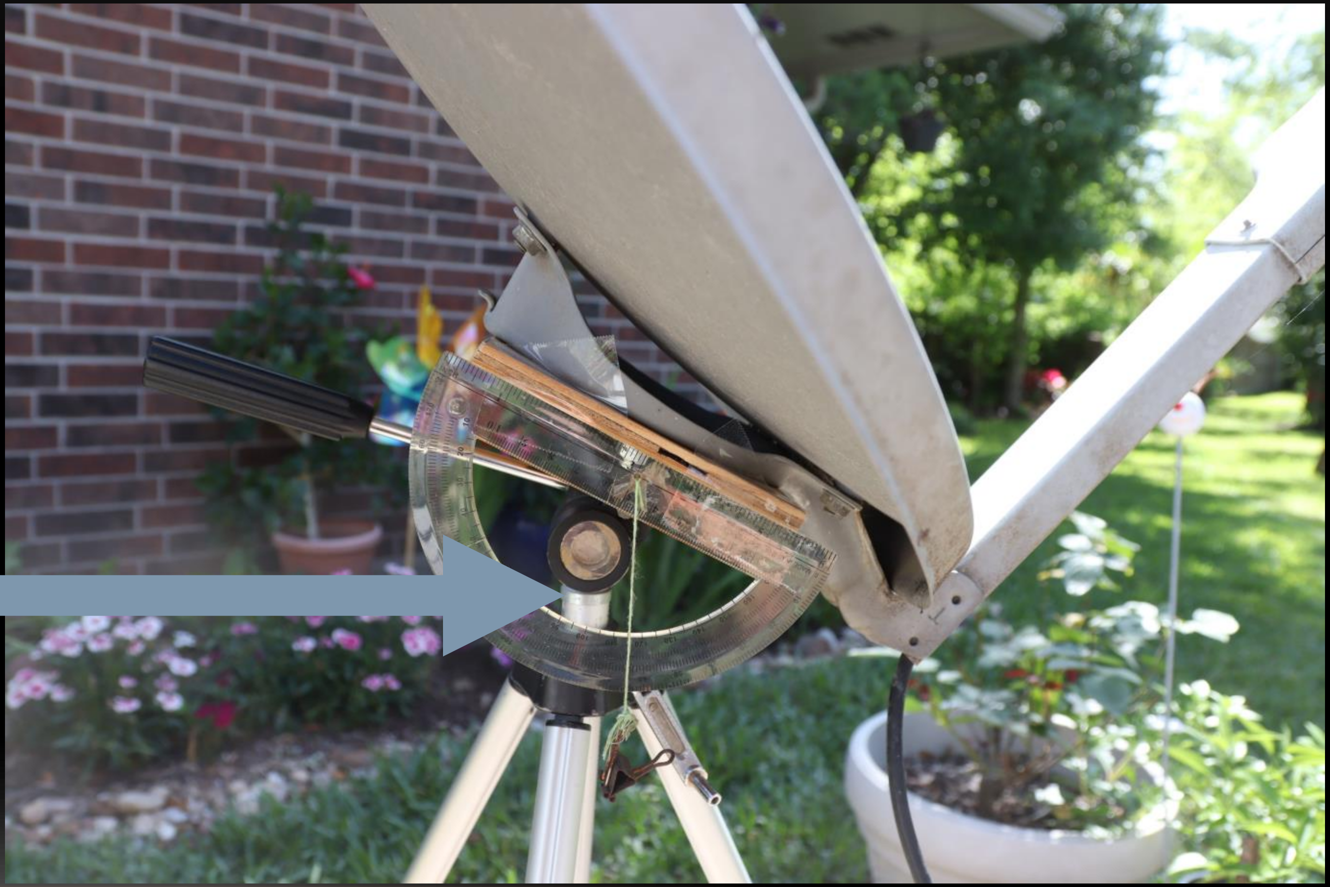
Using the Moon's Declination (at transit) to Set Protractor

Local Latitude – Moon's DEC = Protractor Setting

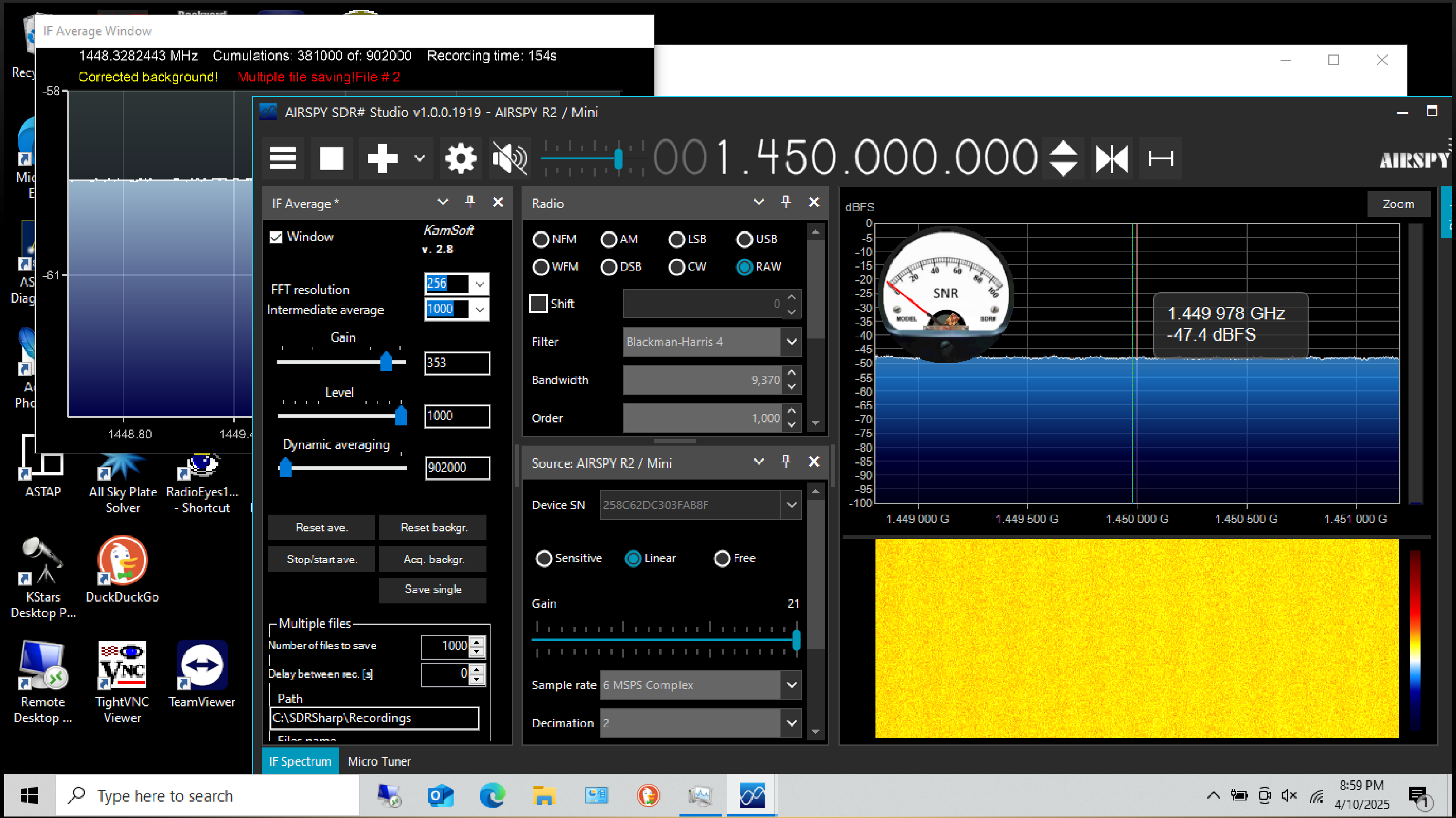
Example:

29º 36' - 04º 24' = 25º 12'

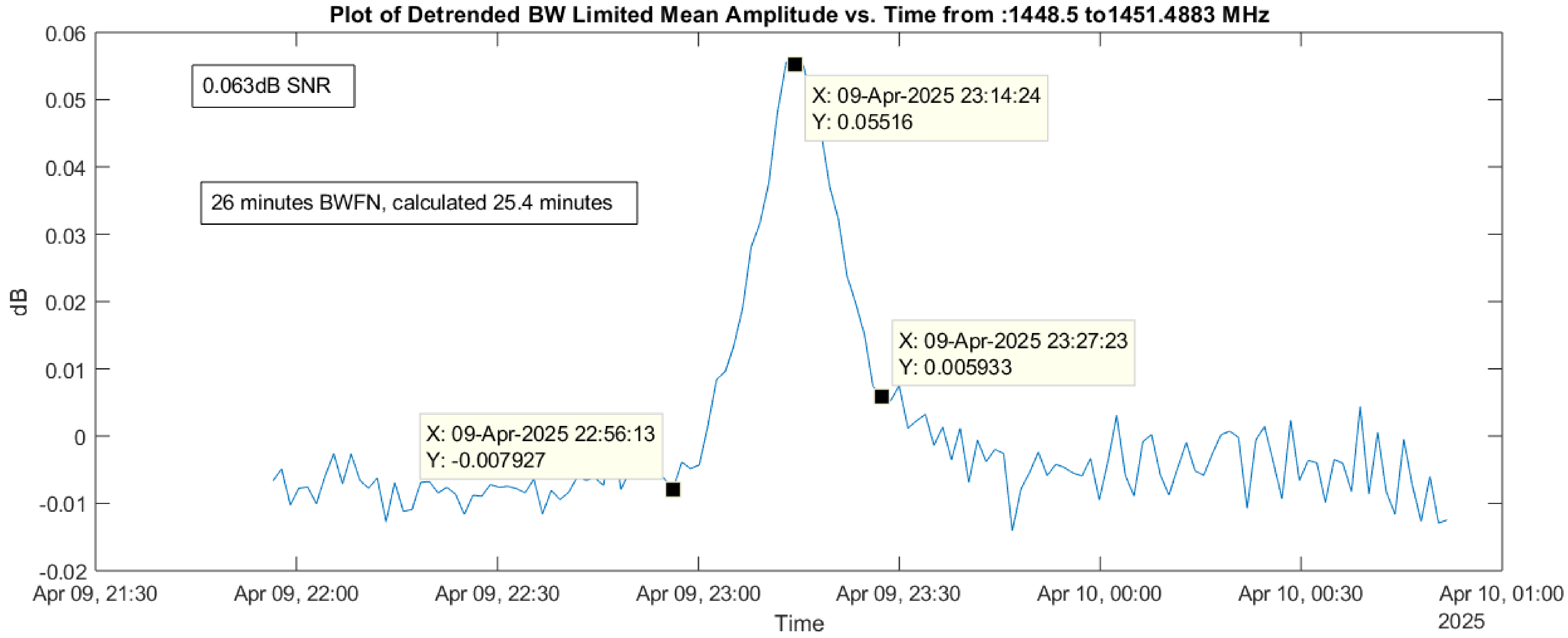
=> Set protractor 25º 12'
South of straight up



Making the Measurement, Software



SDR# with IF Average Plugin – IF Average Plugin creates data files that can be plotted in other program (Excel, Matlab, etc.; example uses Matlab)



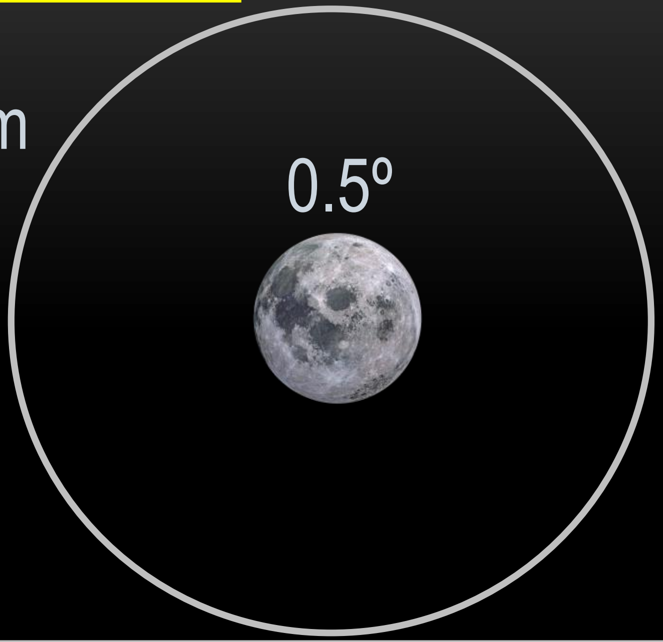
Moon Measurement – Amplitude vs. Time

How to use measurement to determine temperature of the Moon

Math is Fun !!

$$Tmoon = \frac{Teff}{R}$$

Antenna Beam
HPBW 3.17°



$$R = \frac{Moon(solid\ angle)}{Antenna\ HPBW\ (solid\ angle)} = \frac{\pi r_{Moon}^2}{\pi r_{HPBW}^2}$$

$$R = \frac{\pi \cdot (0.25^0)^2}{\pi \cdot (1.59^0)^2} = 0.0247$$

From SARA instruction videos

HPBW (half power beam width)

$$HPBW = 70^0 \frac{\lambda}{D}$$

λ = wavelength, D = diameter

$$HPBW = 70^0 \frac{0.0236m}{0.5207m} = 3.17^0$$

Method used for calculations from Klaus Henning, facebook Amateur Radio Astronomy Group 1/10/25

$$Teff = Ttotal - Tsys$$

$$Tsys = system\ noise\ level$$

$$Tsys = \frac{Th - yTc}{y - 1}$$

$Th = temperature\ of\ hot\ area, garage\ wall\ (82^0F)$

$Tc = temperature\ of\ cold\ area, sky\ (10K)$

Need Th in Kelvin, K

$$(((82^oF - 32^0F)\frac{5}{9}) + 273.15K) = 300.9K$$

$$Tsys = \frac{300.9K - 2.0893(10K)}{2.0893 - 1}$$

$$Tsys = 257K$$

$$PwrhotdB - PwrcolddB = 10\log(y)$$

$PwrhotdB = Hot\ power\ measured\ in\ dB$

$PwrcolddB = Cold\ power\ measured\ in\ dB$

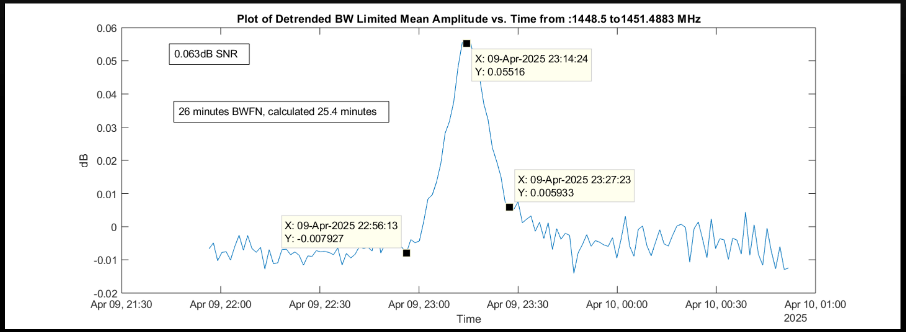
$-47.5\text{dB} - (-50.7\text{dB}) = 3.2\text{dB} = 10\log(\text{y})$

$\text{y} = 2.0893$

$$Teff = Ttotal - Tsys$$

$$\Delta TdB = MoondB\ above\ cold\ sky = 0.063dB$$

$$\frac{Ttotal}{Tsys} = 10^{\Delta Tdb/10}$$



$$\frac{Ttotal}{Tsys} = 10^{0.063db/10} = 1.0146$$

$$Ttotal = Tsys \cdot 1.0146 = 257K \cdot 1.0146 = 260.75K$$

$$Teff = Ttotal - Tsys = 260.75K - 257K = 3.75K$$

$$Tmoon = \frac{Teff}{R} = \frac{3.75K}{0.0247} = 151.8K$$

Measured temperature of the Moon: 151.8K

Expected temperature, a little above 200K?

The Radio Sky, Spectra, the Solar System and Our Galaxy 8-55

Wavelength = 2.36cm

Changes with phase of the Moon

Data taken about half way between first quarter and full Moon

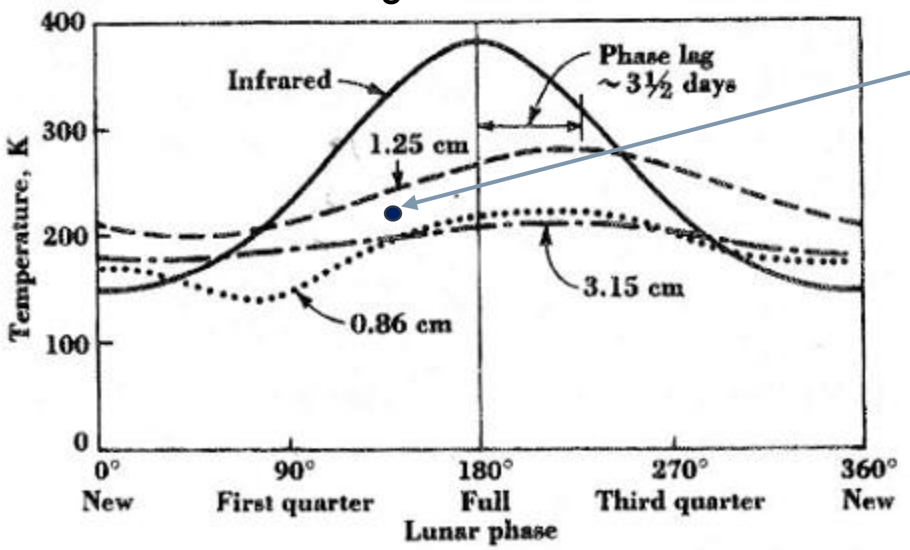
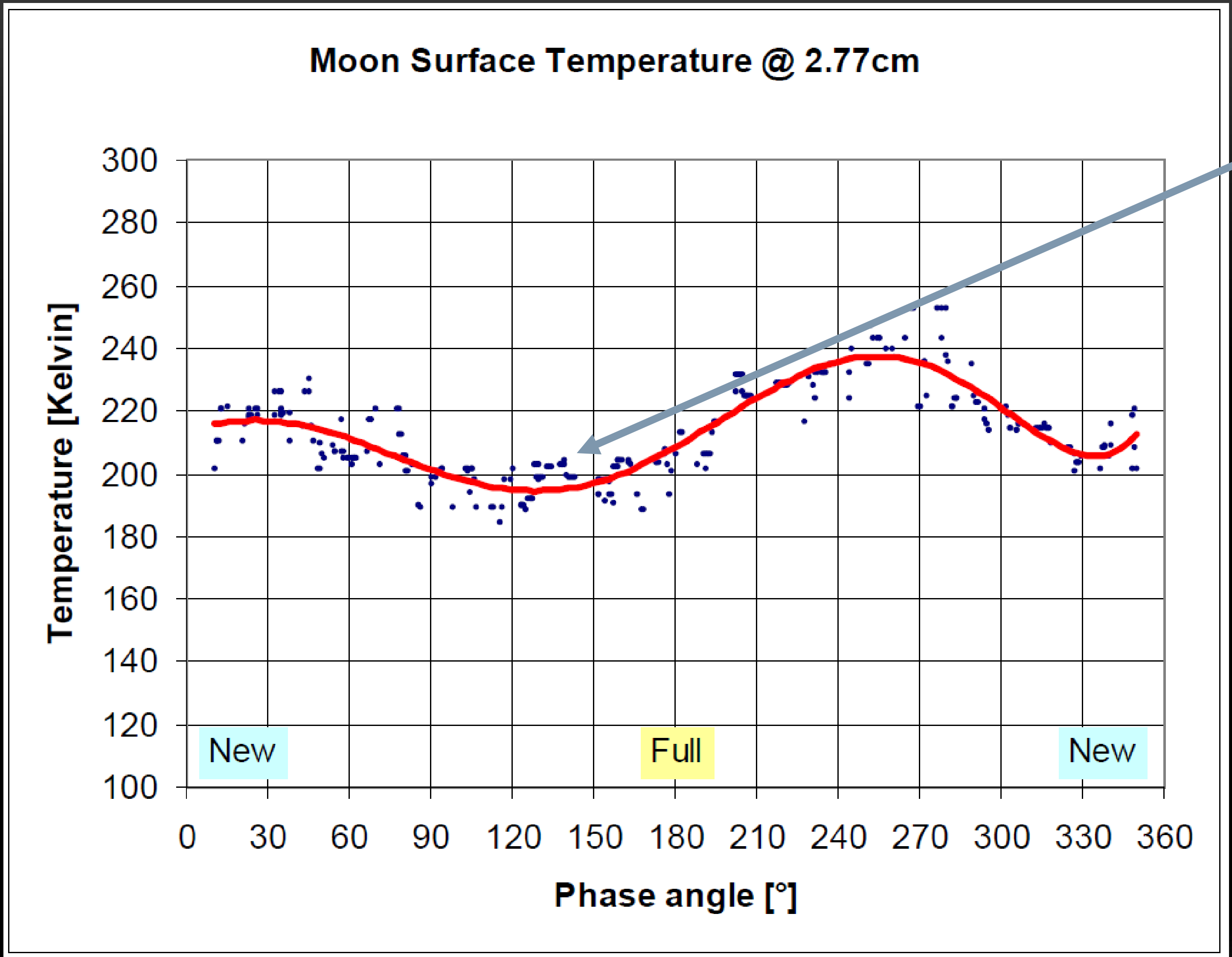


Fig. 8-41. Lunar temperature in kelvins as a function of lunar phase, showing the temperature variation, at infrared wavelengths and at wavelengths of 0.86, 1.25, and 3.15 cm. The temperatures are those of an equivalent blackbody radiator.

Radio Astronomy by John D. Kraus

"The smaller temperature range of the radio temperatures as compared to the infrared values is taken to indicate that the microwave radiation originates at some depth below the surface of the Moon, whereas the infrared radiation comes from a thin surface layer."



ETH Zürich RADIO ASTRONOMY AND PLASMA PHYSICS GROUP

The Moon's Temperature at λ=2.77cm

Christian Monstein

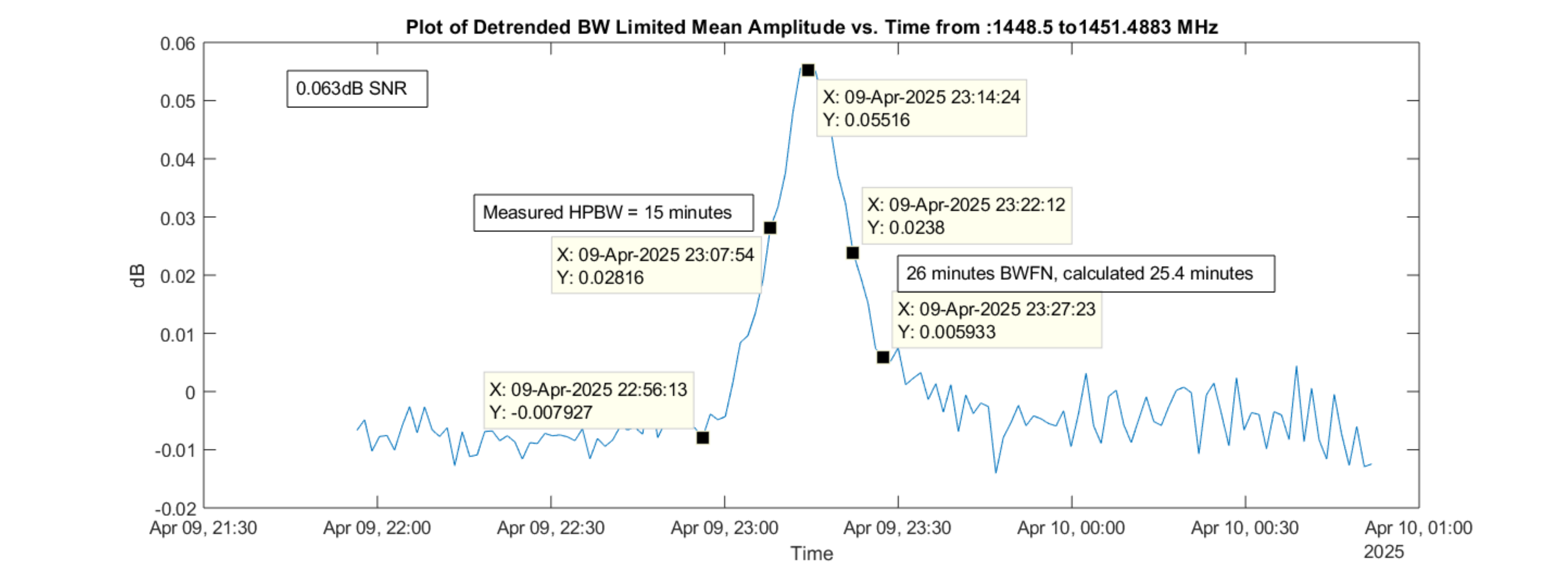
Actual measurements just above 200K

Another reference at approx. same wavelength: 2.77cm vs. 2.36cm

Where could there be errors in our method or calculation?

What about if we measure HPBW rather than calculate it?

15min/60min x 15⁰/hour = 3.75⁰



$$R = \frac{\pi \cdot (0.25^0)^2}{\pi \cdot (1.875^0)^2} = 0.0178$$

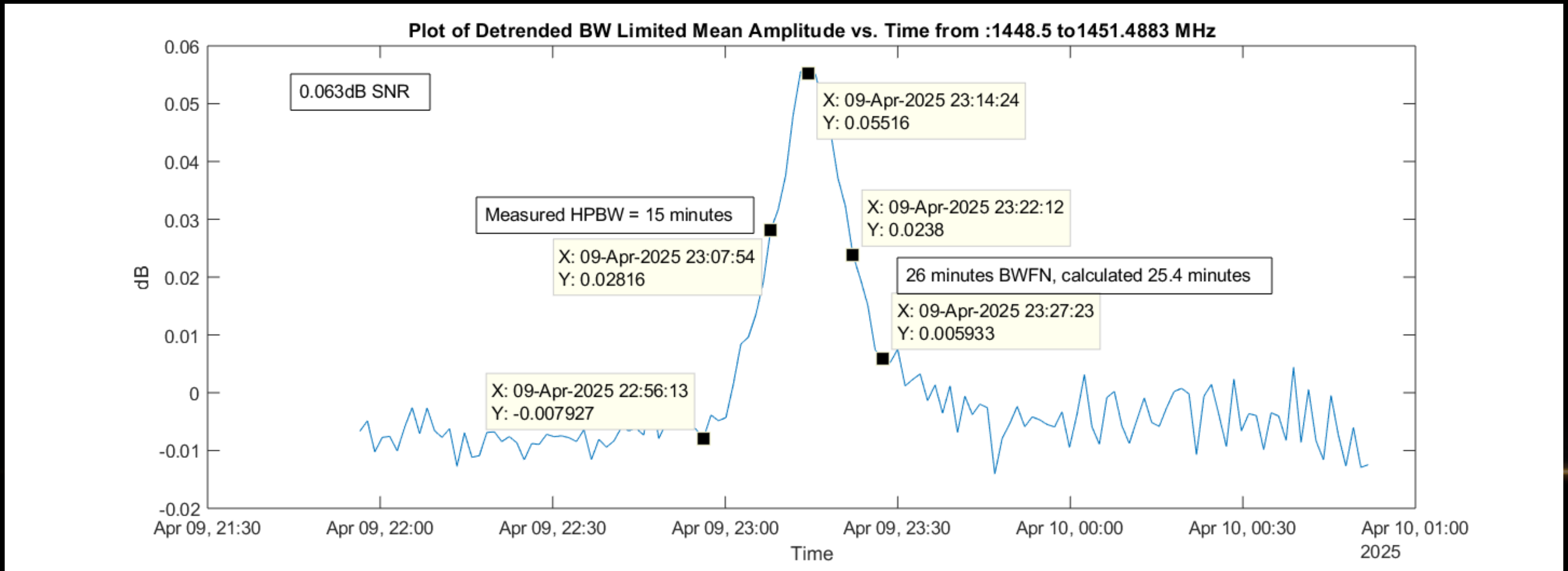
$$Tmoon = \frac{Teff}{R} = \frac{3.75K}{0.0178} = 210K$$

About expected value

Conclusion =>

1. A reasonably ok signal can be received from the Moon at 12.7GHz with a Satellite TV Dish antenna

2. The temperature of the Moon can be measured, with relaxed precision, if measured HPBW is used, and patience



Future Projects Related to Satellite TV Dish Antenna

1. If find another Dish 500 with same LNBs can make an interferometer

2. 39” vs. 20” dish could be used to get better results