Practical results of using small offset parabolic antenna for MW EME operation

by Mirek Kasal
OK2AQ

mirek@kasals.com

http://www.urel.feec.vutbr.cz/esl/files/EME/EME.htm

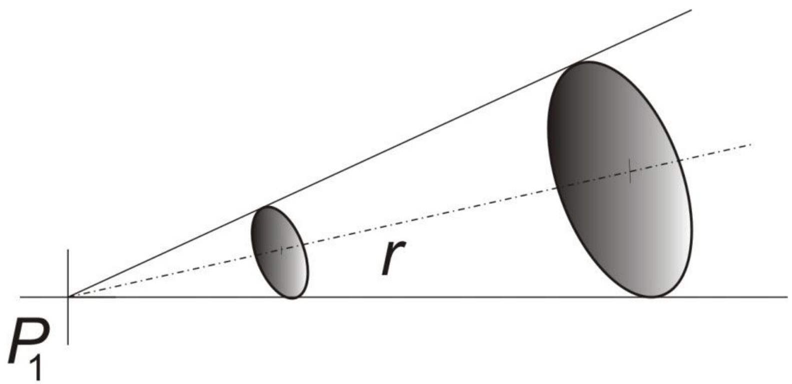
28th EME and Microwave seminar 2019

Outline

1. A bit of calculation
2. Small offset dish and right feed
3. Focused antenna
4. Sun, Moon and ground noise
5. MW EME operation with small dish

- Es’Hail-2 QO-100

Why we can use smaller antennas for **MW** EME ?



$$L_0 = \left(\frac{4\pi \cdot r}{\lambda} \right)^2$$

$$\Pi_2 = \frac{P_1}{4\pi \cdot r^2} \qquad P_2 = \Pi_2 \cdot S_2 \qquad S_2 = \frac{\lambda^2}{4\pi}$$

The loss of direct elmag. wave propagation in free space is proportional to the square of the distance and inversely proportional to the square of the wavelength. This means that at 10 GHz we have 20 dB more attenuation than at 1 GHz

Are the microwaves therefore disqualified for longer distances?

We all know not!

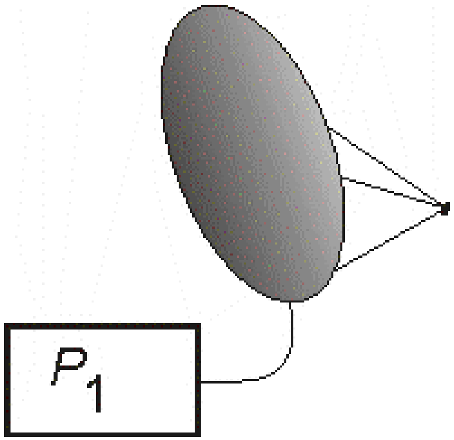
$$G_{\max} = \frac{S_{ef}}{S_i} = \frac{4\pi}{\lambda^2} S_{ef}$$

$$G_{\max} = \eta \left(\frac{\pi \cdot D}{\lambda} \right)^2$$

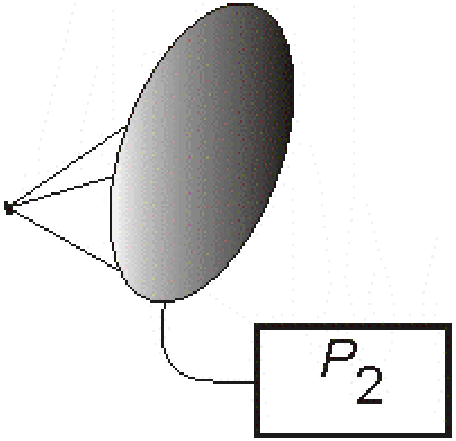
But why?

Including antenna gain, Link Budget at 10 GHz is 20 dB better than at 1 GHz.

And that's why we can work on MW EME with smaller antennas.

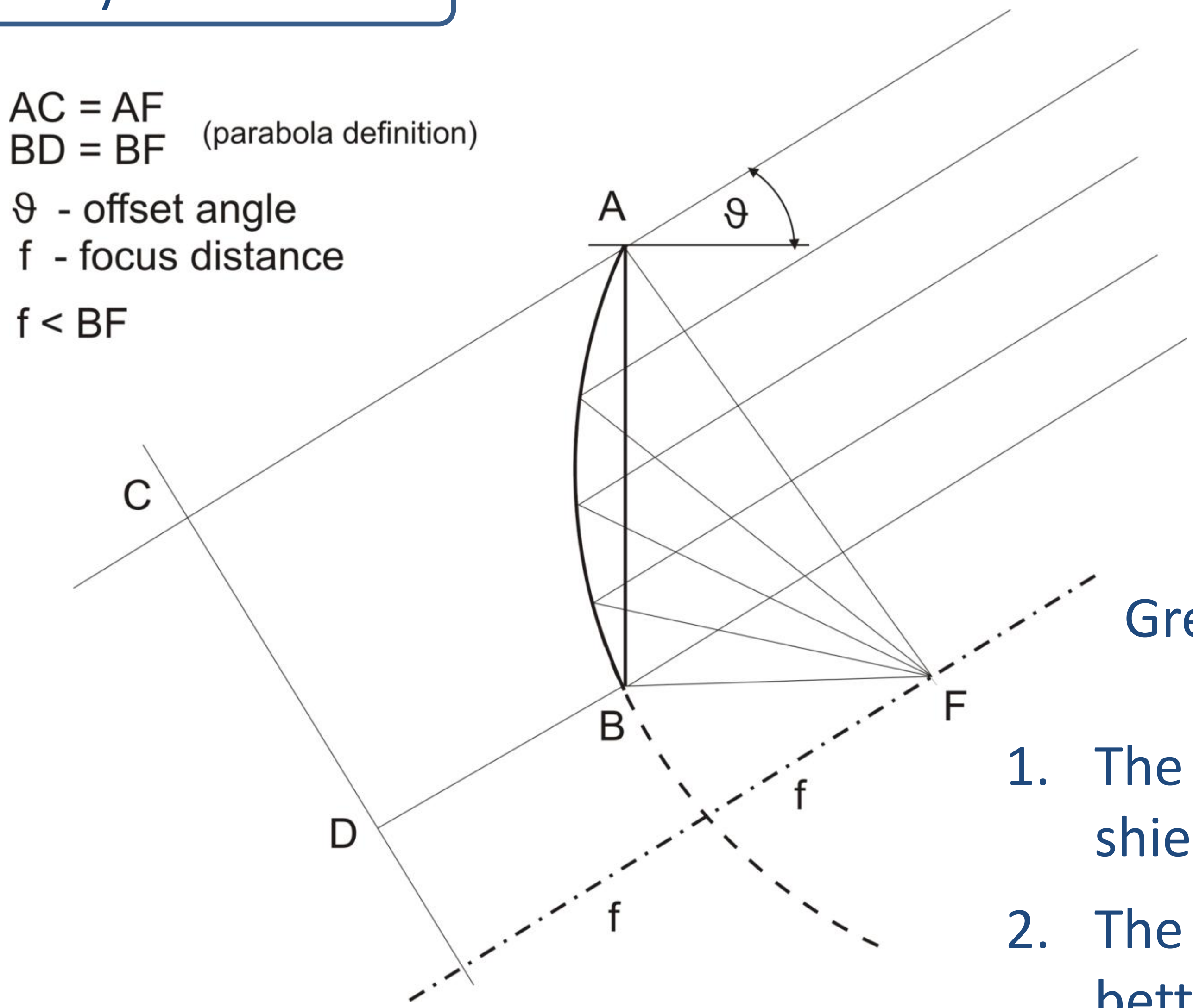


2 x



The dish with the same aperture has a gain of 20 dB greater at 10 GHz than at 1 GHz.

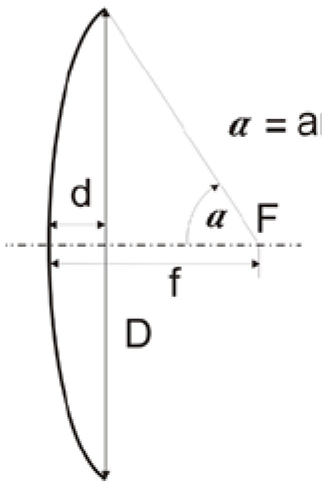
Why offset dish ?



Greater G/T ratio

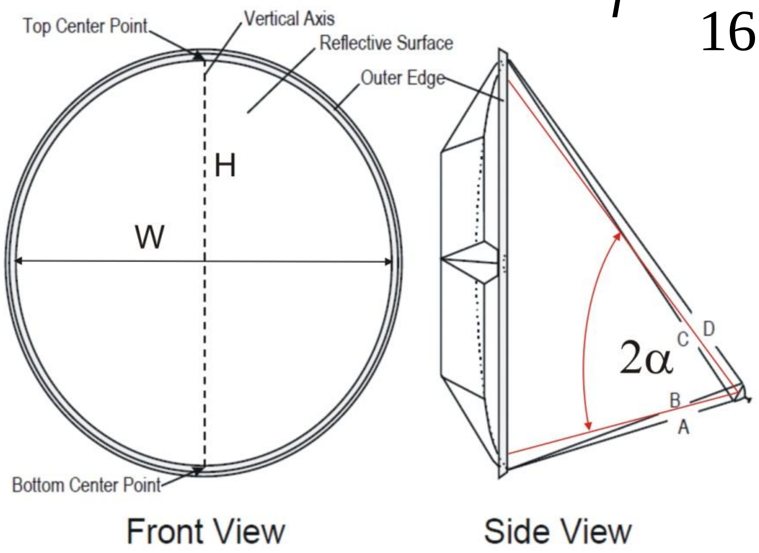
1. The aperture is not shielded by feed
2. The spill over is better eliminated at low elevation

The Feed



$$\alpha = \mathrm{arctg}\,\frac{8(f/D)}{16(f/D)^2-1}$$

$$f = \frac{D^2}{16 \cdot d}$$

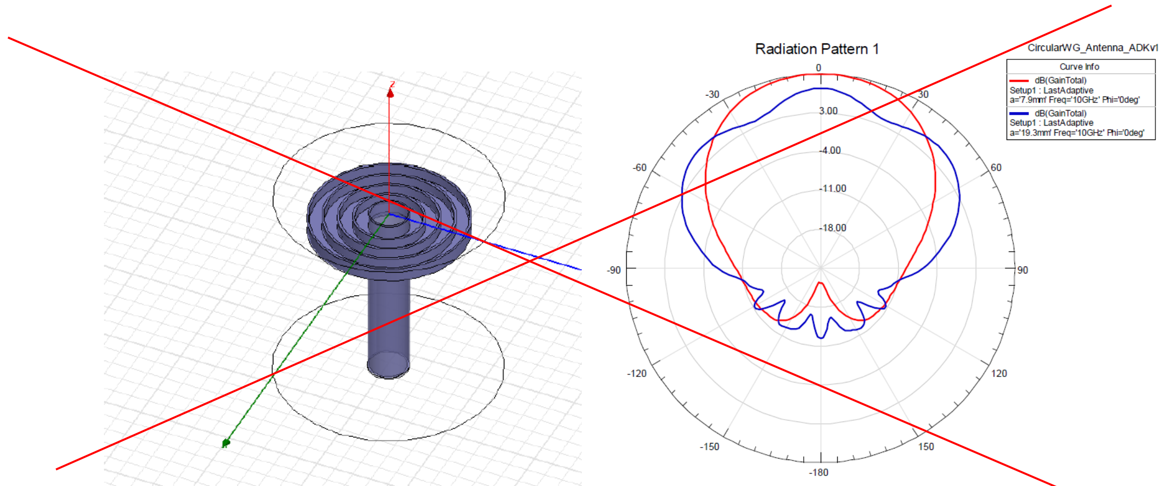


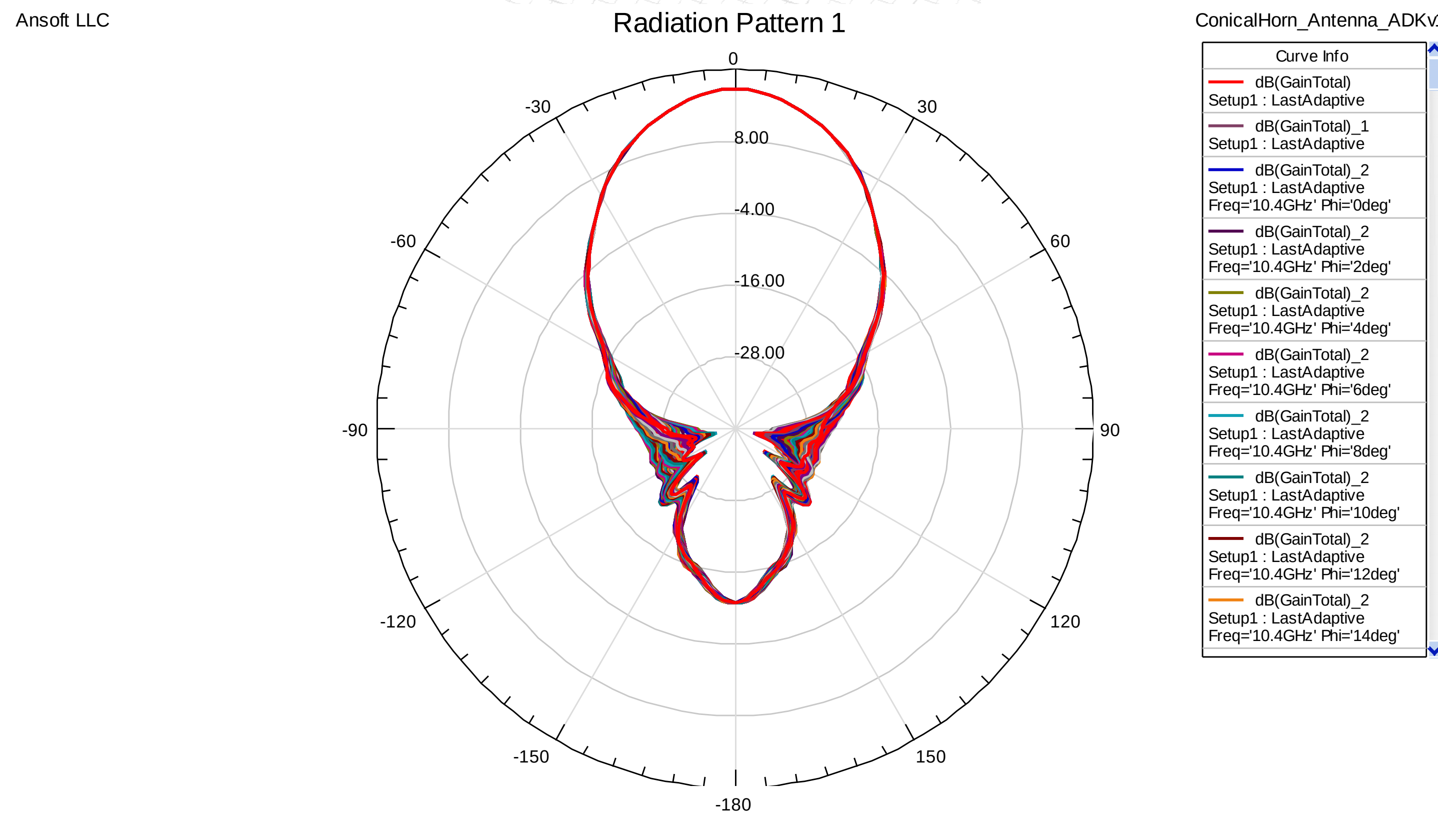
$$f = \frac{W^3}{16 \cdot d \cdot H}$$

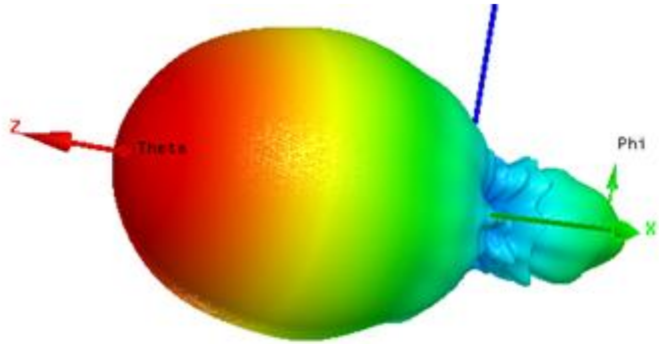
For small offset angle: W~D and then $\alpha = \arctan \frac{8(f/W)}{16(f/W)^2 - 1}$

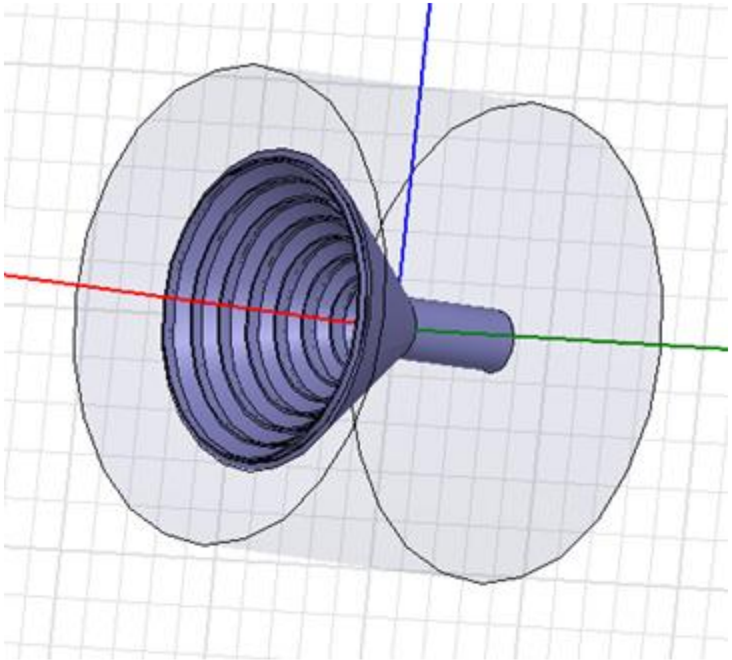
f/D	alpha	2*alpha
0,4	64,01077	128,0215
0,6	45,23973	90,47946
0,8	34,70805	69,4161

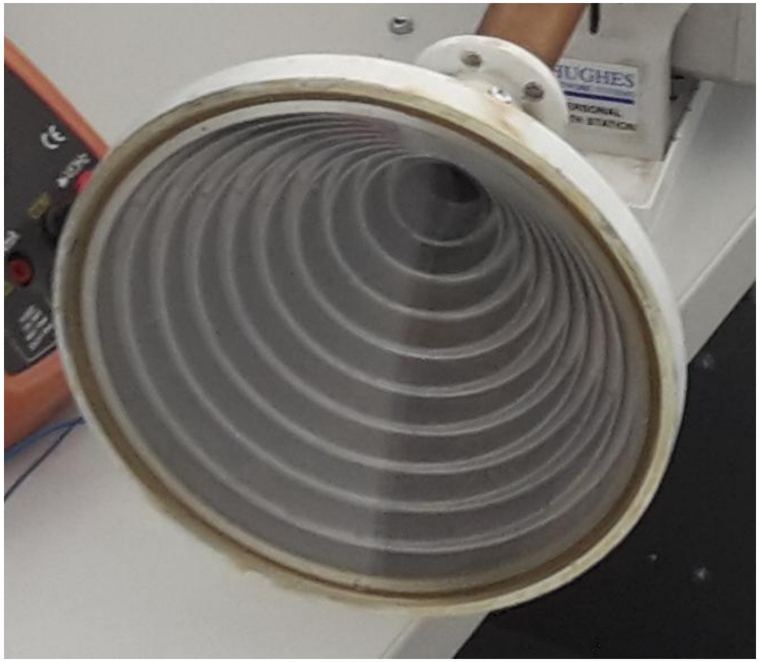
A Feed for offset dish with f/D = 0.8







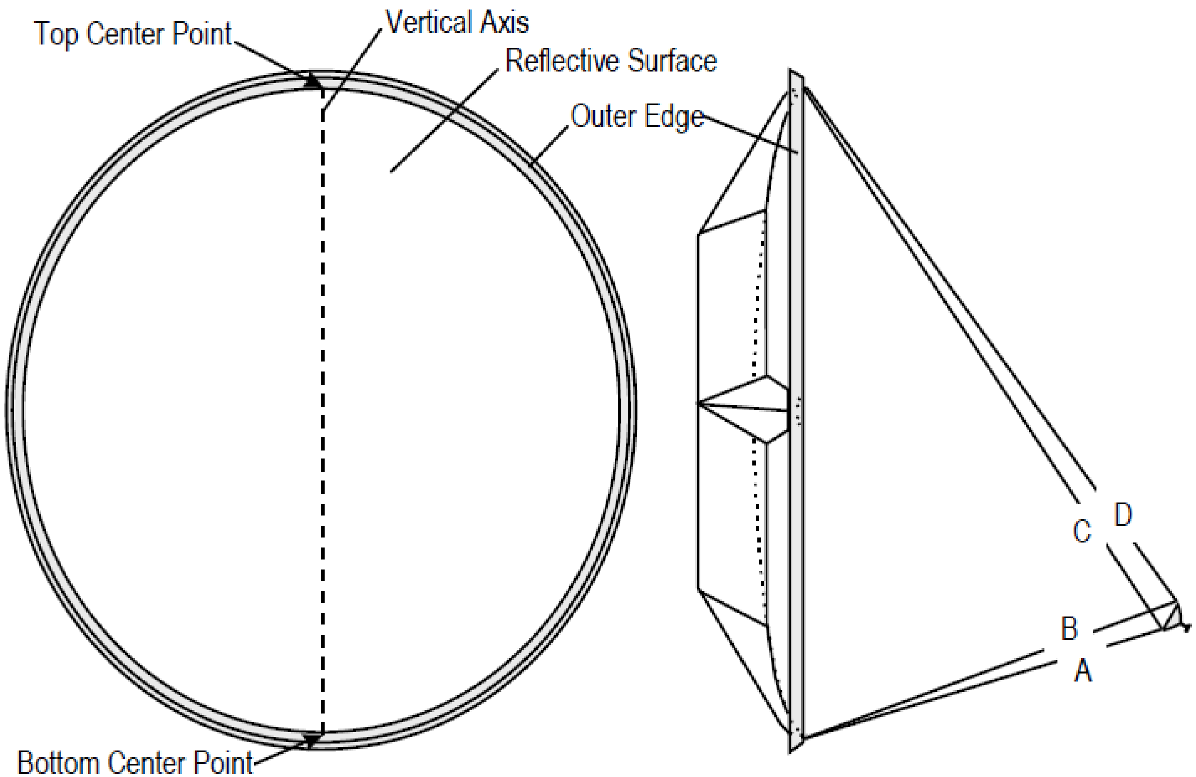




Feedhorn for the f/D = 0.8

Focused Antenna

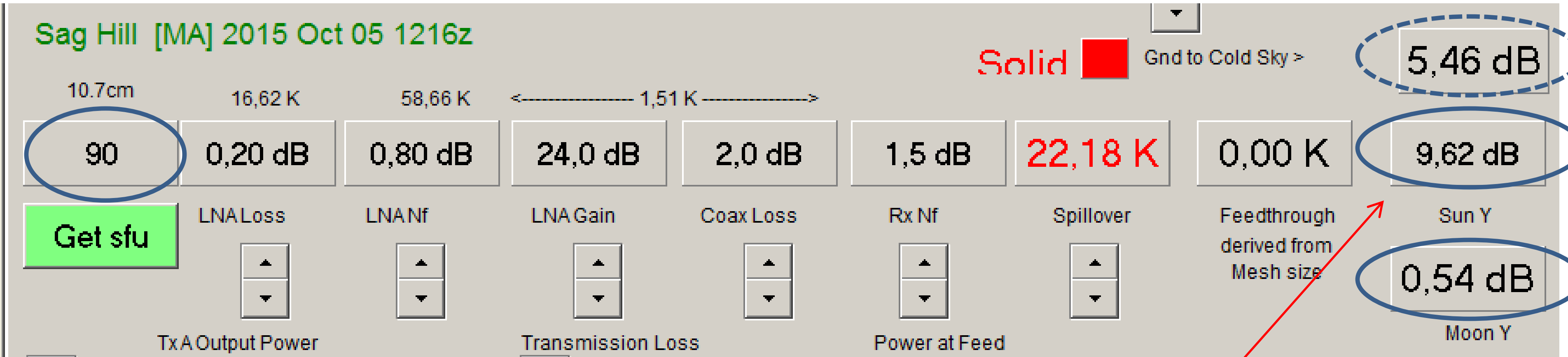
34,25 x 25,4 = 870 mm



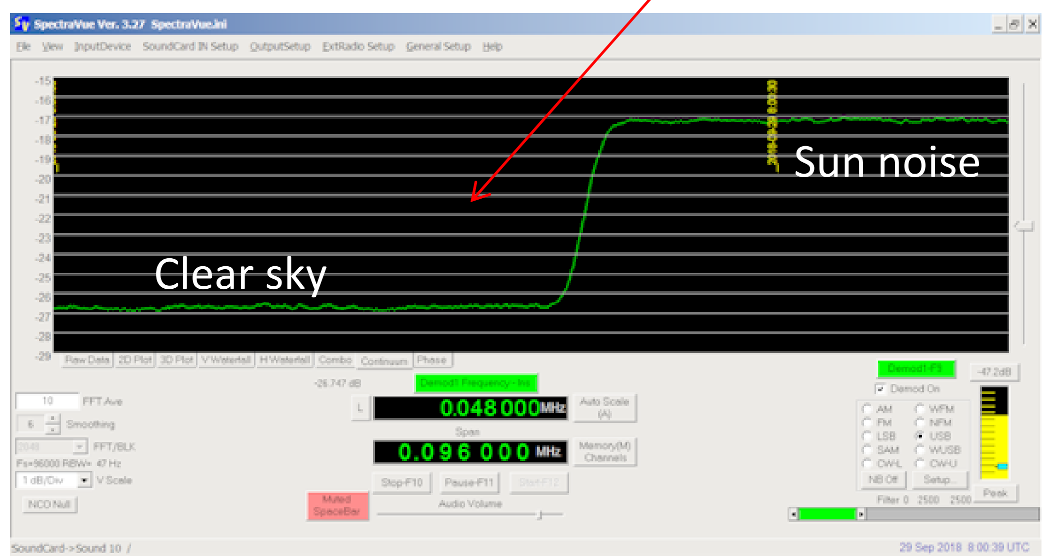
Front View   Side View

A	34.25 in. (34-1/4" or 820 mm)
B	37.08 in. (37-1/16" or 942 mm)
C	51.87 in. (51-7/8" or 1318 mm)
D	49.04 in. (49-1/16" or 1246 mm)

Sun Noise



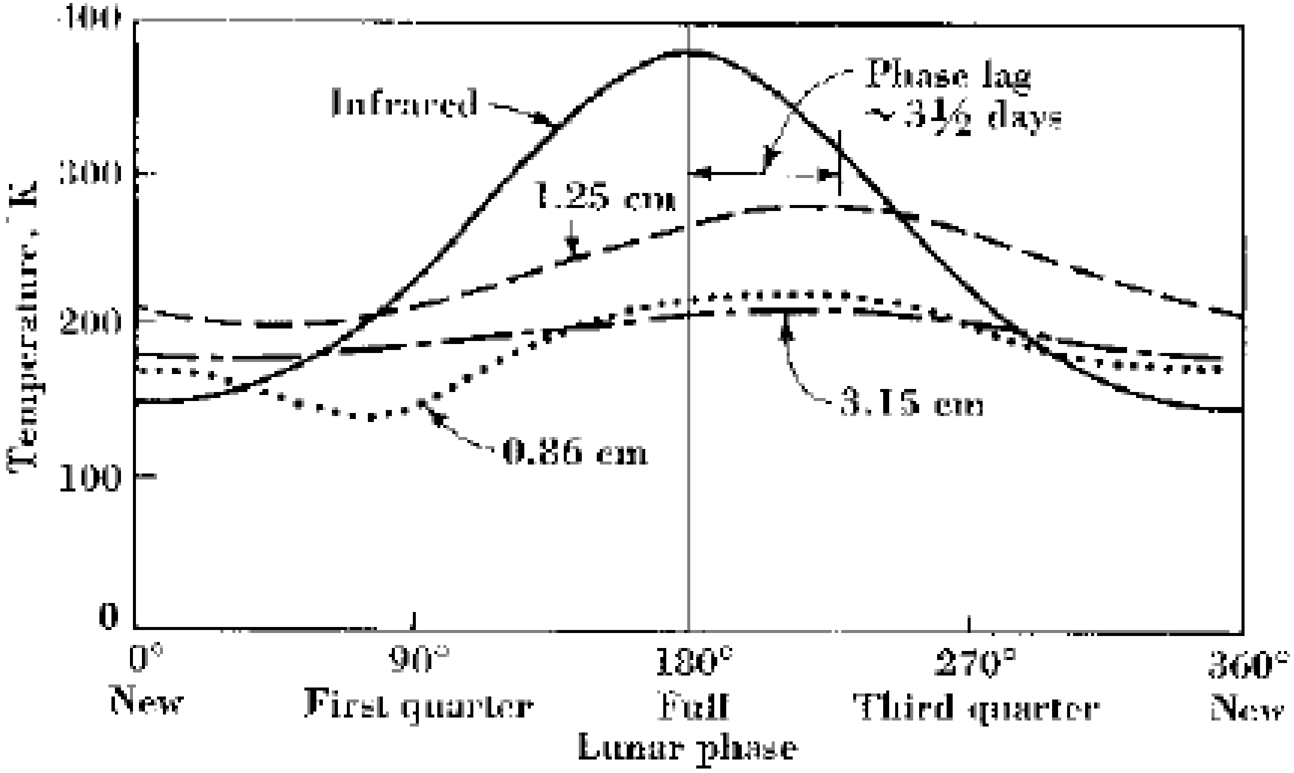
When focusing the antenna, it is necessary to record a wider range, say +/- 40 mm, and determine the correct focus position by interpolation.



Spectra Vue by RF Space

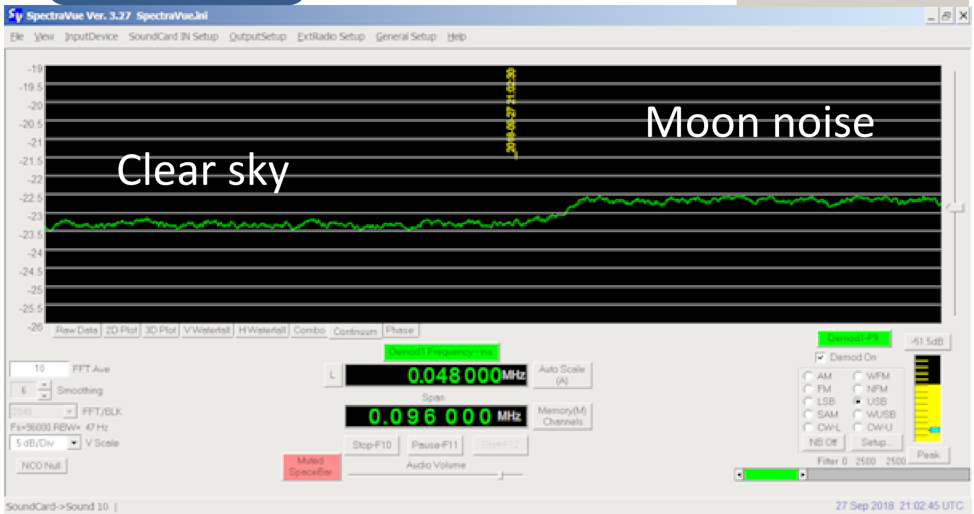
Moon noise and ground noise

Moon brightness temperature



Ref: John D. Kraus, Radio Astronomy, McGraw-Hill,1966, pp 339

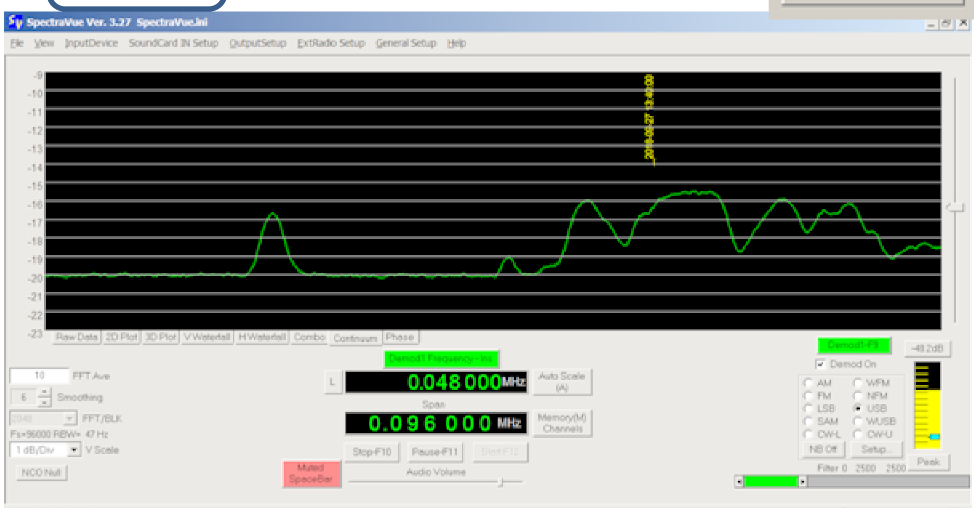
MN/CS



Do not change the focus position according to this signal.

GN ?

290 K



Radiometric scan around at 10 deg elevation.
The offset antenna radiates horizontally if it is inclined to ground at an offset angle (17,3º).

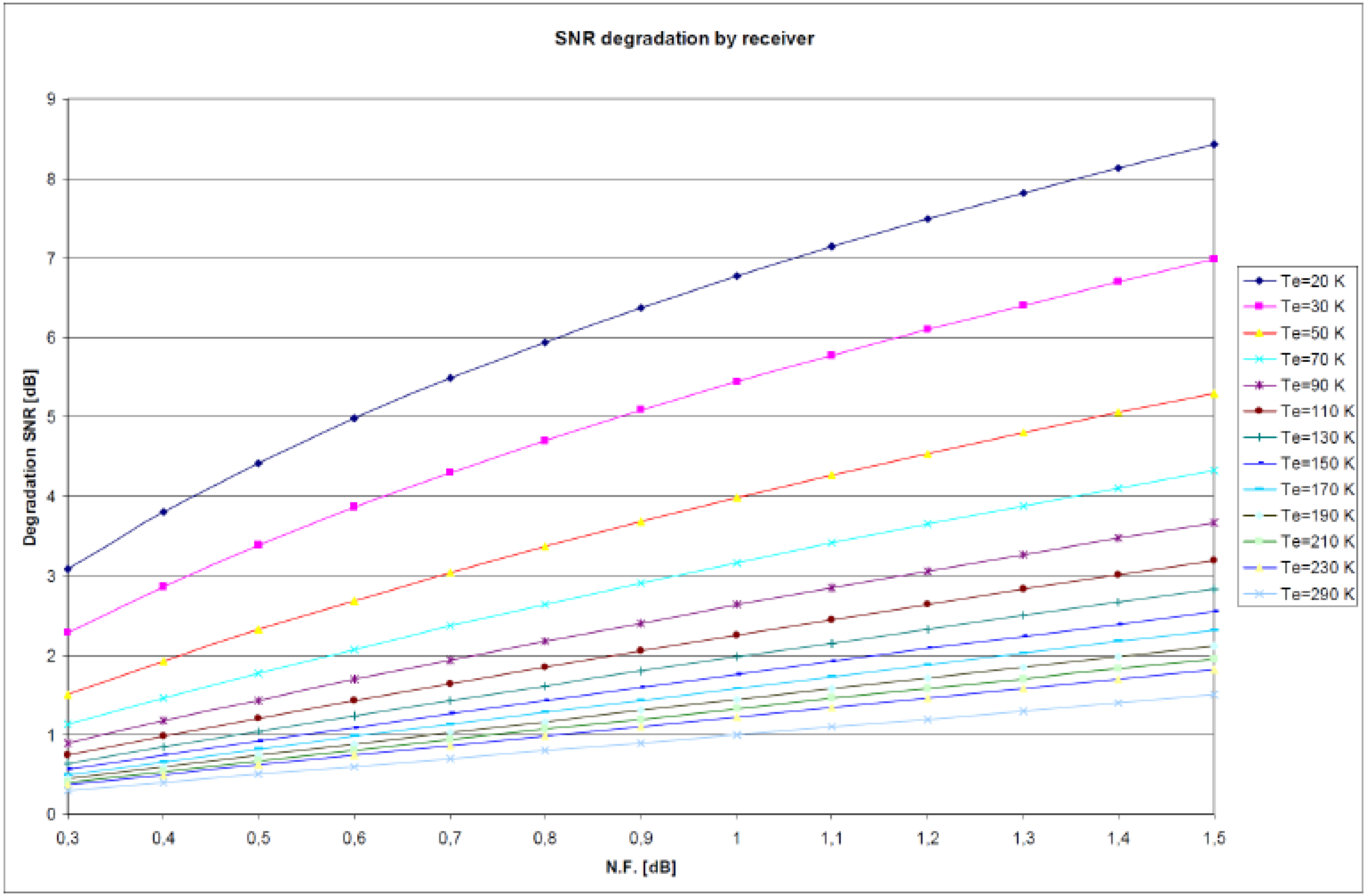
EME operation on MW with small dish

What we lack in the antenna we have to compensate otherwise - how?

1. G/T high as possible
2. Enough power
3. Frequency accuracy and stability including Doppler shift compensation ability
4. Precise automatic antenna pointing with continual monitoring of Moon noise and possibility to change polarization
5. Advanced signal processing
6. Good planning

Ad 1) LNA plays a much bigger role than with large antennas

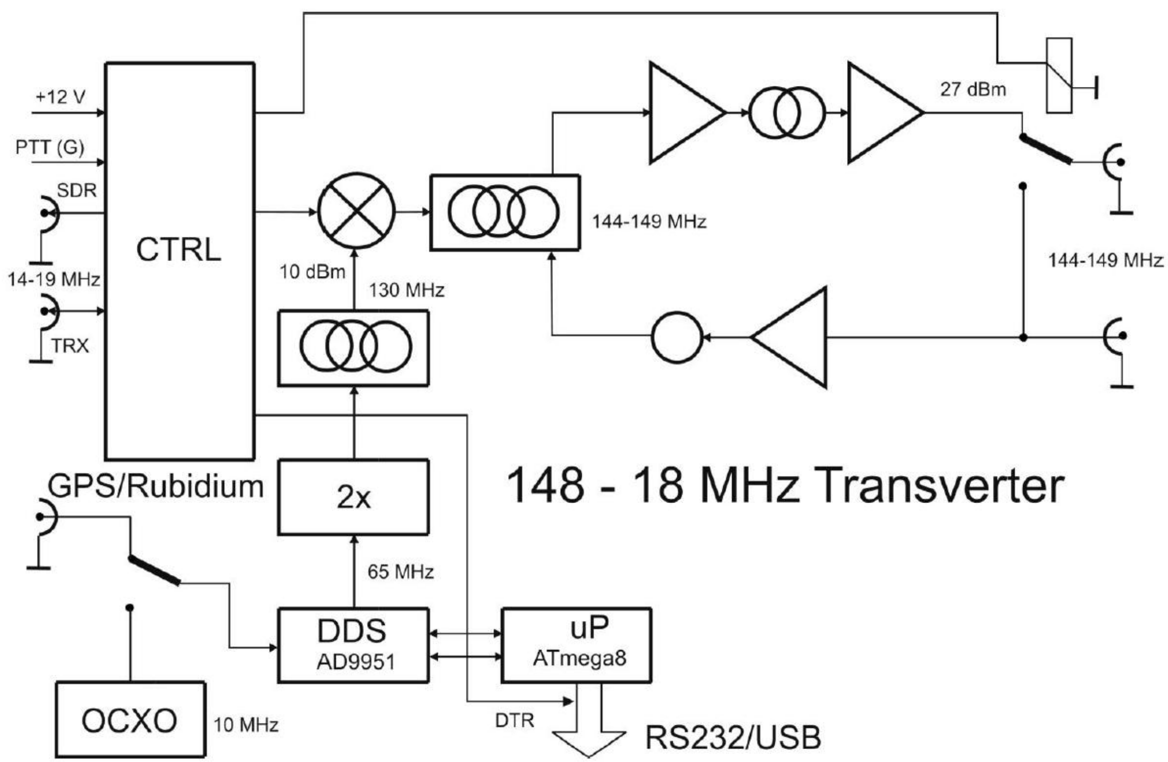
$$T_S = T_{SKY} + T_G + T_{bM} + T_{Rx} = T_e + T_{Rx}$$



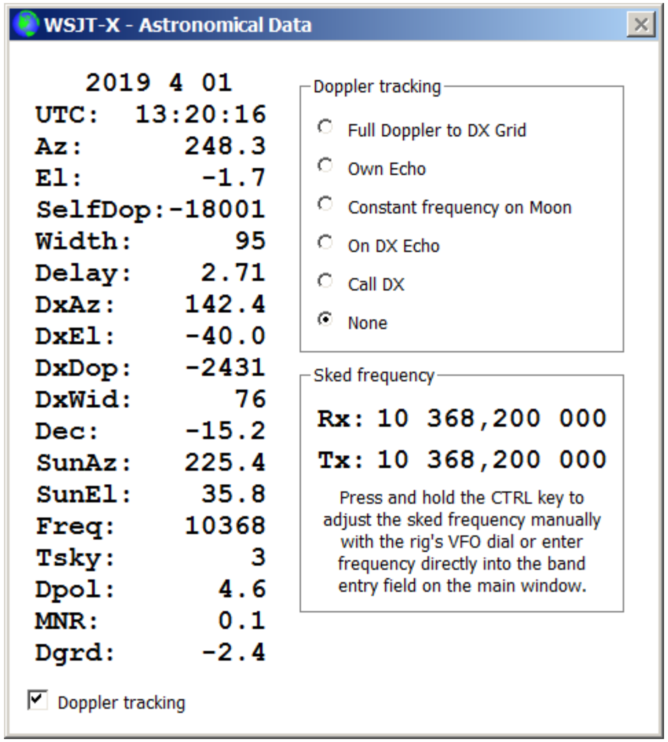
Ad 2) Enough power is - 20 W minimum,
50 W exactly right on 10 GHz (one is enough)

Ad 3) Frequency accuracy and stability including Doppler shift compensation ability

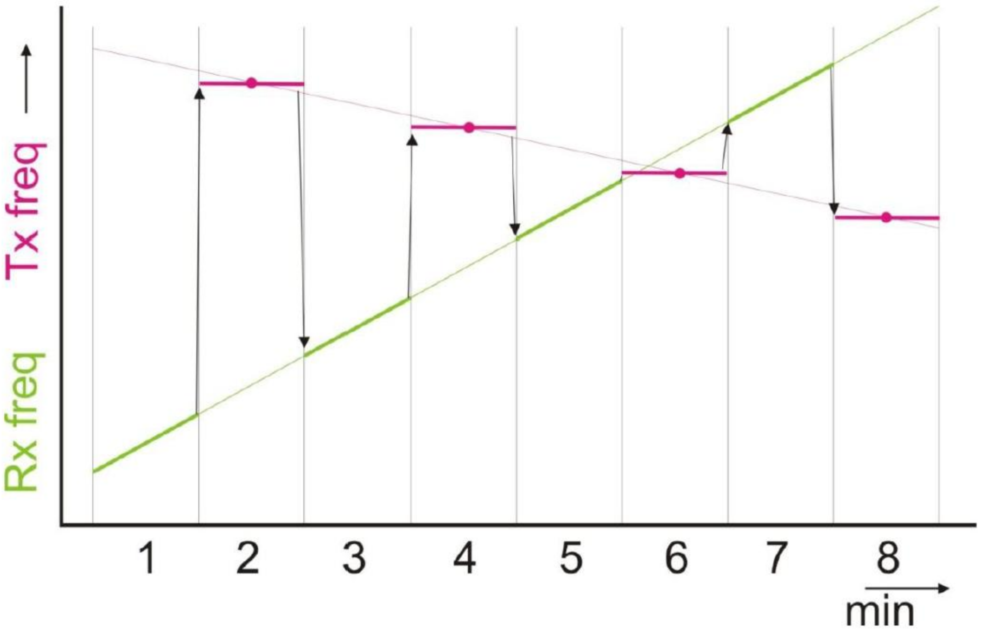
Because with a small antenna we will work along CW often DIGI modes the frequency precision must be better than 100 Hz on 10 GHz. For this reason, the frequencies of the microwave transverter but also VHF/UHF transceiver need to be controlled by an atomic oscillator - cesium (GPS) or rubidium.



Doppler shift compensation



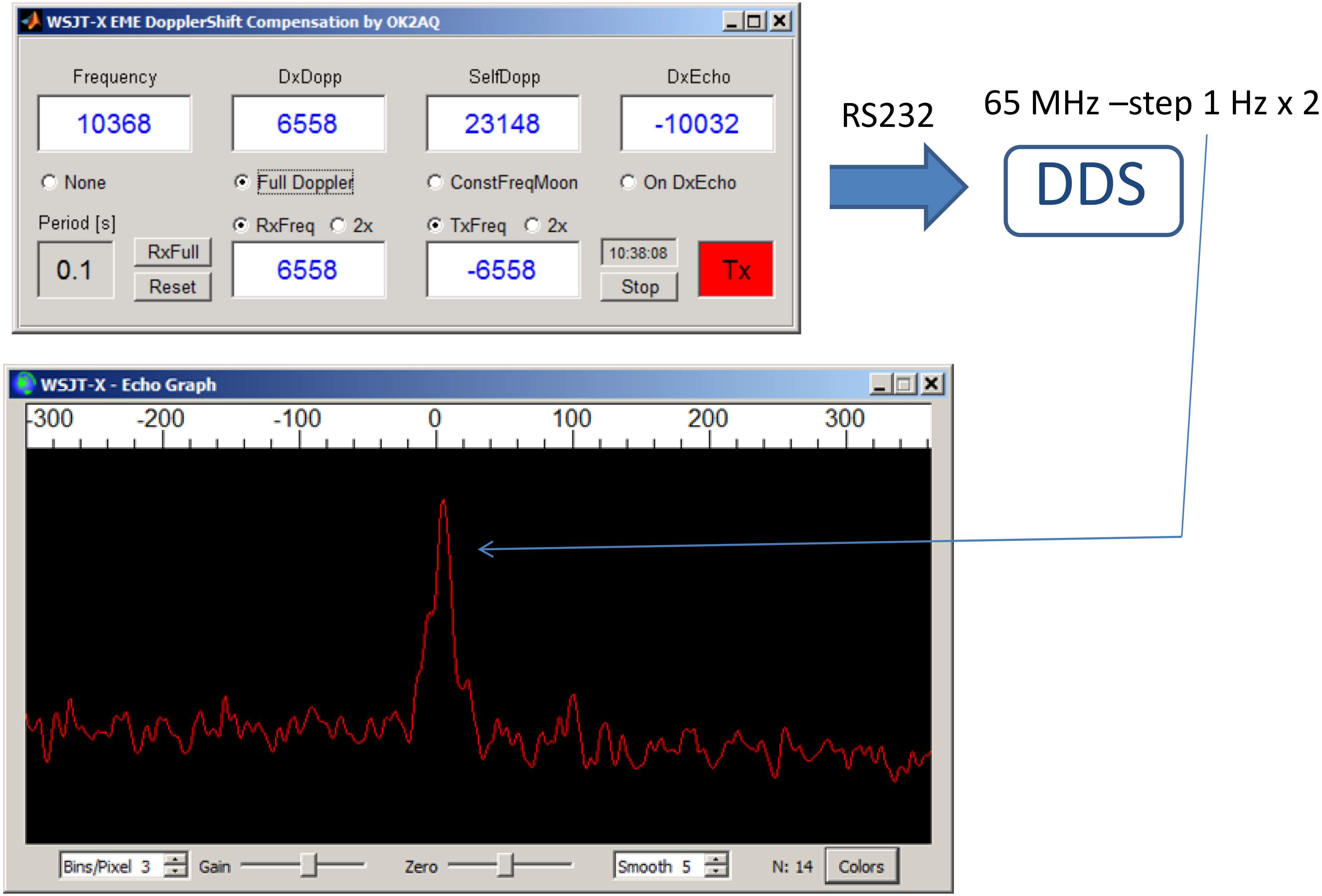
The problem is that most transceivers cannot change the frequency by CAT during transmission.



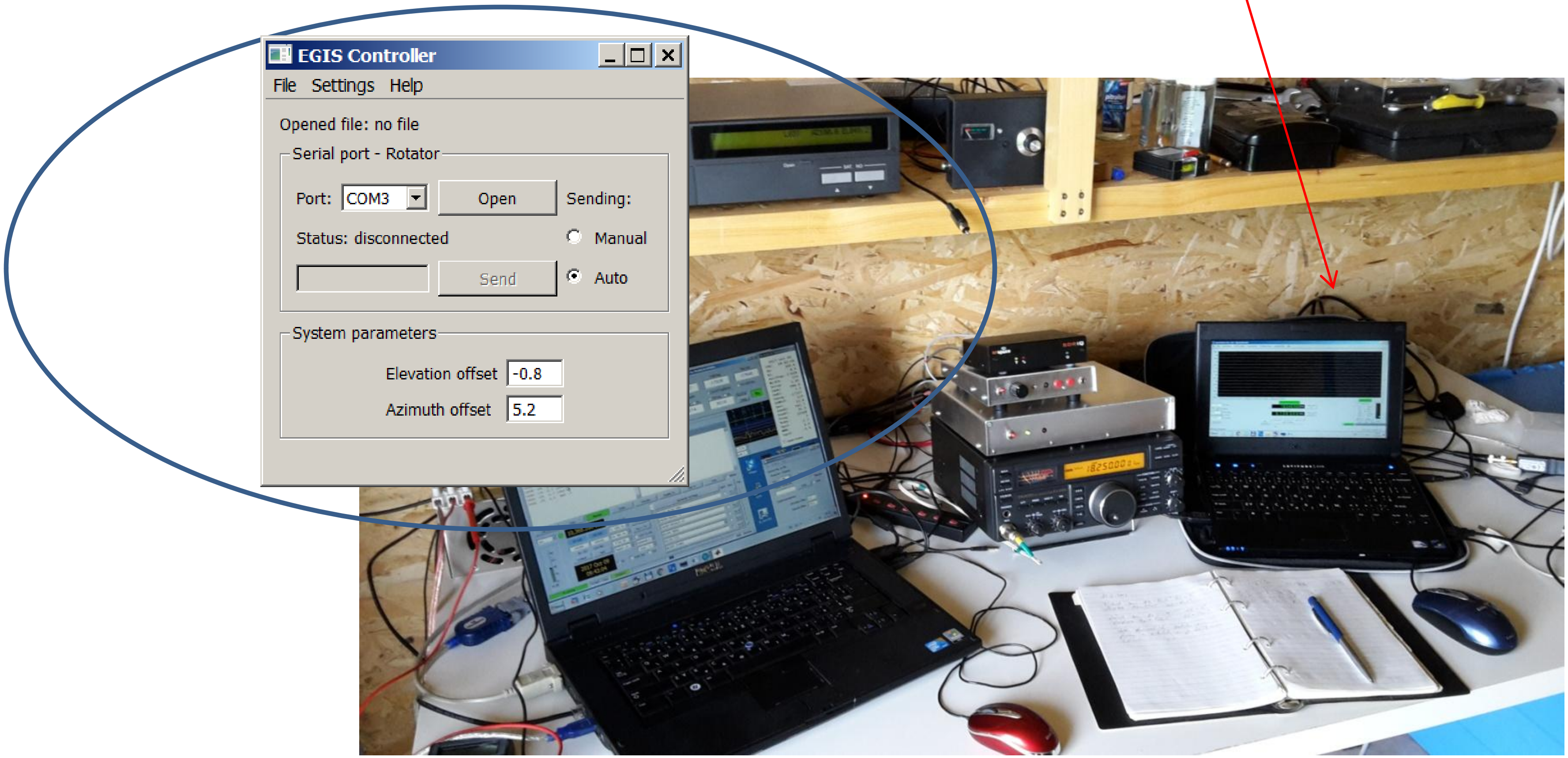
CFOM is preferred

Most transceivers have the lowest step 10 Hz in the CAT control.

MATLAB program - source data are from WSJT-X



Ad 4) Precise automatic antenna pointing with continual monitoring of Moon noise and possibility to change polarization.

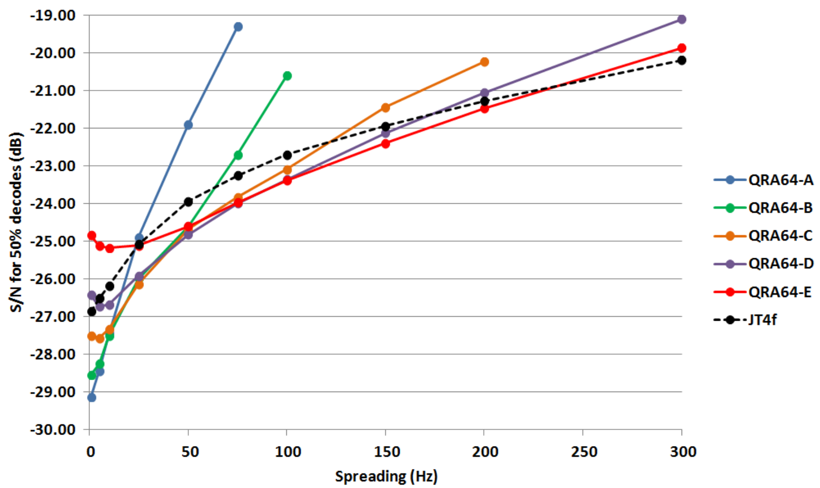


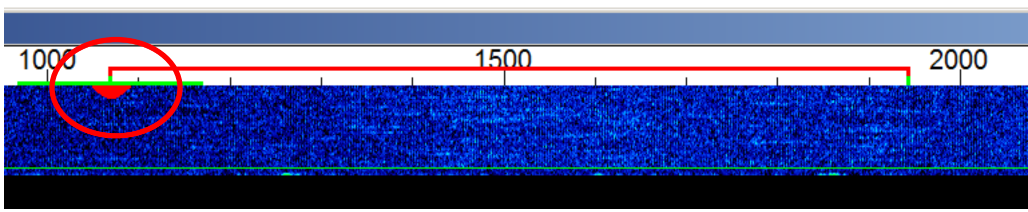
Ad 5) Advanced signal processing

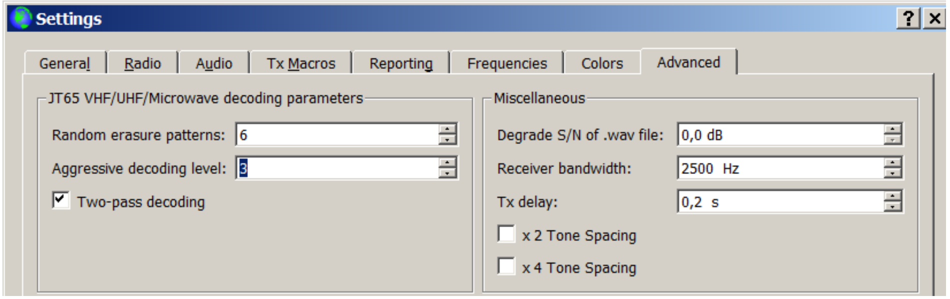
If the station is able to work well in digi modes, it is able to work well even CW, but not always vice versa. In the case of CW, automatic Doppler shift correction can be used, especially when using narrow audio filters.

QRA64 versus JT by VK7MO and G3WDG:

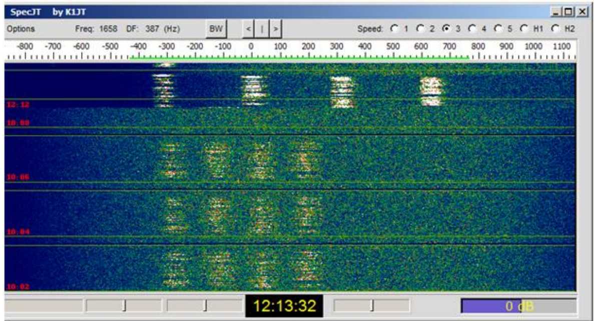
- QRA64 does not use a call3.txt file and has a significant advantage of around 4 dB when working a random station.
- While QRA64 has a relatively small advantage of around 1 to 1.5 dB when working skeds, every dB counts when working marginal EME signals.
- A significant advantage of QRA64 is that it is virtually immune to false decodes.



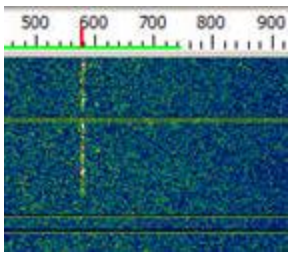




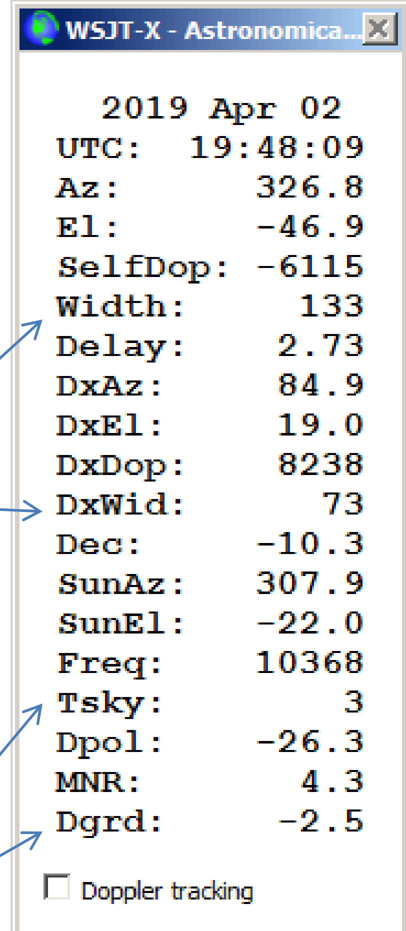
Ad 6) Good planning



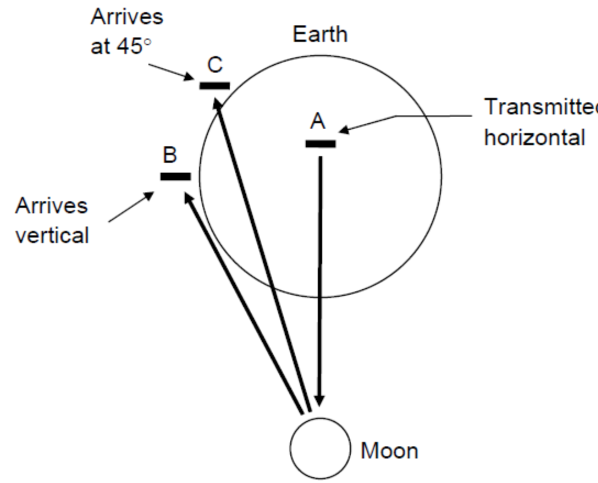
Spreaded spectrum



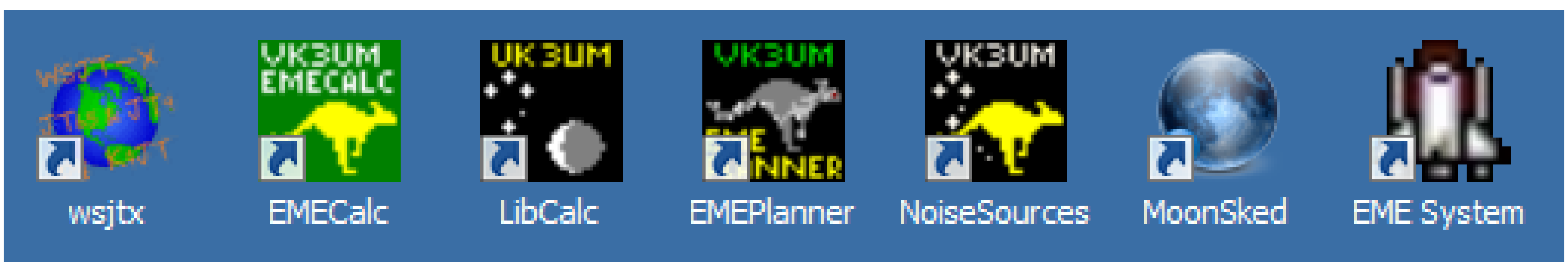
to Moon in perigee and cold sky



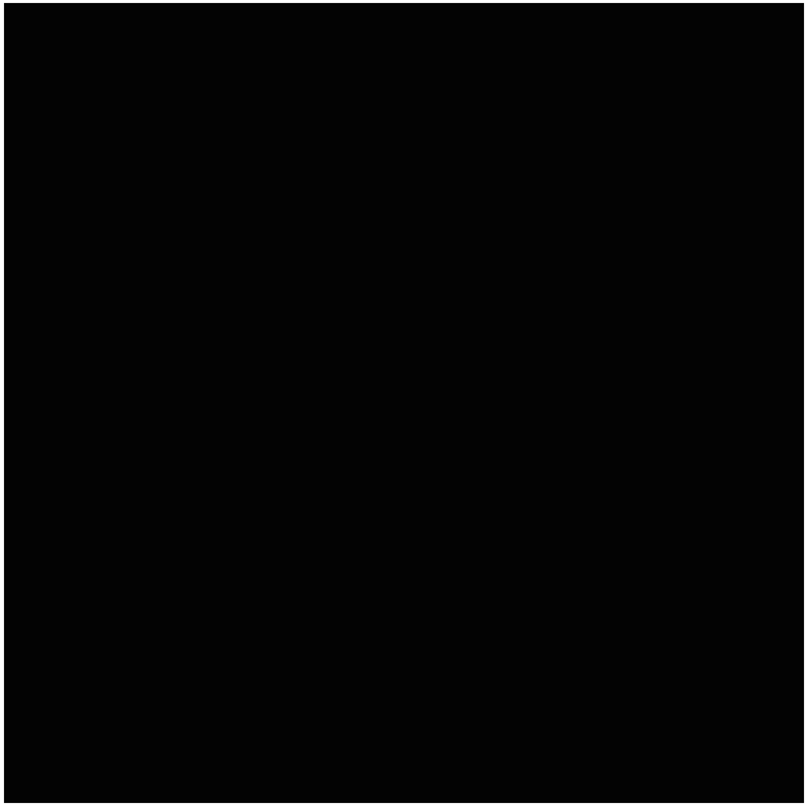
$$L_{Dpol} = 20.\log\left(\cos D_{pol}\right) \quad [\text{dB}]$$

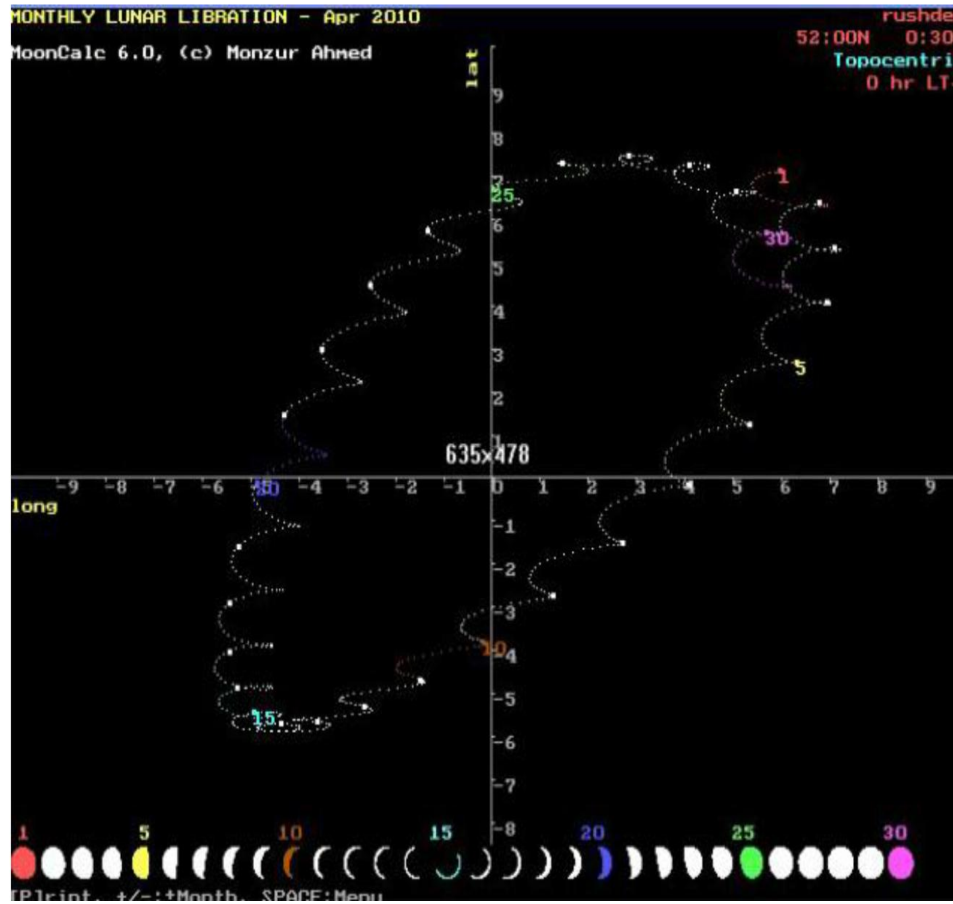


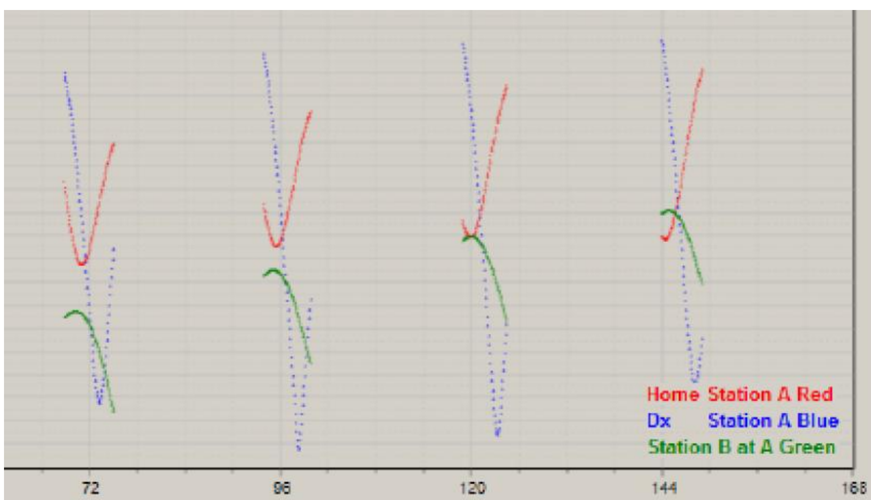
LP versus CP – LP is 1 – 1.6 dB better



Moon Libration – spreaded spectrum







OK2AQ – 1.2 m offset dish

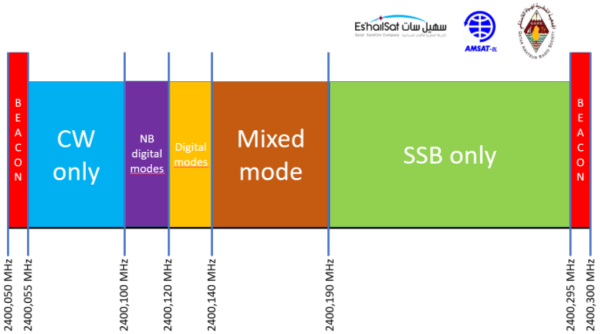
VK7MO – 0.77 m dish

VK7MO – 1.13 m dish

HB9Q as 3DA0MB, EA6/HB9COG and HB0/HB9DBM – 1.5 m dish

63 CW + Digi Initials
25 DXCC

Es'Hail-2 QO-100



Launch: Q4 2018 – **Position:** 26 deg East – **Lifetime:** 15+ years

Frequencies narrow band (**NB**) transponder (bandwidth 250 kHz):

	lower end	upper end	polarisation
Uplink	2400.050 MHz	2400.300 MHz	RHCP
Downlink	10489.550 MHz	10489.800 MHz	vertical

Frequencies wide band (**WB**) transponder (bandwidth 8 MHz):

	lower end	upper end	polarisation
Uplink	2401.500 MHz	2409.500 MHz	RHCP
Downlink	10491.000 MHz	10499.000 MHz	horizontal

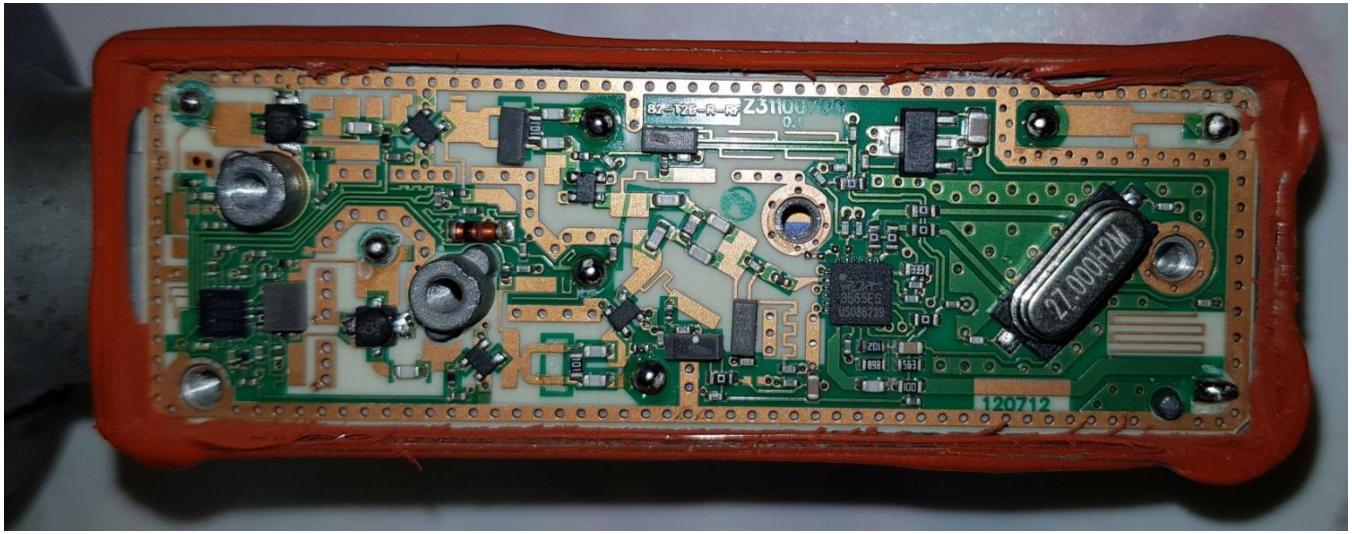
Brno: Az =166.9^{o} ; El = 32.9^{o}

Praha: Az =165.1^{o} ; El = 31.7^{o}

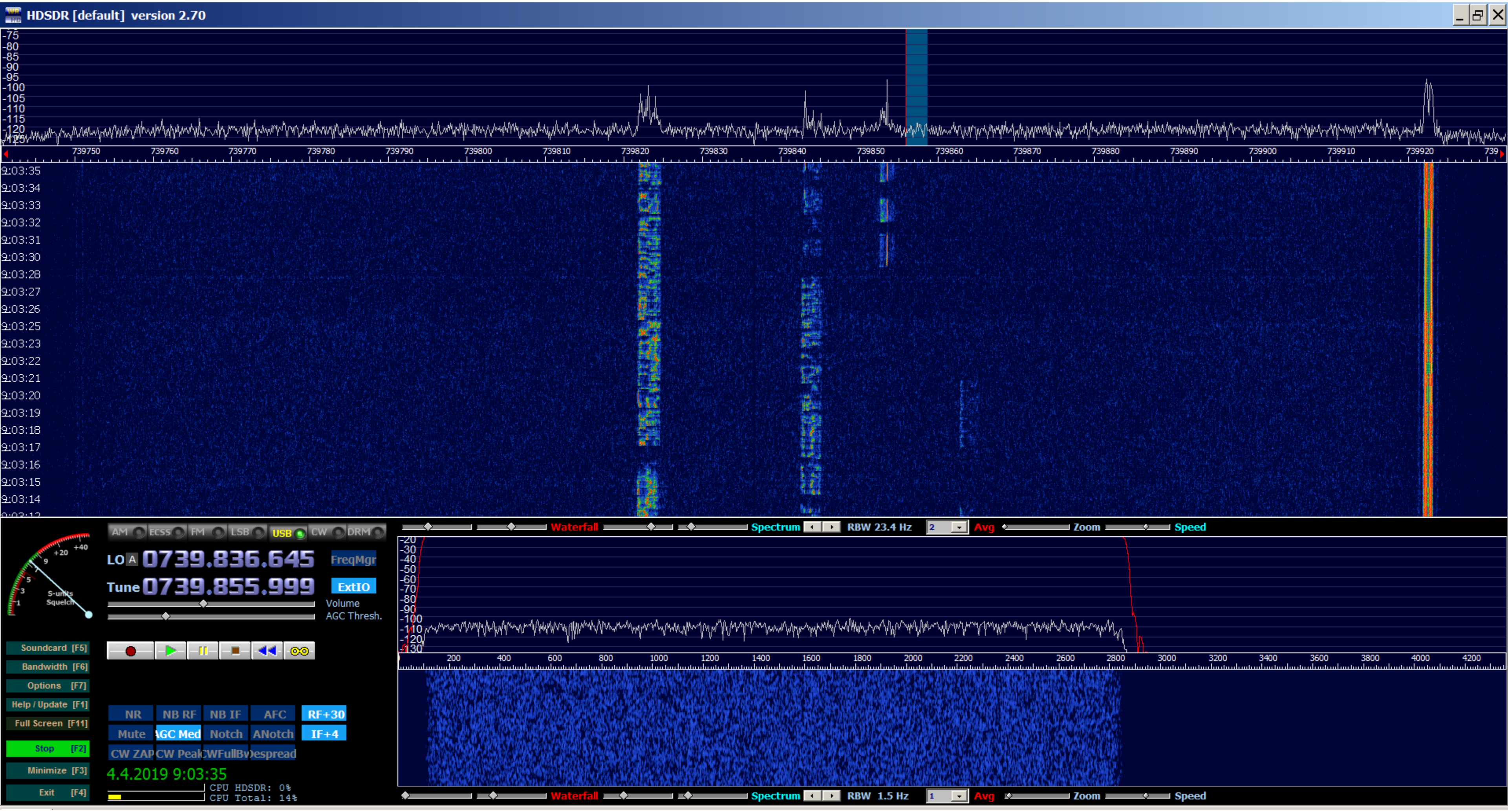
Rx

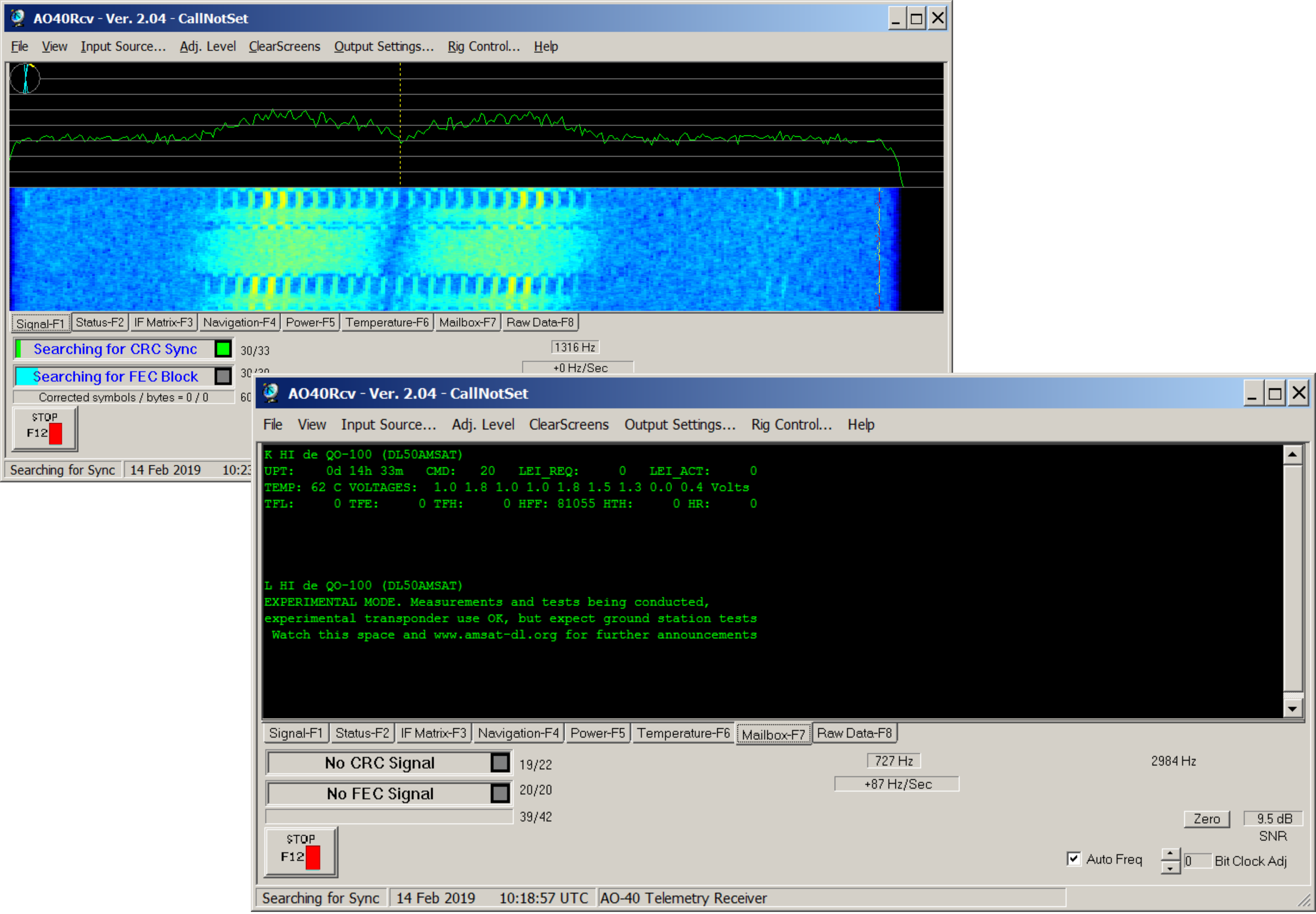
[OCTAGON OPTIMA LNB Twin Slim OTLSO **PLL**]

IF = 10.489,650 -9750 = 739,650 MHz

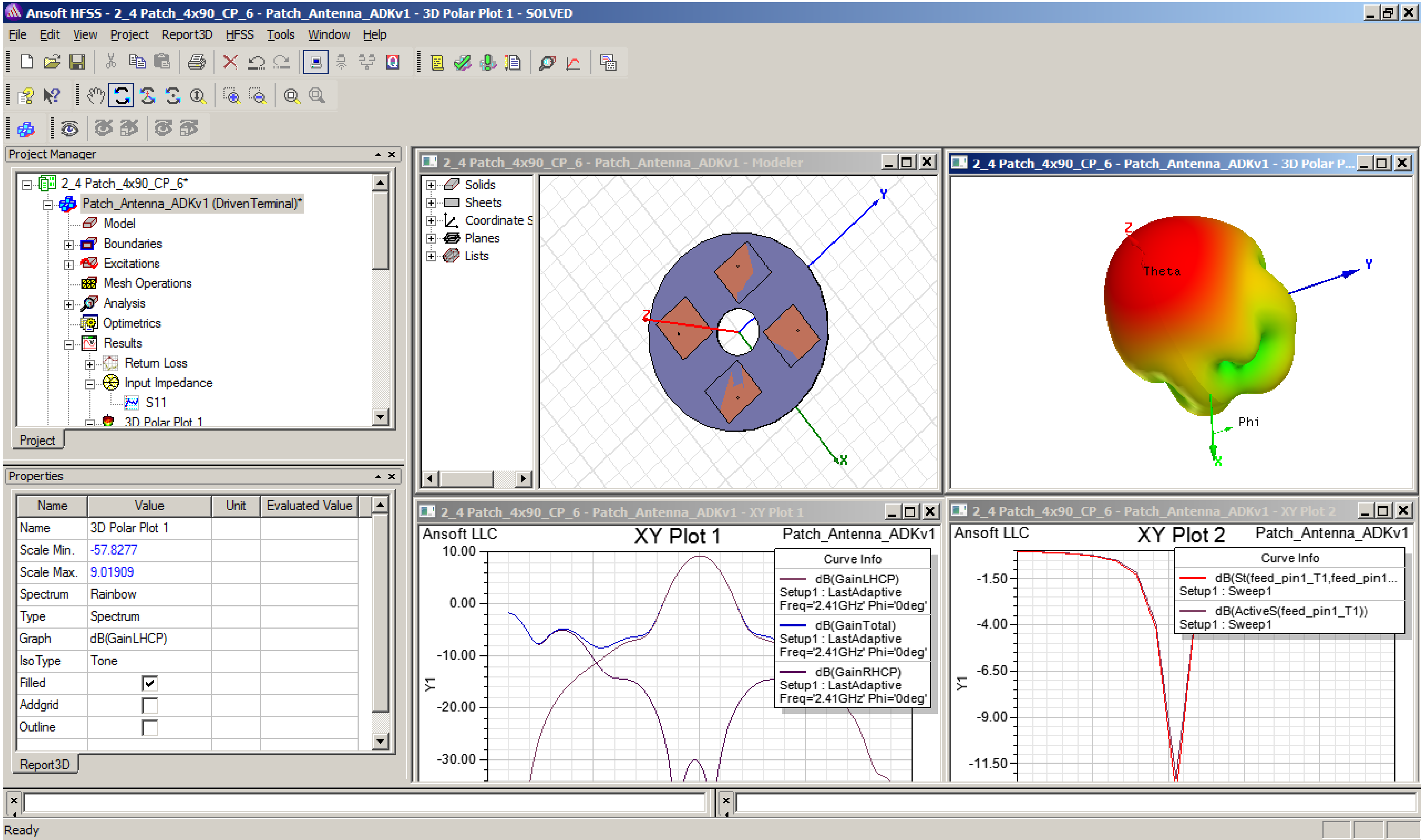

27.000H2M
120712

HDSDR Screen




AO40Rcv - Ver. 2.04 - CallNotSet
File View Input Source... Adj. Level ClearScreens Output Settings... Rig Control... Help
Signal-F1 Status-F2 IF Matrix-F3 Navigation-F4 Power-F5 Temperature-F6 Mailbox-F7 Raw Data-F8
Searching for CRC Sync
30/33
Searching for FEC Block
1316 Hz
+0 Hz/Sec
Corrected symbols / bytes = 0 / 0
STOP F12
Searching for Sync
14 Feb 2019
AO40Rcv - Ver. 2.04 - CallNotSet
File View Input Source... Adj. Level ClearScreens Output Settings... Rig Control... Help
K HI de QO-100 (DL50AMSAT)
UPT: 0d 14h 33m CMD: 20 LEI_REQ: 0 LEI_ACT: 0
TEMP: 62 C VOLTAGES: 1.0 1.8 1.0 1.0 1.8 1.5 1.3 0.0 0.4 Volts
TFL: 0 TFE: 0 TFH: 0 HFF: 81055 HTH: 0 HR: 0
L HI de QO-100 (DL50AMSAT)
EXPERIMENTAL MODE. Measurements and tests being conducted,
experimental transponder use OK, but expect ground station tests
Watch this space and www.amsat-dl.org for further announcements
Signal-F1 Status-F2 IF Matrix-F3 Navigation-F4 Power-F5 Temperature-F6 Mailbox-F7 Raw Data-F8
No CRC Signal
19/22
No FEC Signal
20/20
39/42
727 Hz
+87 Hz/Sec
2984 Hz
Zero
9.5 dB
SNR
Auto Freq
0
Bit Clock Adj
STOP F12
Searching for Sync
14 Feb 2019
10:18:57 UTC
AO-40 Telemetry Receiver

4 x Patch phased for LHCP



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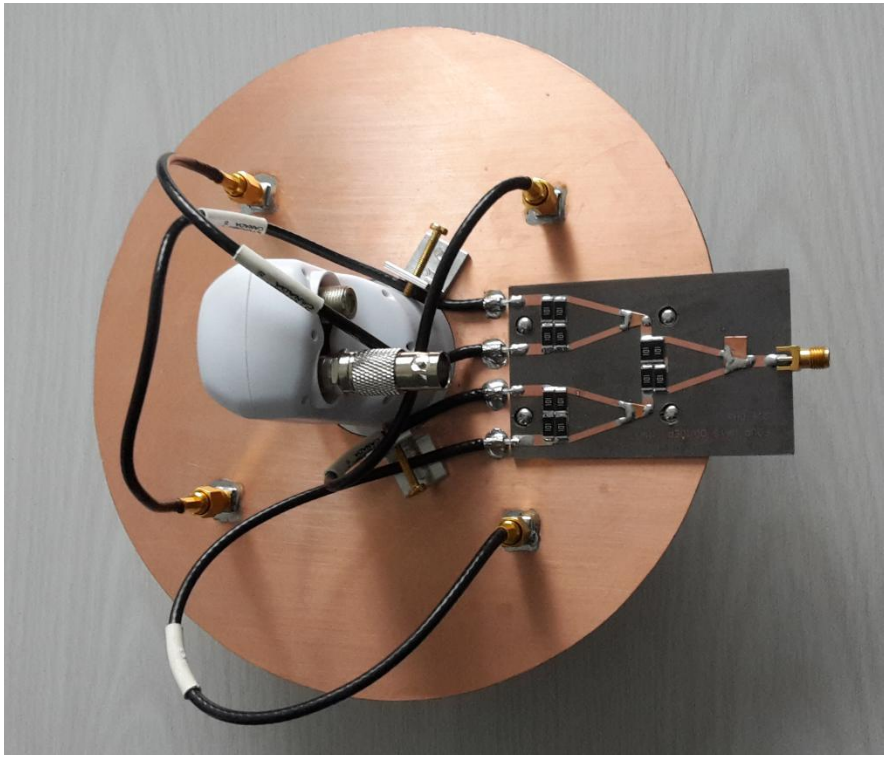
DIGI



Thank you for attention
Děkuji Vám za pozornost