EME Fundamentals

… from basic physics to digi-modes…

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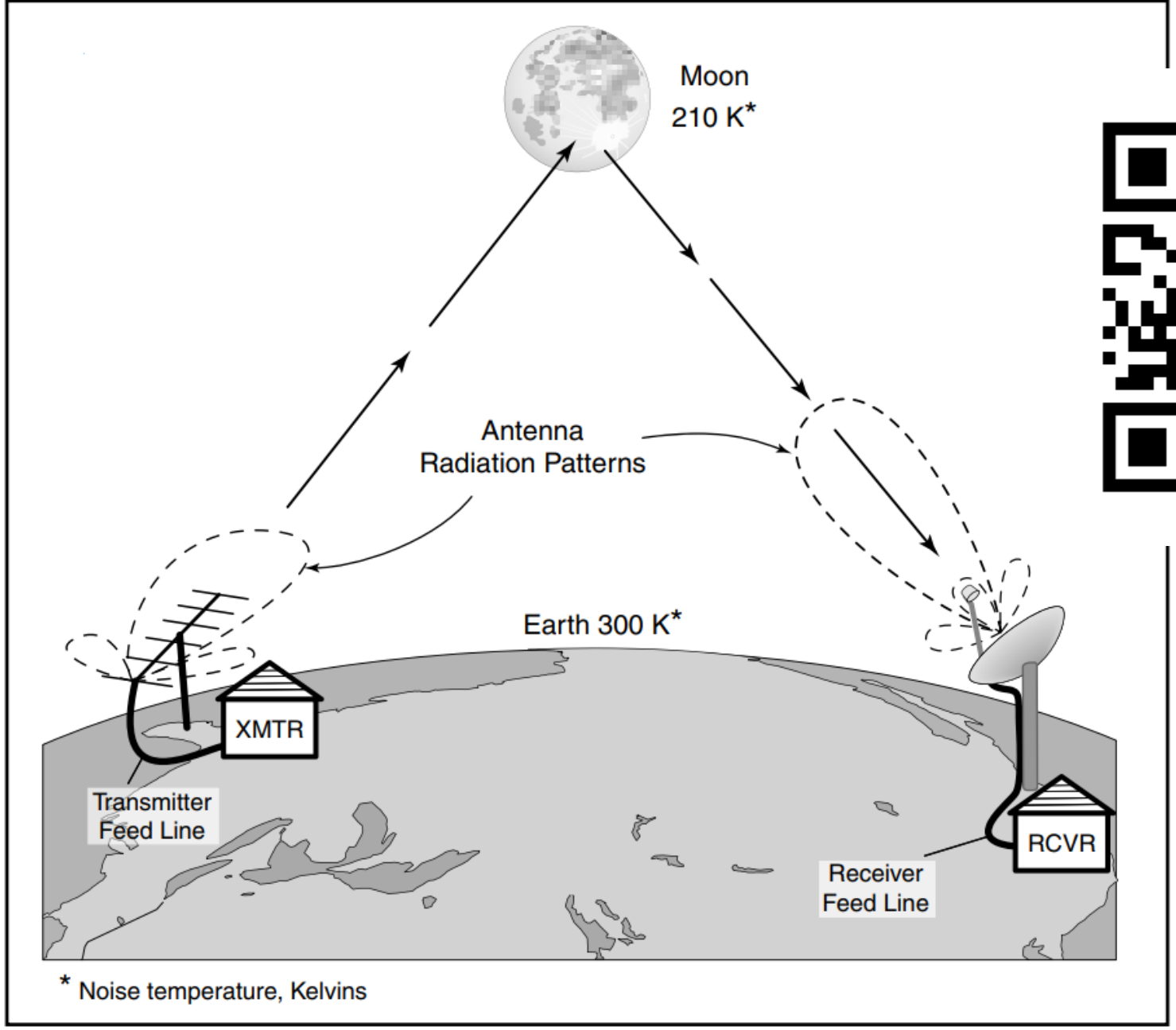
K1JT

Overview

- EME fundamentals and limits
- Tweaking your setup
- Software and Digi-modes for EME



https://wsjt.sourceforge.io/Hbk_2010_Ch30_EME.pdf

EME Path Loss

$$p_r = p_t \, g_t \, g_r \, l$$

$$l = \frac{\eta \lambda^2 r^2}{64 \, \pi^2 d^4}$$

Two-Way EME Path Loss with Isotropic Antennas

Frequency (MHz)	*Average Path Loss (dB)*
50	–242.9
144	–252.1
222	–255.8
432	–261.6
902	–268.0
1296	–271.2
2304	–276.2
3456	–279.7
5760	–284.1
10368	–289.2
24048	–293.5

Signal-to-Noise Ratio

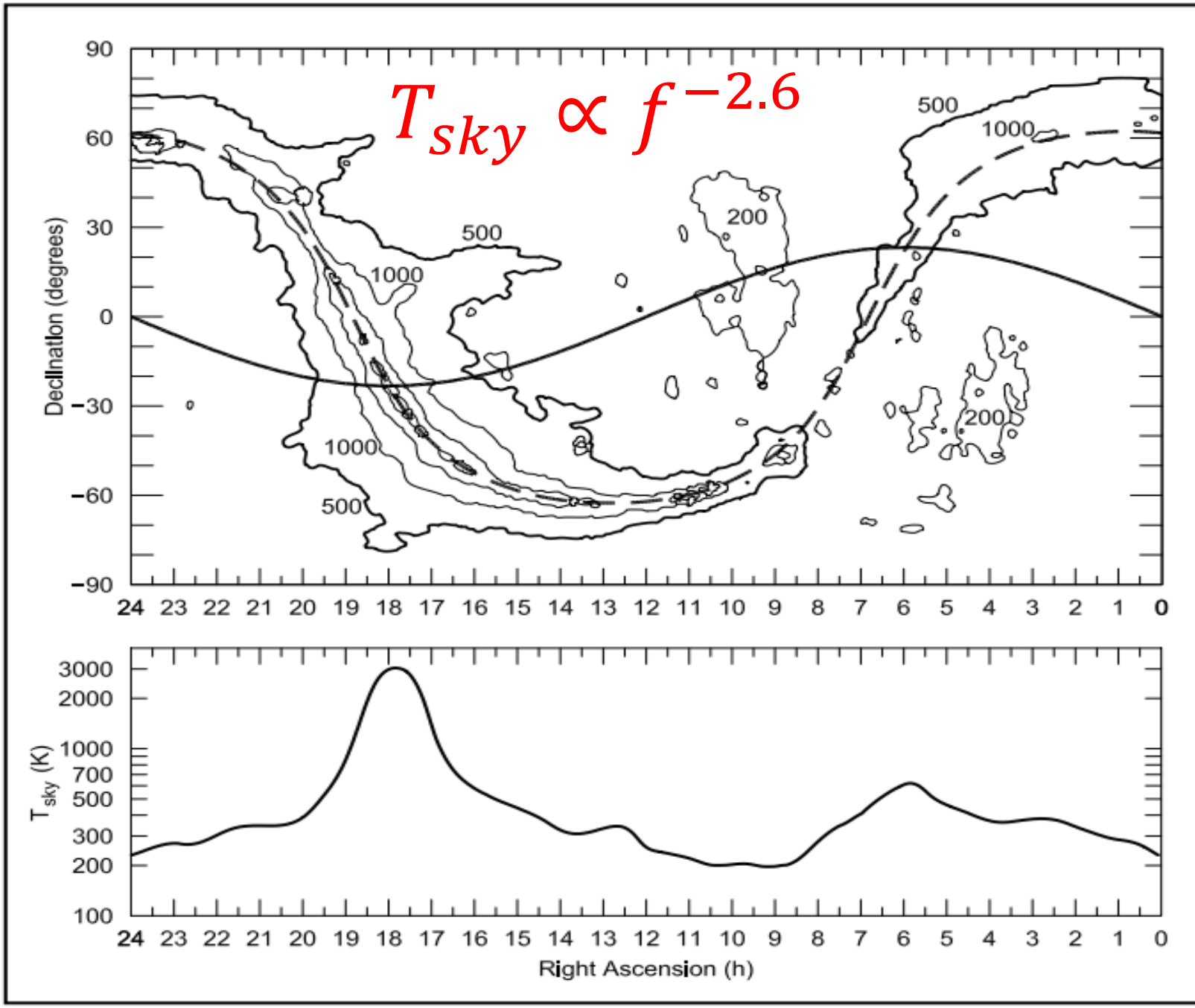
$$\frac{S}{N} = \frac{p_r}{p_n} = \frac{p_t\, g_t\, g_r\, l}{k T_s B}$$

System noise temperature

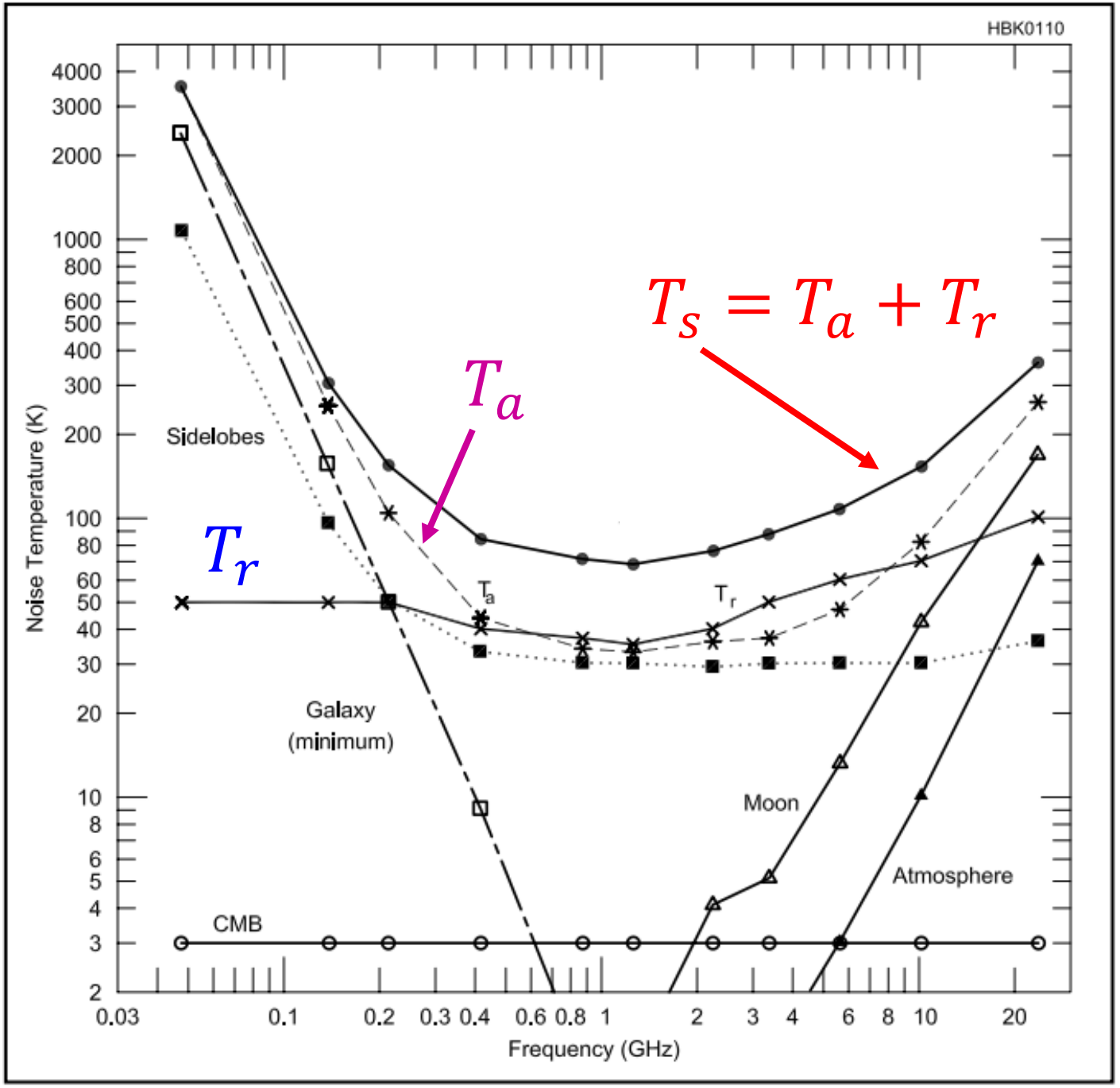
$$T_s = T_a + T_r$$

Received bandwidth

Galactic Noise 144 MHz



System Noise Temperature T_s



Signal-to-Noise Ratio

$$\frac{S}{N} = \frac{p_r}{p_n} = \frac{p_t\ g_t\ g_r\ l}{kT_sB}$$

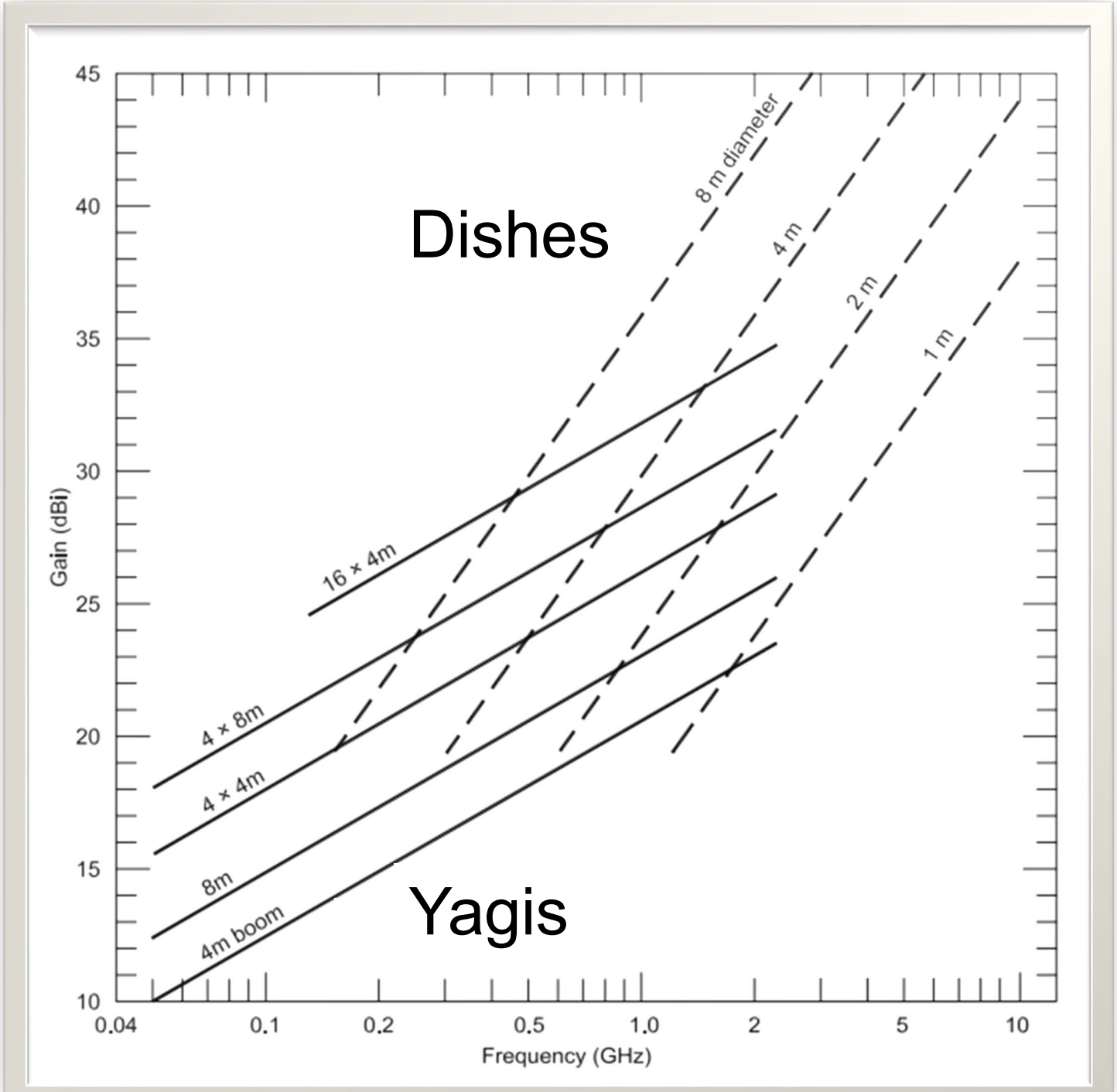
System noise temperature

$$T_s = T_a + T_r$$

Received bandwidth

Q: What can I control ??

What type of antenna ??



How much power ??

(Assume S/N = 0 dB, B = 100 Hz)

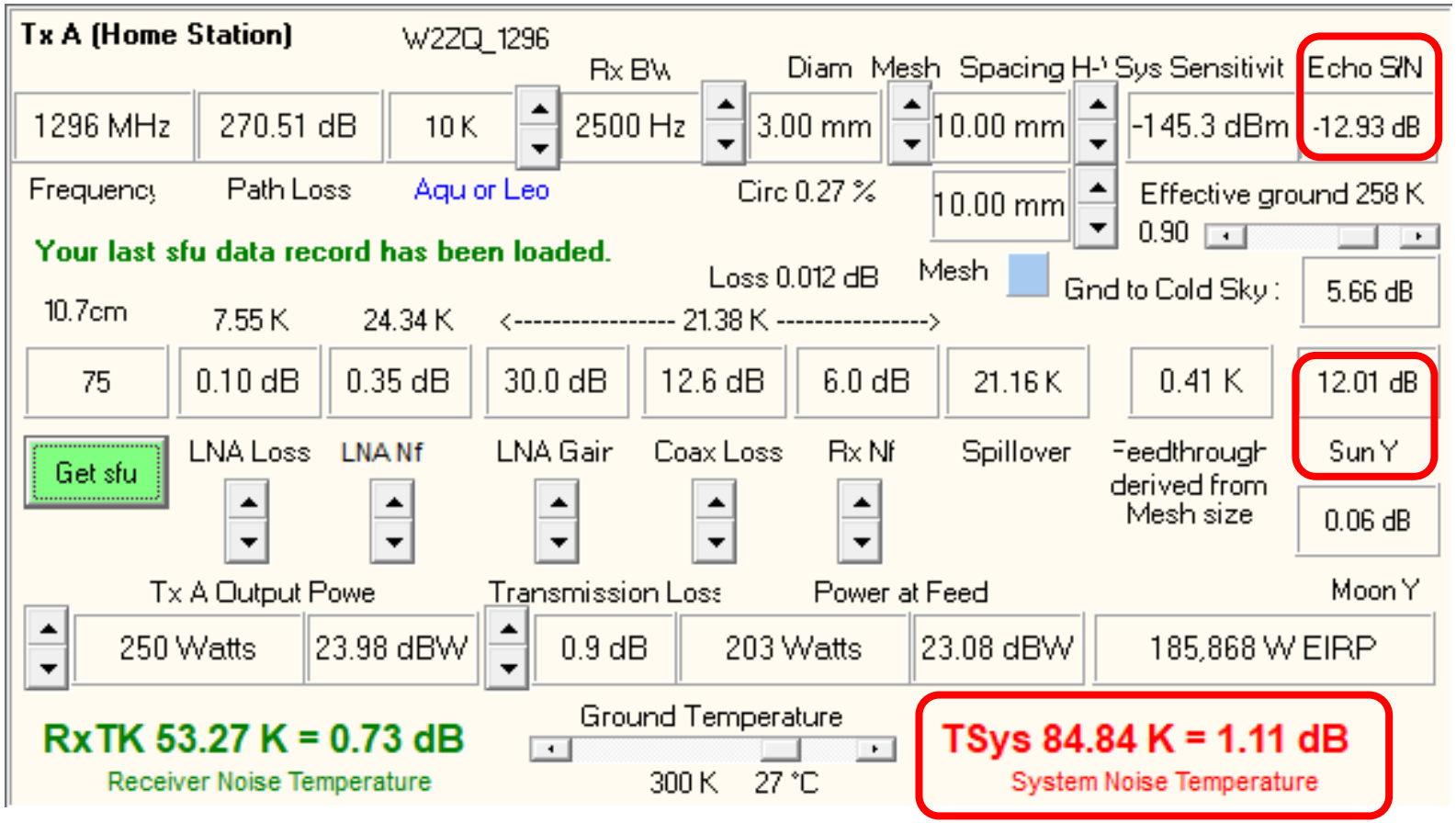
Freq (MHz)	*Ant Type[1]*	*G (dBi)*	*HPBW (deg)*	*TxPwr (W)*
50	4×12 m	19.7	18.8	1200
144	4×6 m	21.0	15.4	500
432	4×6 m	25.0	10.5	250
1296	3 m	29.5	5.5	160
2304	3 m	34.5	3.1	60
3456	2 m	34.8	3.0	120
5760	2 m	39.2	1.8	60
10368	2 m	44.3	1.0	25

0 dB

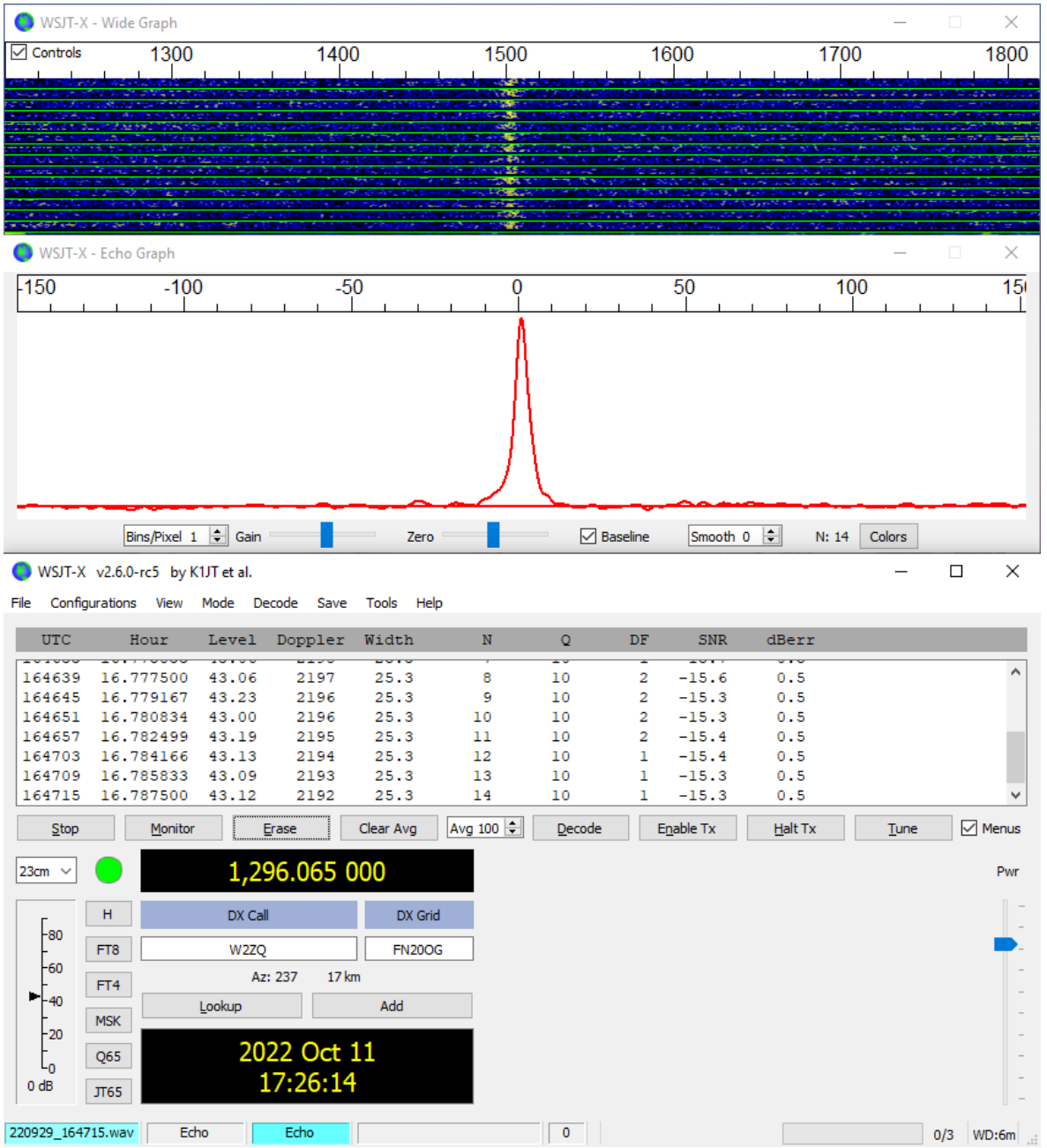
-15 dB

EMECalc by VK3UM

https://www.vk5dj.com/doug.html



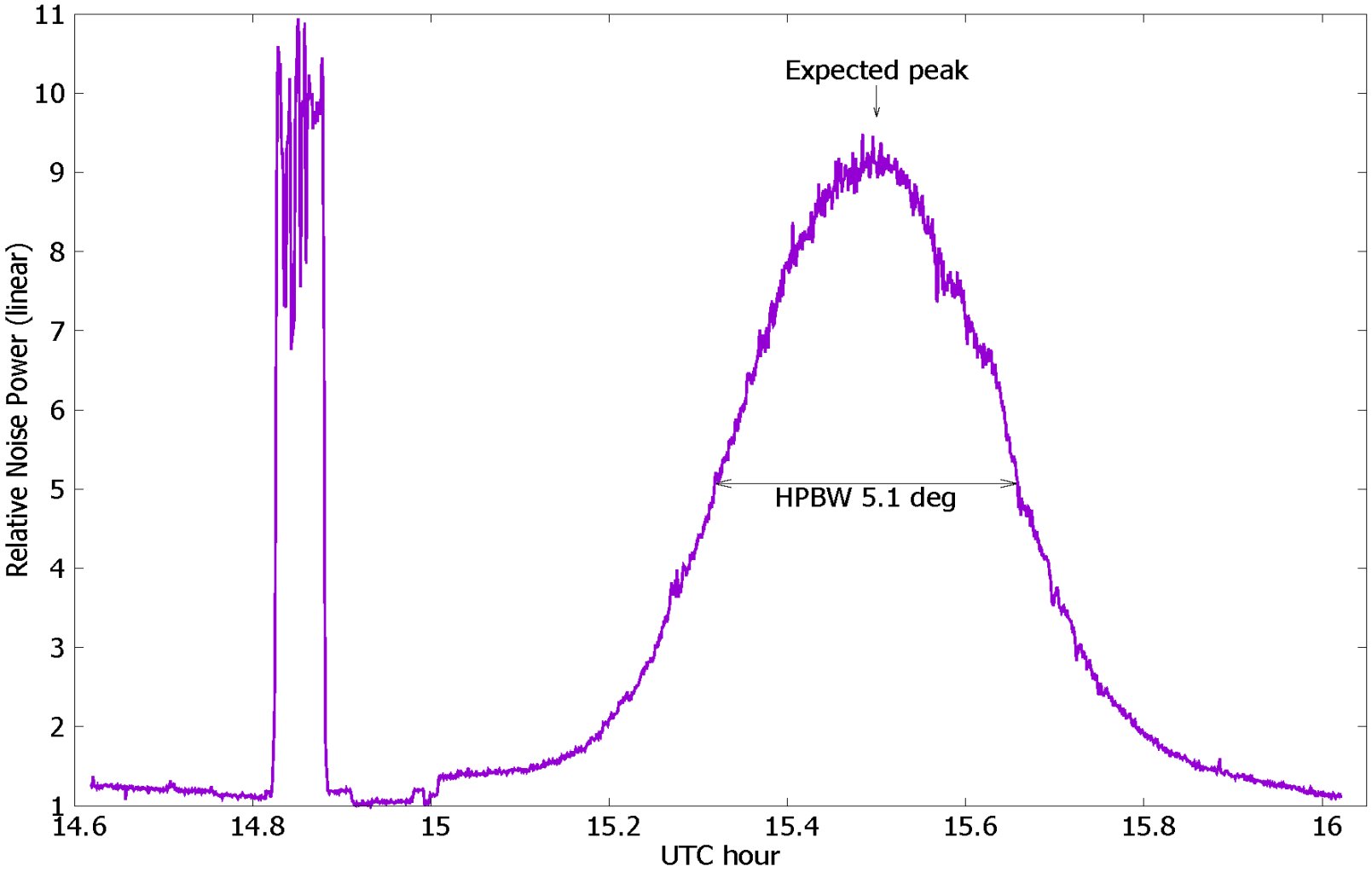
W2ZQ
EME echoes
SNR = -15.3 dB



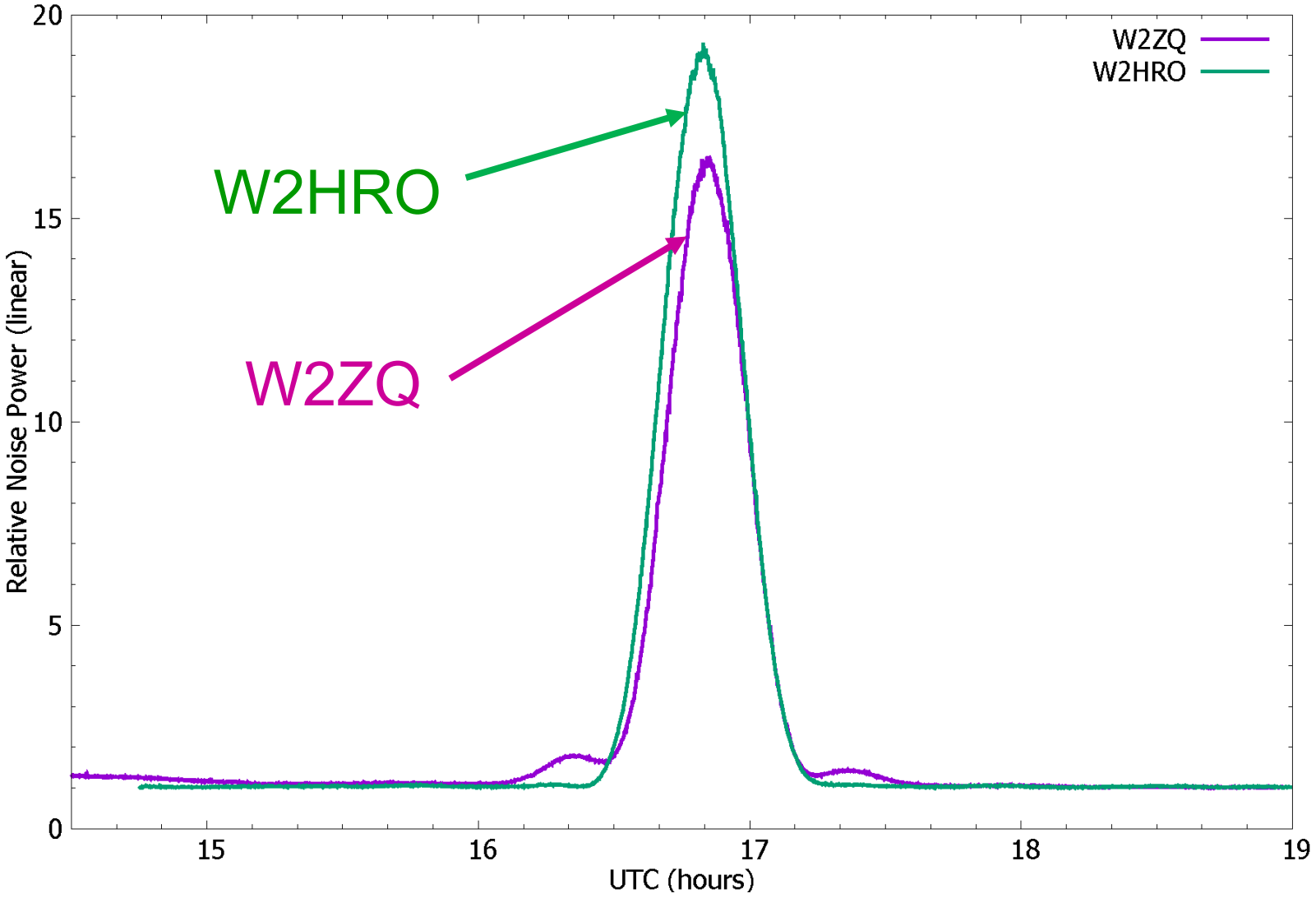
https://wsjt.sourceforge.io/wsjtx.html

Testing your setup…

W2ZQ: Sun Noise, 1296 MHz

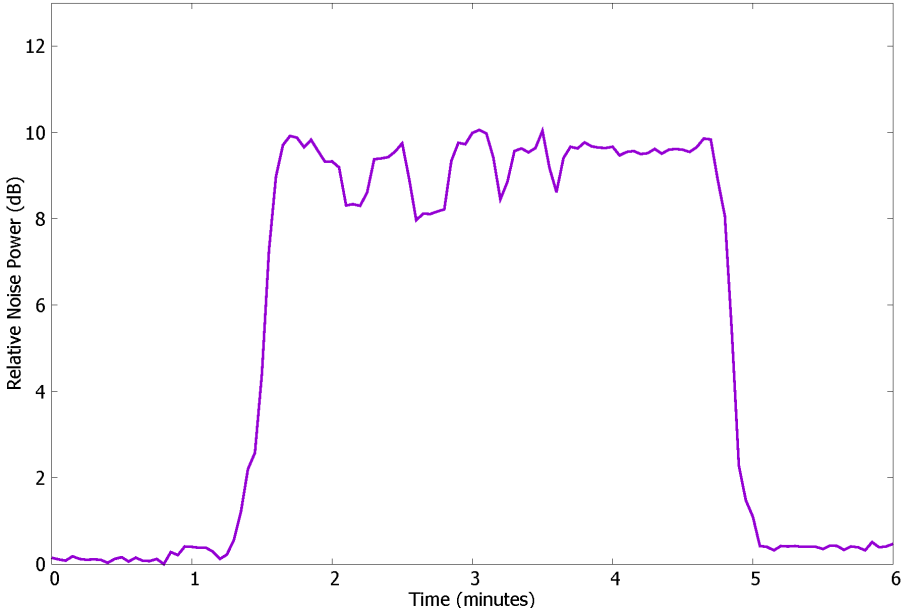


Antenna Pattern

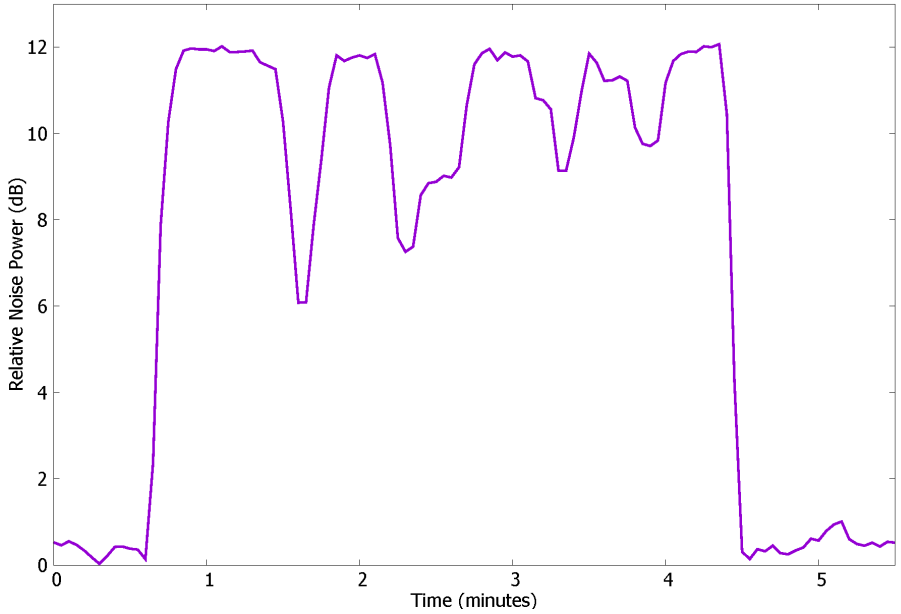


Focus Adjustment

Before: Y_{sun} = 10 dB



After: Y_{sun} = 12 dB



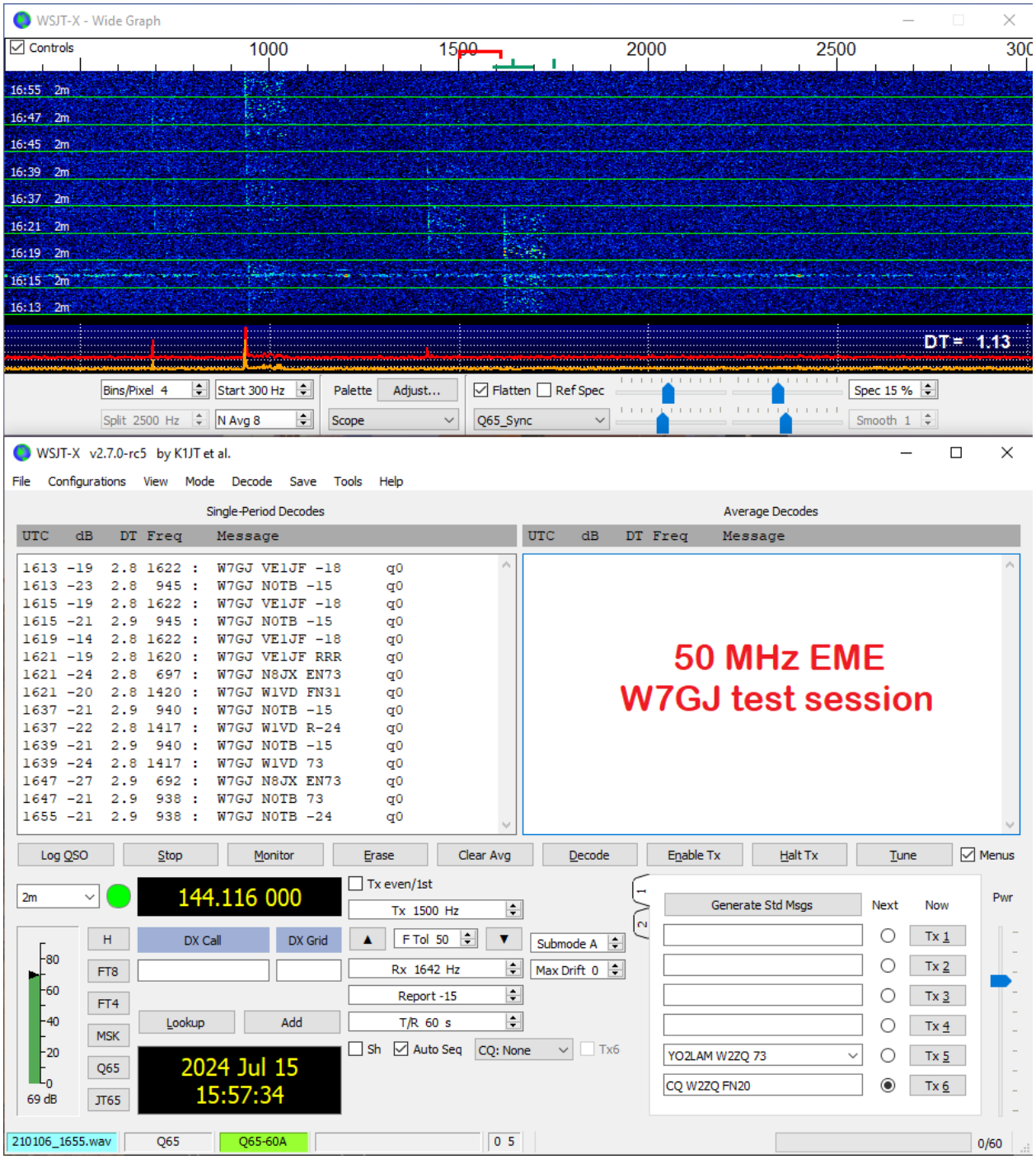
Software and Digi-Modes

WSJT-X

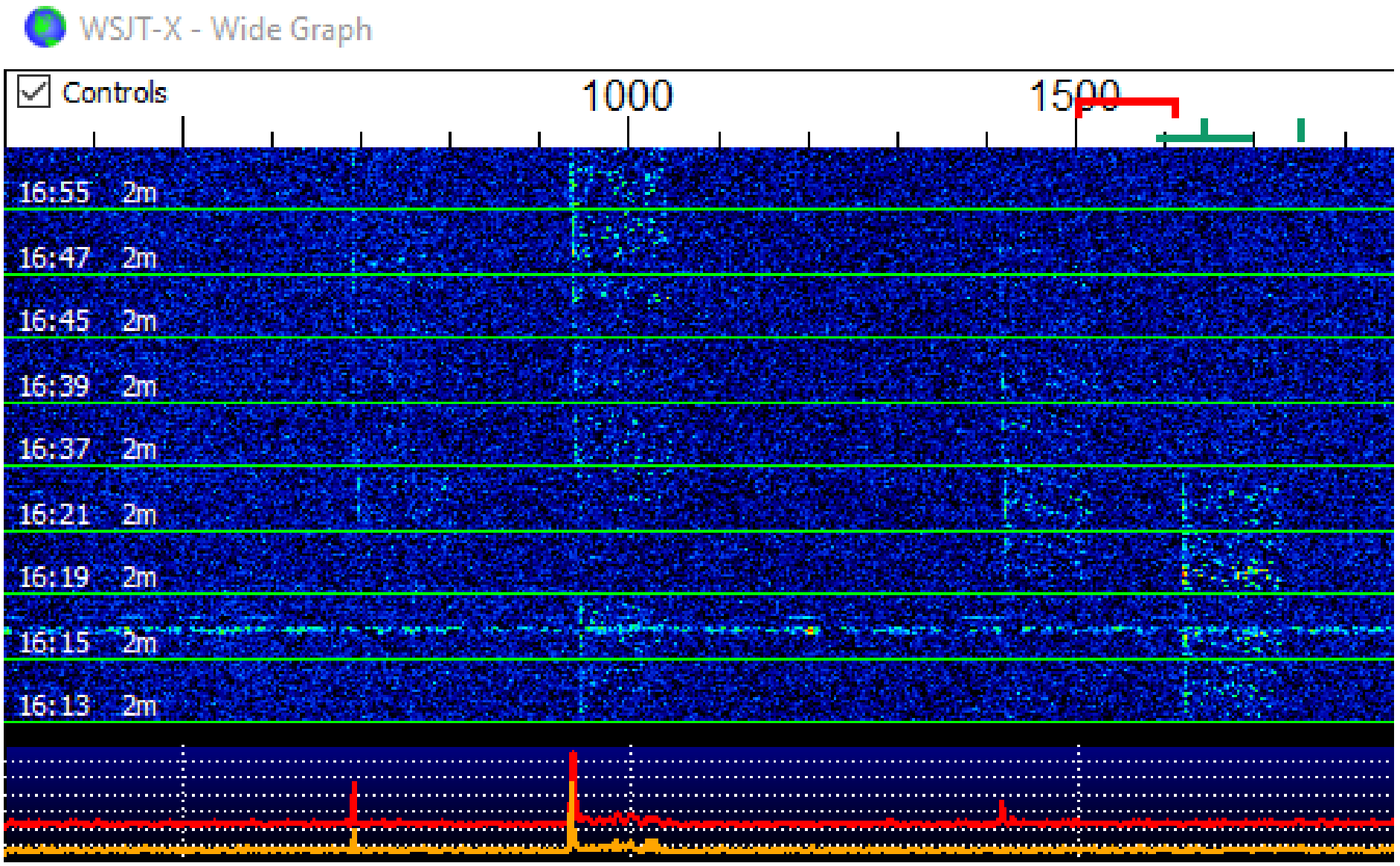
QMAP

Q65

WSJT-X


WSJT-X - Wide Graph
Controls
1000
1500
2000
2500
16:55 2m
16:47 2m
16:45 2m
16:39 2m
16:37 2m
16:21 2m
16:19 2m
16:15 2m
16:13 2m
DT = 1.13
Bins/Pixel 4
Start 300 Hz
Palette
Adjust...
Flatten
Ref Spec
Spec 15 %
Split 2500 Hz
N Avg 8
Scope
Q65_Sync
Smooth 1
WSJT-X v2.7.0-rc5 by K1JT et al.
File Configurations View Mode Decode Save Tools Help
Single-Period Decodes
Average Decodes
UTC dB DT Freq Message
1613 -19 2.8 1622 : W7GJ VE1JF -18 q0
1613 -23 2.8 945 : W7GJ N0TB -15 q0
1615 -19 2.8 1622 : W7GJ VE1JF -18 q0
1615 -21 2.9 945 : W7GJ N0TB -15 q0
1619 -14 2.8 1622 : W7GJ VE1JF -18 q0
1621 -19 2.8 1620 : W7GJ VE1JF RRR q0
1621 -24 2.8 697 : W7GJ N8JX EN73 q0
1621 -20 2.8 1420 : W7GJ W1VD FN31 q0
1637 -21 2.9 940 : W7GJ N0TB -15 q0
1637 -22 2.8 1417 : W7GJ W1VD R-24 q0
1639 -21 2.9 940 : W7GJ N0TB -15 q0
1639 -24 2.8 1417 : W7GJ W1VD 73 q0
1647 -27 2.9 692 : W7GJ N8JX EN73 q0
1647 -21 2.9 938 : W7GJ N0TB 73 q0
1655 -21 2.9 938 : W7GJ N0TB -24 q0
50 MHz EME
W7GJ test session
Log QSO
Stop
Monitor
Erase
Clear Avg
Decode
Enable Tx
Halt Tx
Tune
Menus
2m
144.116 000
Tx even/1st
Tx 1500 Hz
F Tol 50
Submode A
Rx 1642 Hz
Max Drift 0
Report -15
T/R 60 s
Sh
Auto Seq
CQ: None
Tx6
H
FT8
FT4
MSK
Q65
JT65
DX Call
DX Grid
Lookup
Add
2024 Jul 15
15:57:34
69 dB
Generate Std Msgs
Next
Now
Pwr
Tx 1
Tx 2
Tx 3
Tx 4
Tx 5
Tx 6
YO2LAM W2ZQ 73
CQ W2ZQ FN20
210106_1655.wav
Q65
Q65-60A
0/60

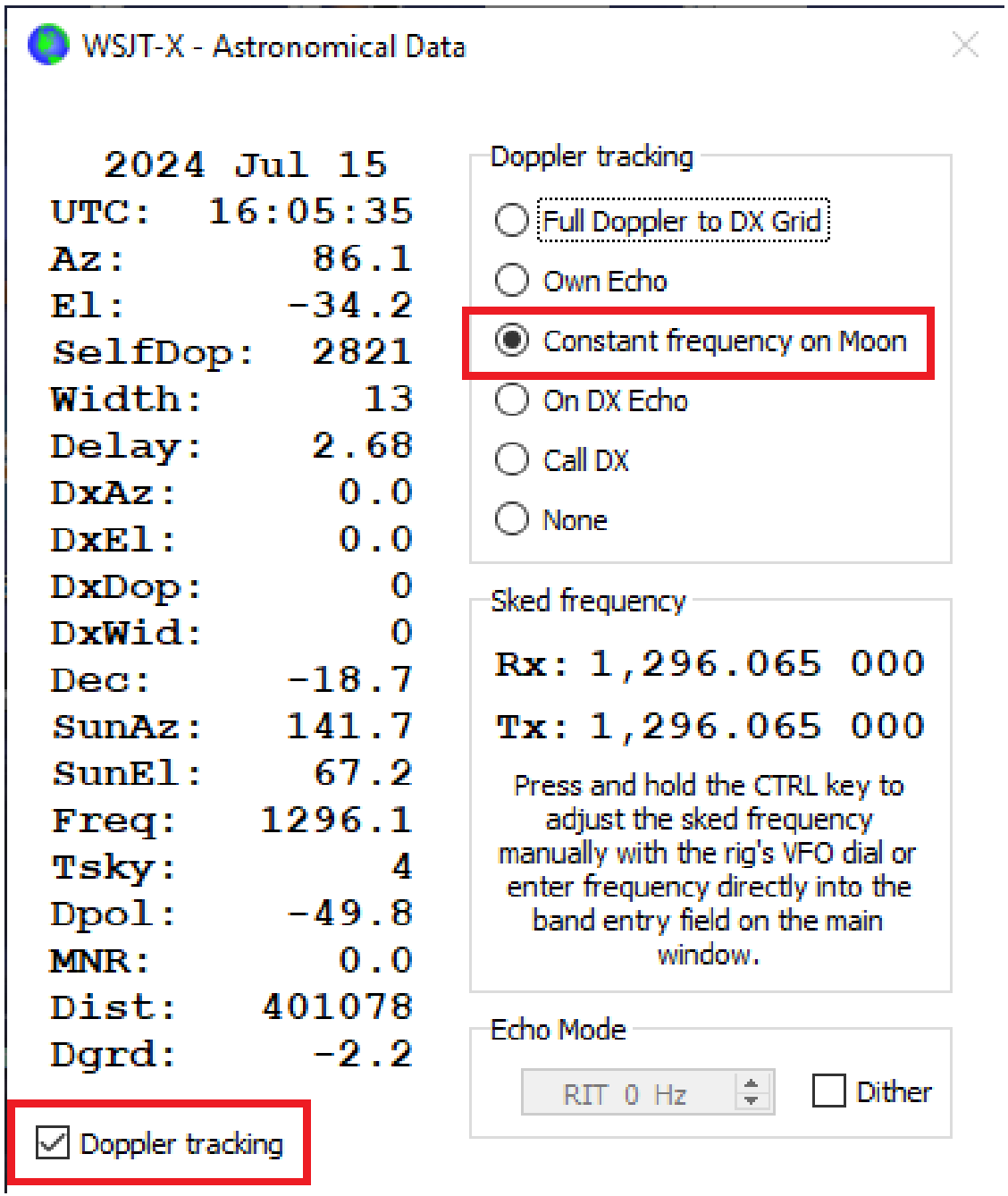
WSJT-X Waterfall



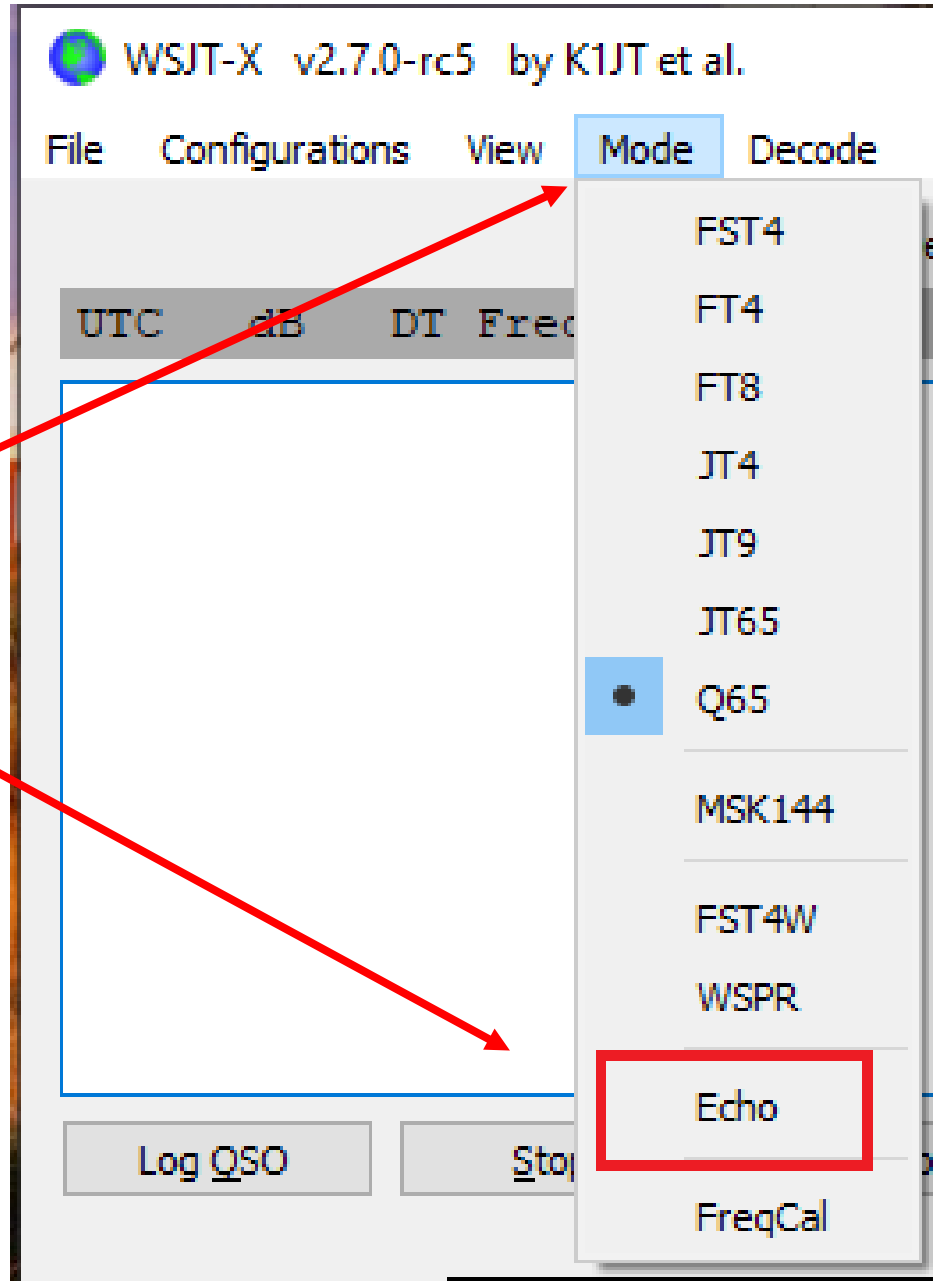
W7GJ works an EME pileup

UTC	dB	DT	Freq		Message
1613	-19	2.8	1622	:	W7GJ VE1JF -18
1613	-23	2.8	945	:	W7GJ N0TB -15
1615	-19	2.8	1622	:	W7GJ VE1JF -18
1615	-21	2.9	945	:	W7GJ N0TB -15
1619	-14	2.8	1622	:	W7GJ VE1JF -18
1621	-19	2.8	1620	:	W7GJ VE1JF RRR
1621	-24	2.8	697	:	W7GJ N8JX EN73
1621	-20	2.8	1420	:	W7GJ W1VD FN31
1637	-21	2.9	940	:	W7GJ N0TB -15
1637	-22	2.8	1417	:	W7GJ W1VD R-24
1639	-21	2.9	940	:	W7GJ N0TB -15
1639	-24	2.8	1417	:	W7GJ W1VD 73
1647	-27	2.9	692	:	W7GJ N8JX EN73
1647	-21	2.9	938	:	W7GJ N0TB 73
1655	-21	2.9	938	:	W7GJ N0TB -24

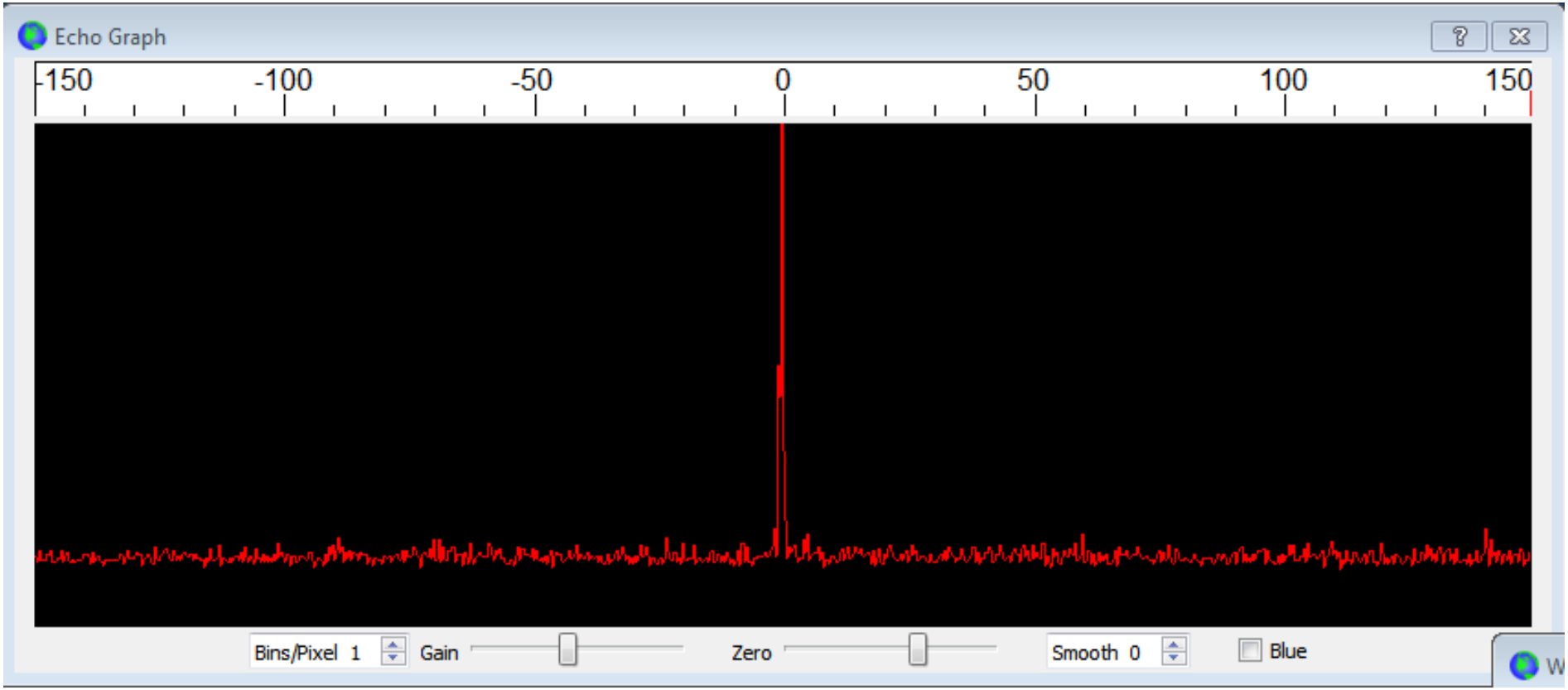
WSJT-X Doppler Tracking



WSJT-X
Echo Mode

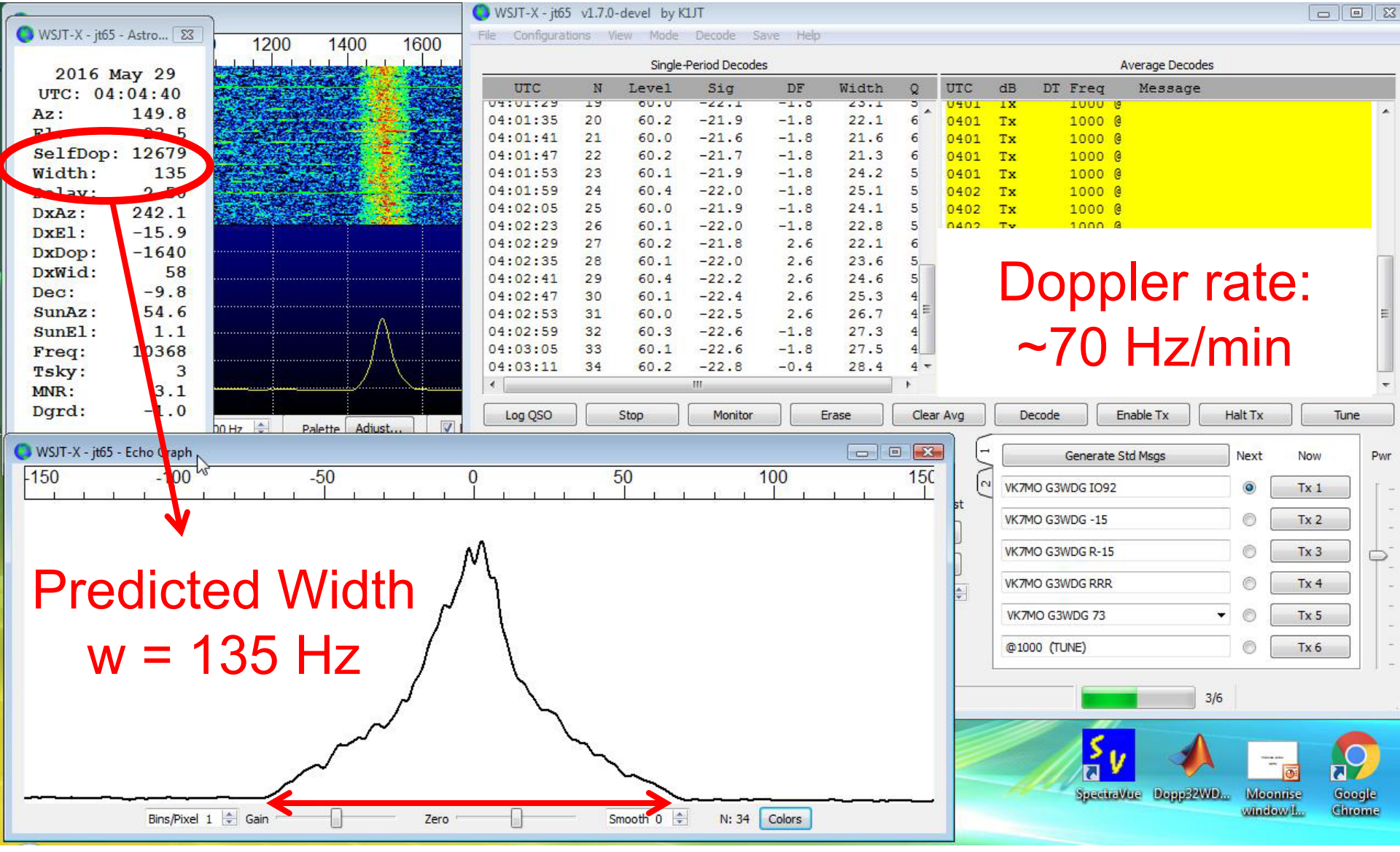


Echo Mode: K1JT, 144 MHz

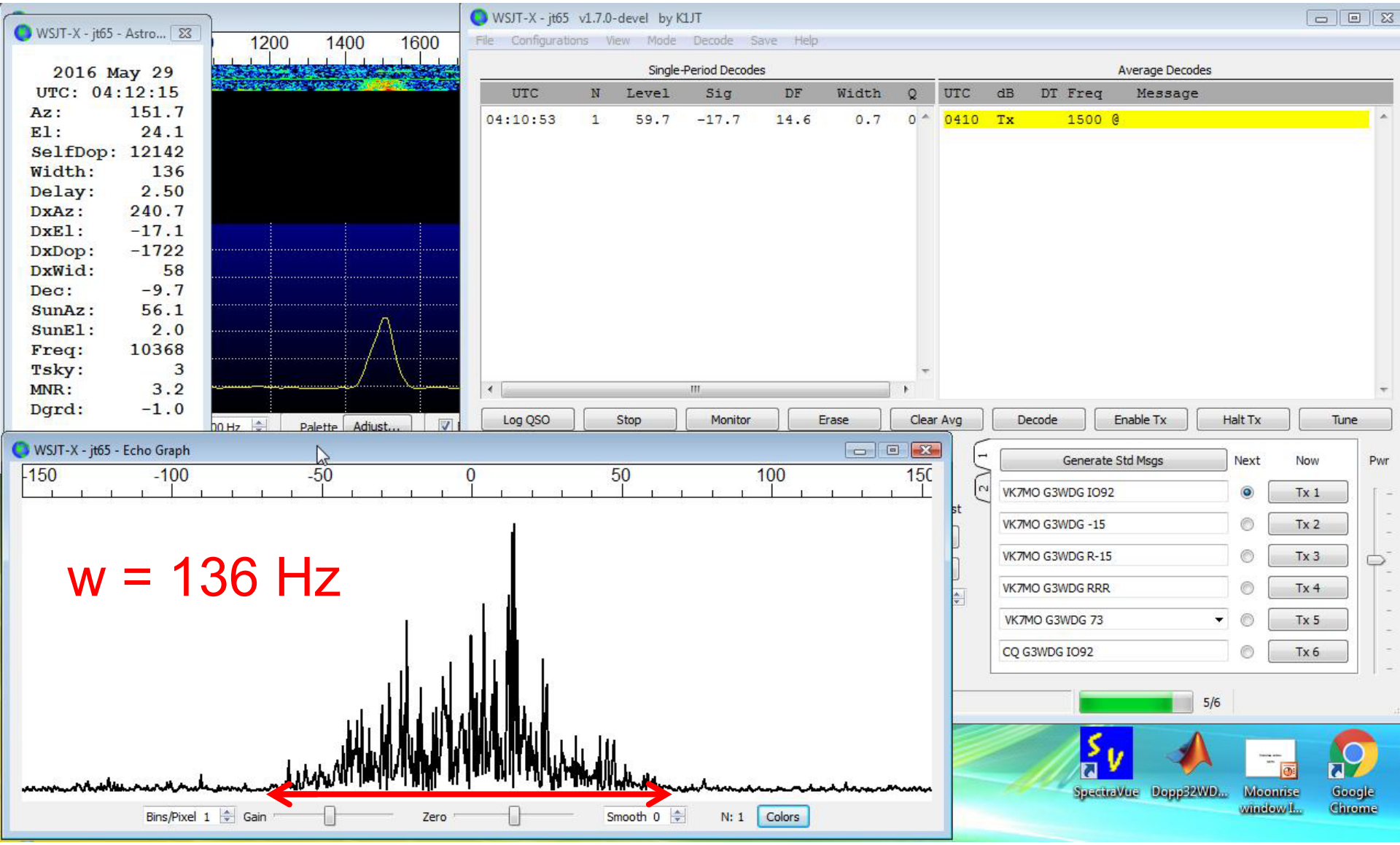


Doppler corrected; predicted spread 2.6 Hz

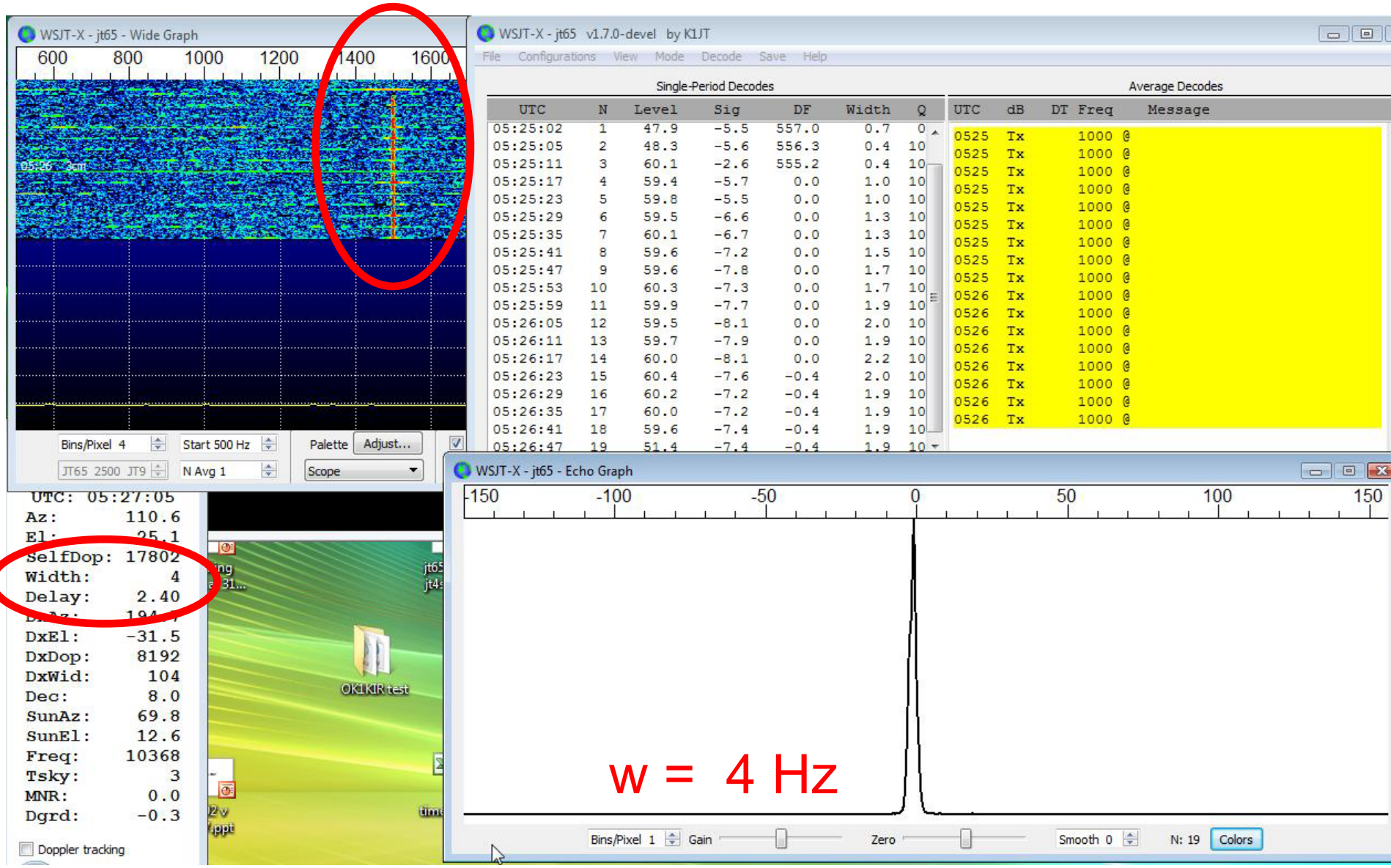
Echo Mode: G3WDG, 10 GHz



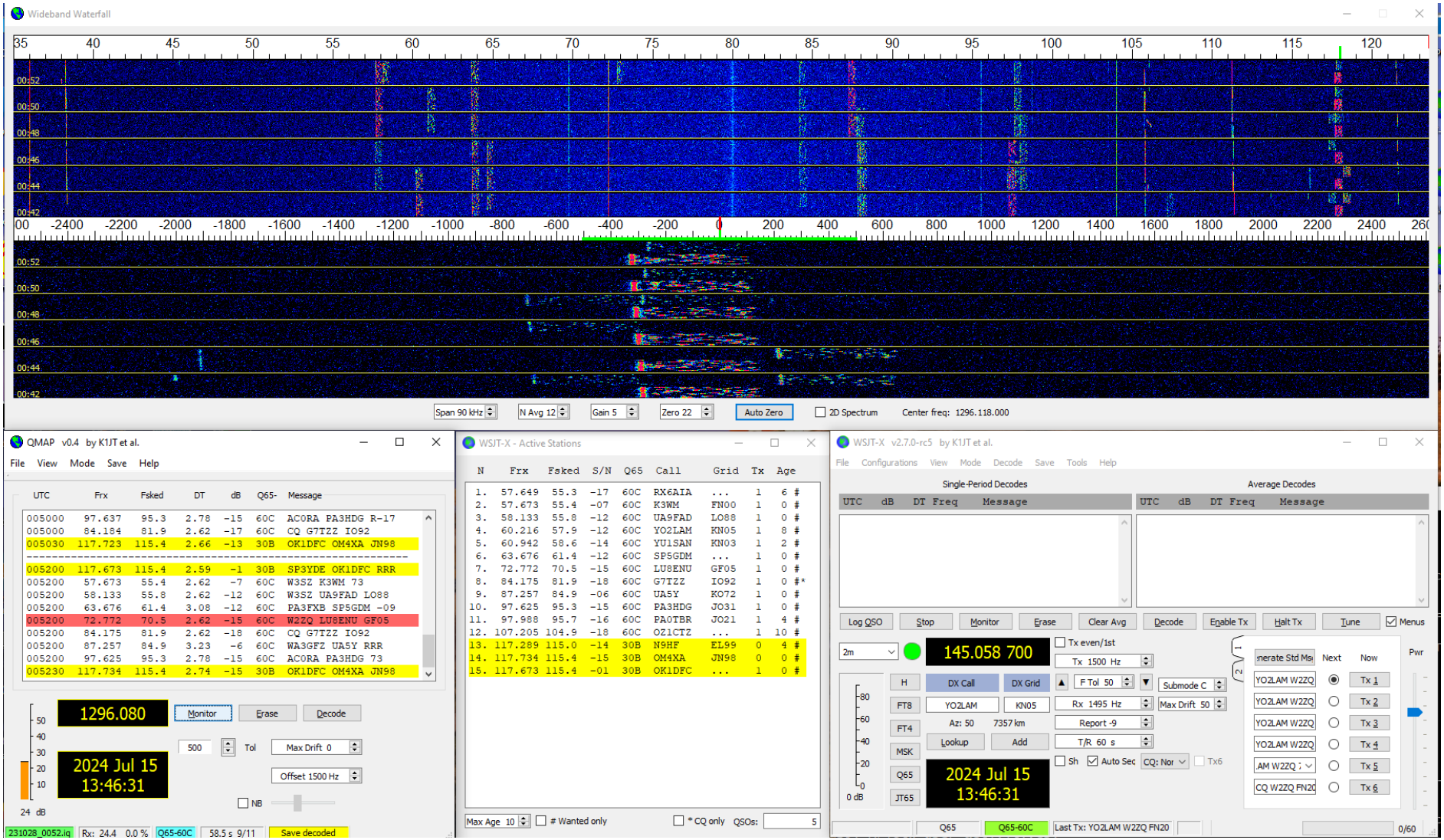
Single-pulse Echo, 10 GHz



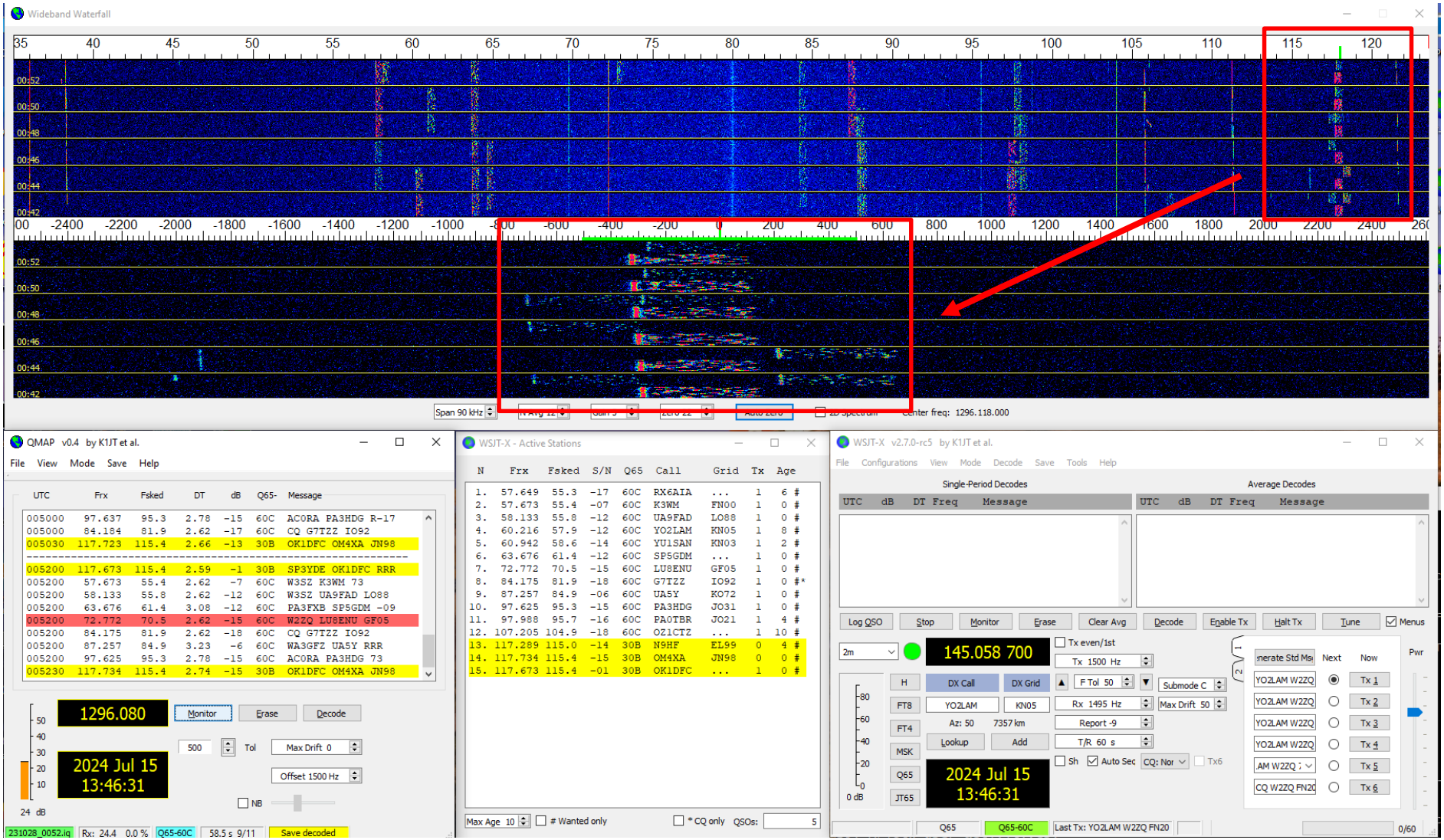
10 GHz echo at libration minimum



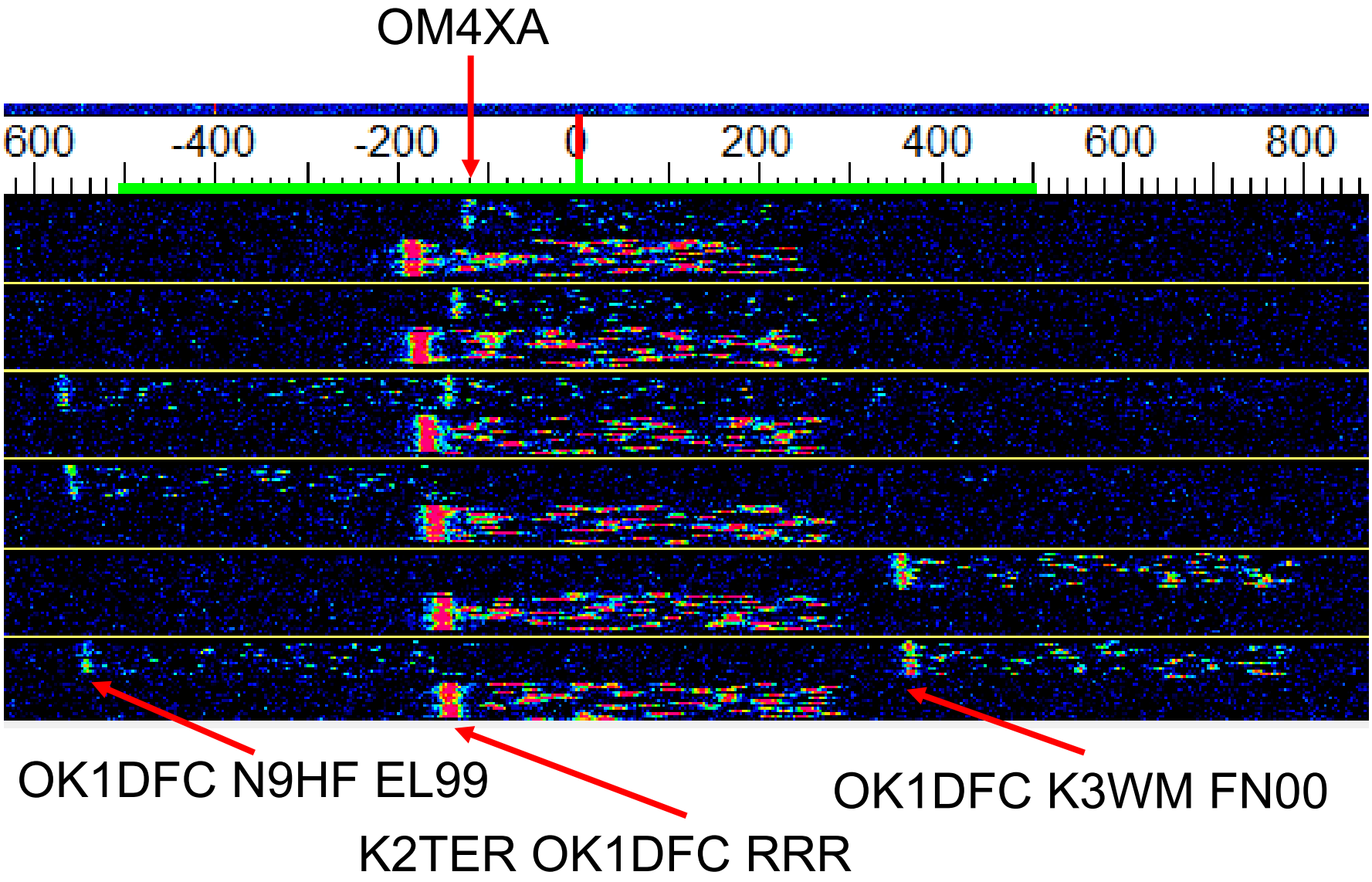
QMAP: Wideband Decoding



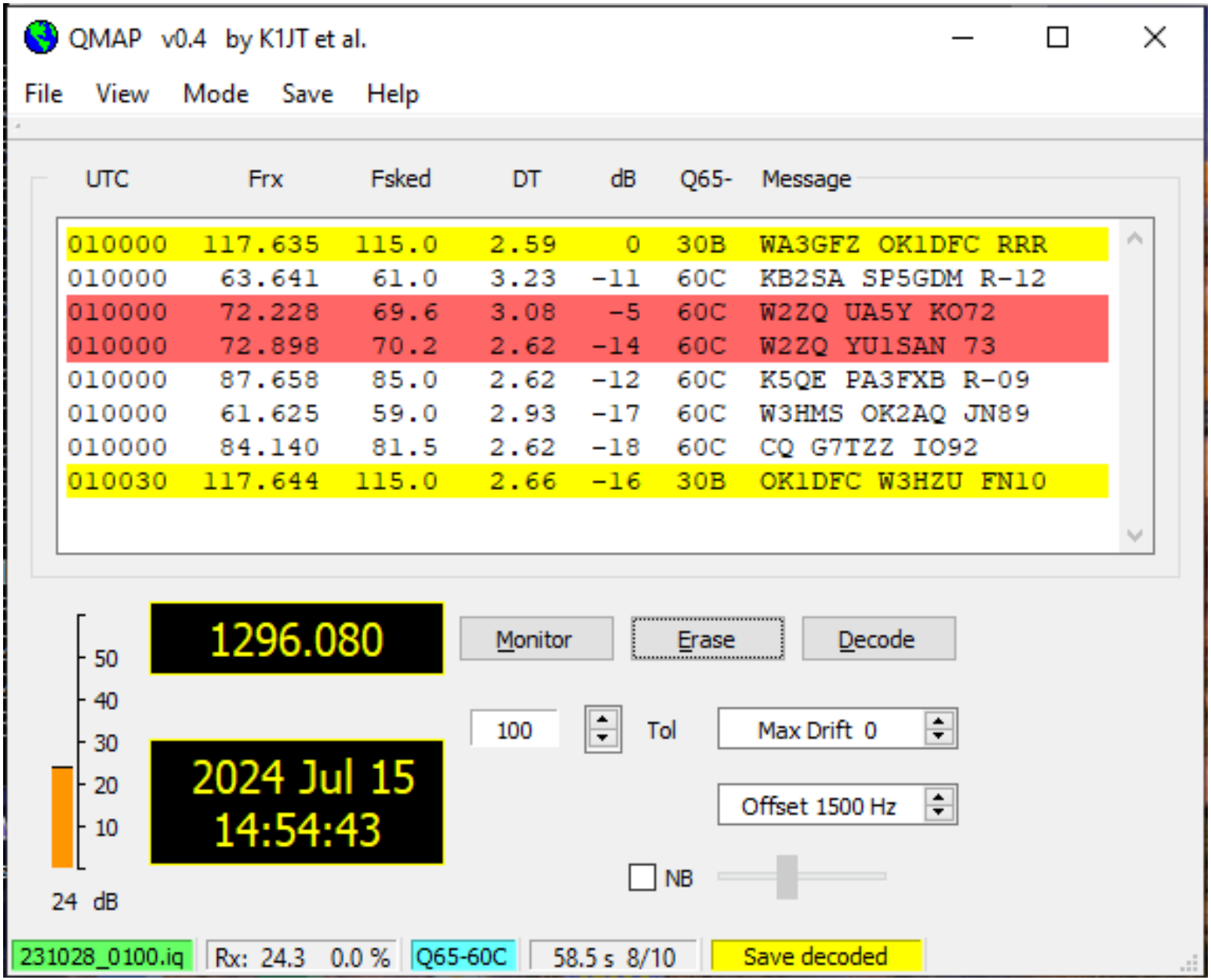
QMAP: Wideband Decoding



QMAP: High-resolution Waterfall

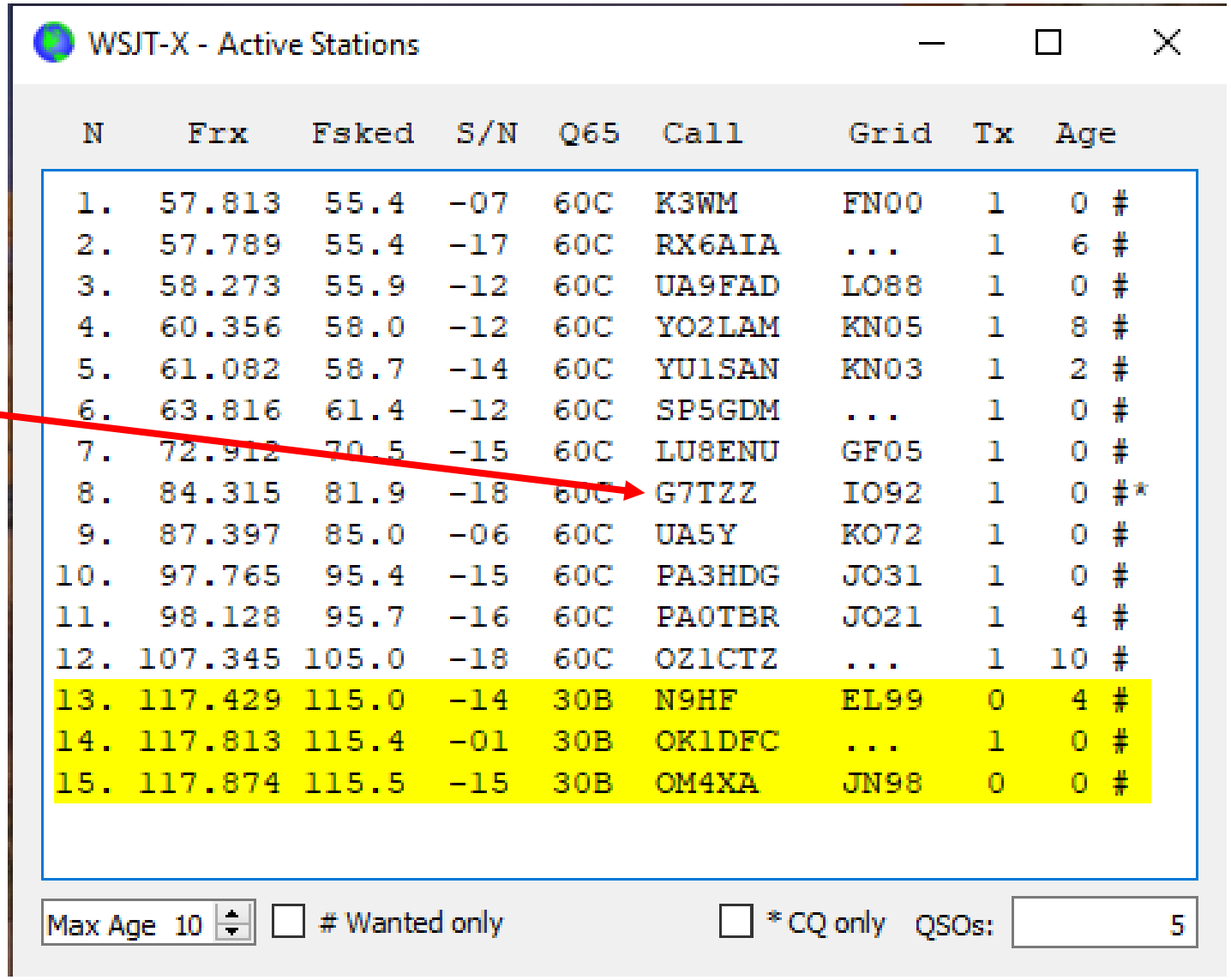


QMAP main window



WSJT-X: Active Stations

Click to work a station



EME Digi-modes

- 50 MHz: Q65-60A
- 144 MHz: Q65-60B, JT65B
- 222, 432 MHz: Q65-60B
- 1296 MHz: Q65-60C Q65-30B
- 2.3+ GHz (depends on Doppler spread)
  Q65-60C, -60D, -60E

Programming Details

- User interface: C++ and Qt
- Number crunching: Fortran
- Core developers: K1JT, G3WJS (SK), K9AN, IV3NWV, DG2YCB, N9ADG, G3WDG
- Open source: GPLv3 license
- Version control with git:

```
$ git clone https://git.code.sf.net/p/wsjt/wsjtx
```