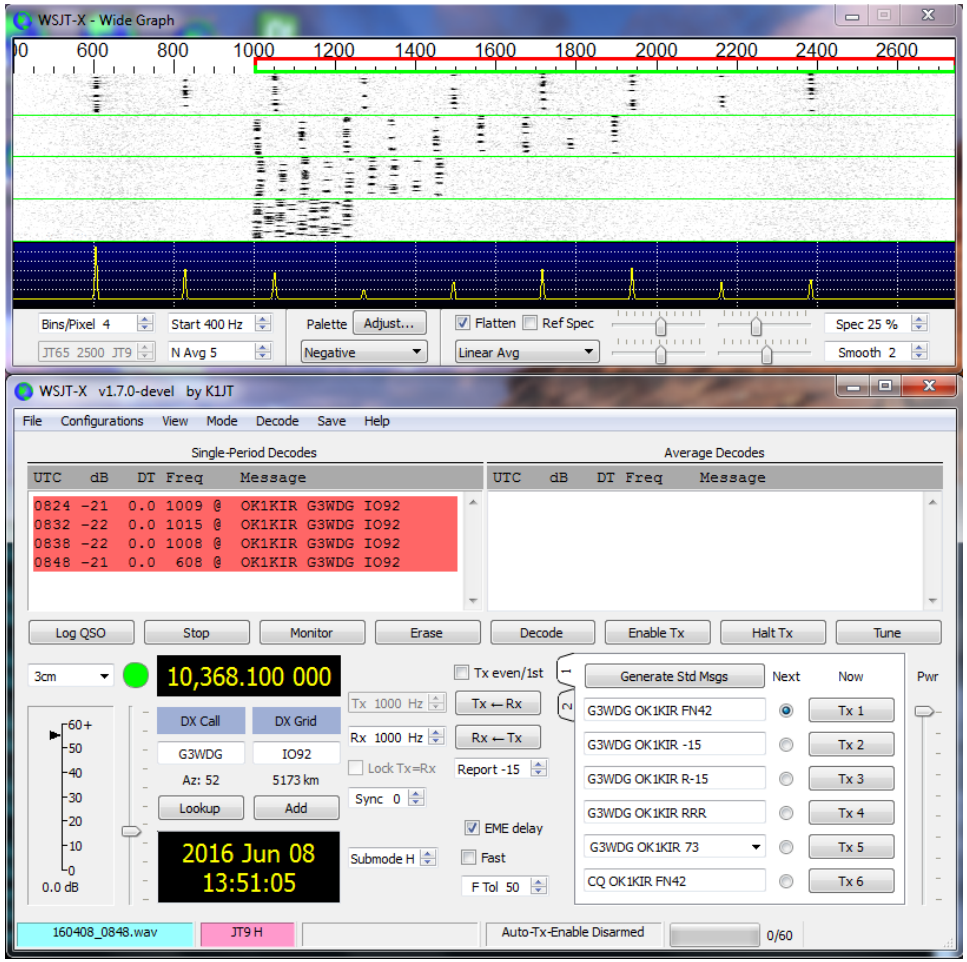
WSJT-X

New Codes, Modes and Tools for Weak-Signal Communication



Joe Taylor
K1JT

EME Conference
Venice
Aug 21, 2016

"JT" Weak-Signal Software

- ***WSJT*** – 2001 – VHF-and-up (meteor scatter, EME, ionoscatter, etc…)
- ***MAP65*** – 2006 – Wideband EME (multi-decode, adaptive polarization)
- ***WSPR*** – 2008 – Quasi-beacon mode (QRP propagation probe)
- ***WSJT-X*** – 2012 – All bands, many modes
  New VHF/UHF/SHF features
  > 4000 users, world-wide

Codes ? Modes ??

- "Code" – symbols to represent information
  - Character-by-character: Morse (CW), baudot, ASCII, FSK441, …
  - Block structured: Reed-Solomon, Convolutional, Turbo, LDPC, QRA, …

- "Mode" – signaling method and protocol: coding, modulation, symbol rate, block size, …
  - SSB, CW, FSK441, JT65, JT4, JT9, JTMSK, …

Block-Structured Messages
Standard minimal QSO

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC –22

K1ABC W9XYZ R–19

W9XYZ K1ABC RRR

K1ABC W9XYZ 73

Minimal QSO with EME “shorthands”

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC FN42 OOO

RO

RRR

73

Relevant VHF+ Propagation Types

Fading rate, depth ↓

- Tropospheric scatter
- Multi-hop (weak) sporadic-E
- EME (VHF, UHF, microwave …)

} slow shallow

- Ionospheric scatter
- Aircraft scatter
- Meteor scatter

} fast deep

Modes in *WSJT-X*

Scatter ➔ "Fast"

- **ISCAT**
- **JT9 E-H**
- **(JTMSK)**
- **MSK144**

EME, QRP ➔ "Slow"

- **JT65**
- **JT4**
- **JT9**
- **QRA64**
- **WSPR**

Echo

Why so many modes?

- Different propagation types
- Code design and parameter optimization for each purpose
  - Fading depth
  - Fading rate (Doppler spread)
  - Frequency stability, sync requirements
- Also important: learning as we go …

Mode design: Tunable parameters

- Block message structure
- Compression ➔ Source encoding
- Error control coding type and rate
- Information transmission rate
- Modulation type
- Symbol rate ➔ Bandwidth
- Synchronization method

Structured Messages: Design choice for ECC Modes

Information block size: 72 bits

Calls and locator:

KA1ABC WB9XYZ EN37

28 + 28 + 15 + 1 = 72

Free text:

TNX BOB 73 GL

71 + 1 = 72

Selected Mode Parameters

Mode	Block Code (k,n)	Q	Modulation	Symbol Rate (Hz)	Sync Fraction	Message Length (s)
JT4	206,72	2	4-FSK	4.375	0.50	47.1
JT9	206,72	8	9-FSK	1.736	0.19	49.0
JT65	63,12	64	65-FSK	2.692	0.50	46.8
QRA64	63,12	64	64-FSK	1.736	0.25	48.4
JT9H fast	206,72	8	9-FSK	200	0.19	0.425
JTMSK	198,72	2	MSK	2000	0.15	0.117
JTMSK sh	24,12	2	MSK	2000	0.31	0.018
MSK144	128,72	2	MSK	2000	0.11	0.072
MSK144 sh	32,16	2	MSK	2000	0.20	0.020

WSJT-X: Recent Advances

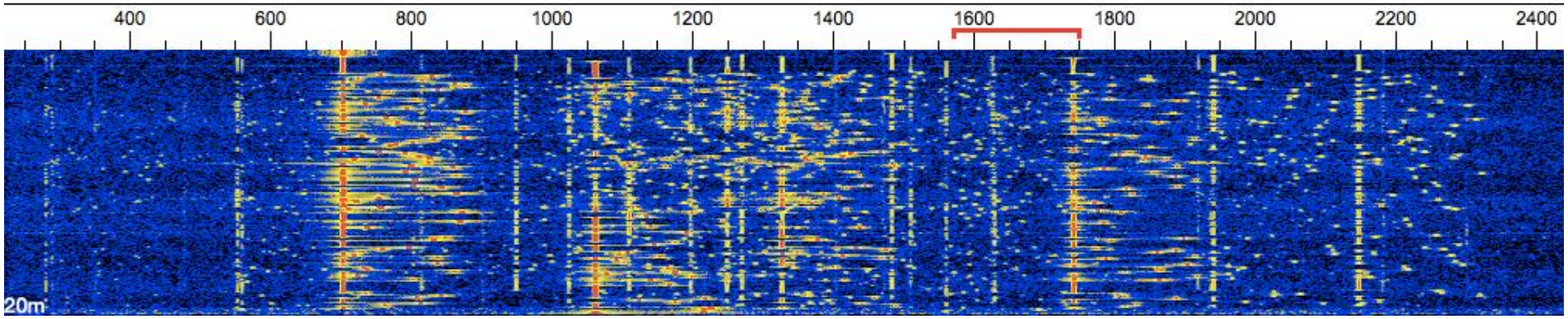
- Platform independence (Windows, Linux, OS X, …)
- Rig control for nearly all radios
- Accurate frequency calibration
- Franke-Taylor decoder for JT65
- Other decoder improvements
- Added modes: WSPR, fast/wide JT9, JT4, (JTMSK), MSK144, QRA64

Franke-Taylor Decoder for JT65

- Published in *QEX* for May-June 2016
  (link on WSJT web site)
- Soft-decision algorithm
- Performs better than Kötter-Vardy
  (patented KVASD no longer used)
- As implemented in *WSJT-X*, includes
  multi-pass decoding
- Fully open source, GPL v3 license

Franke-Taylor Decoder

2 kHz



177 Hz

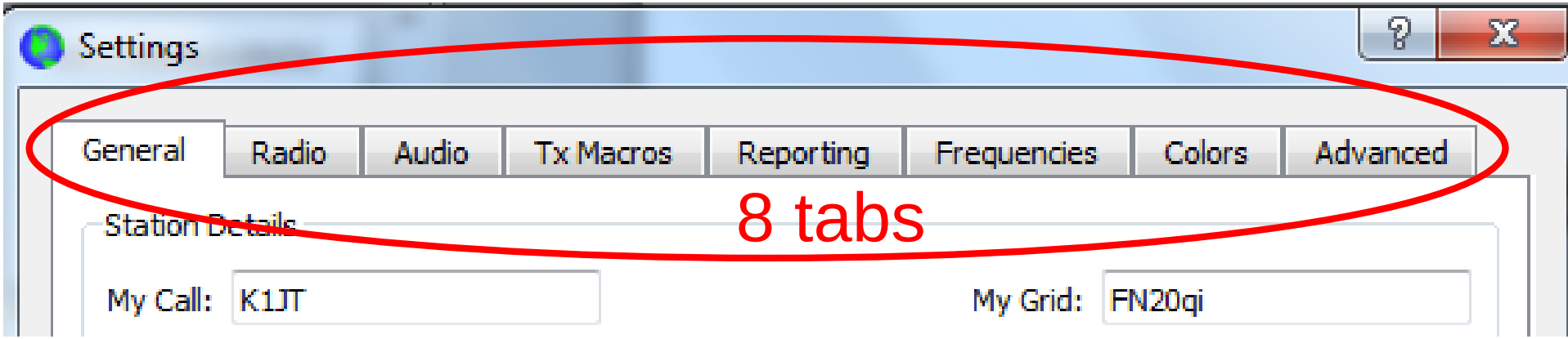
21 JT65A signals, all decoded !

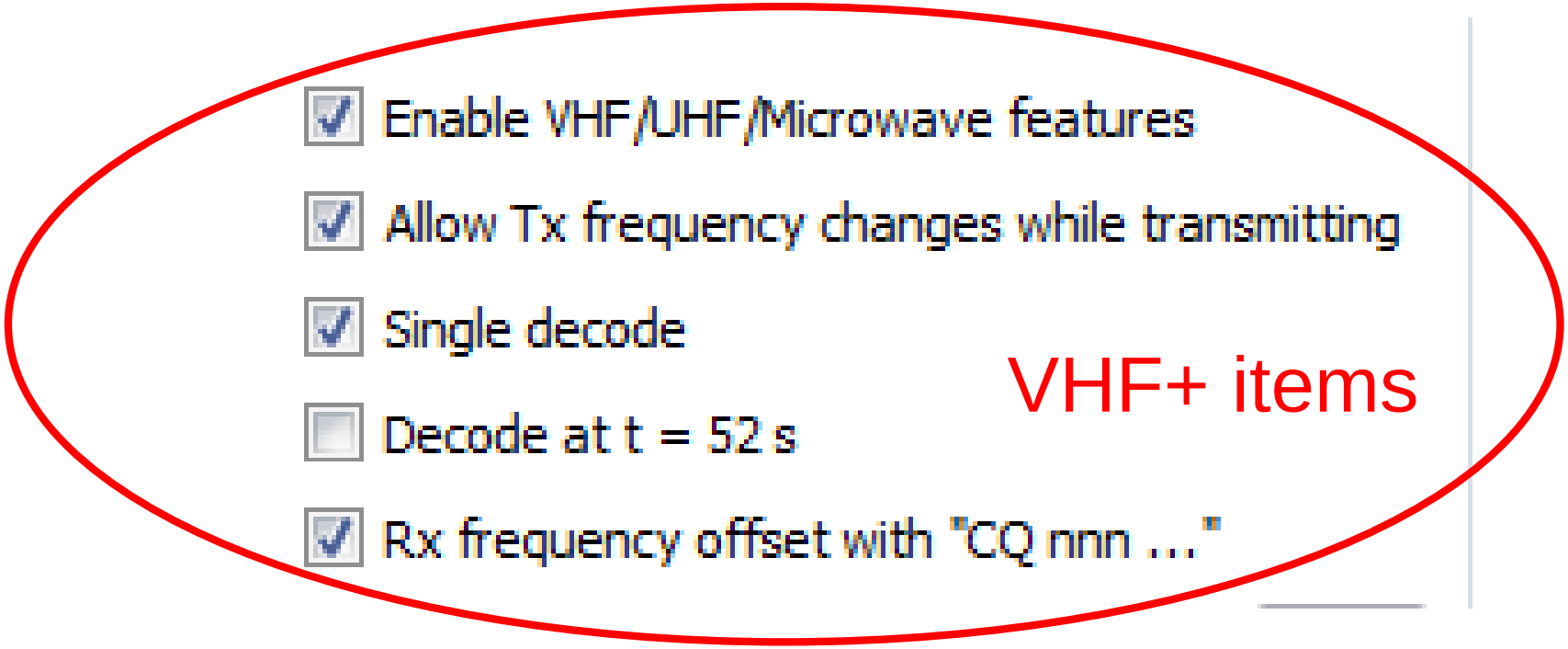
New VHF+ Features in *WSJT-X*

- Transverter offsets
- Automatic EME Doppler tracking
- JPL/NASA planetary ephemeris
  (Moon position and Doppler tracking)
- Enhanced Echo mode
- MSK144, QRA64 modes
- Auto-sequencing for fast modes

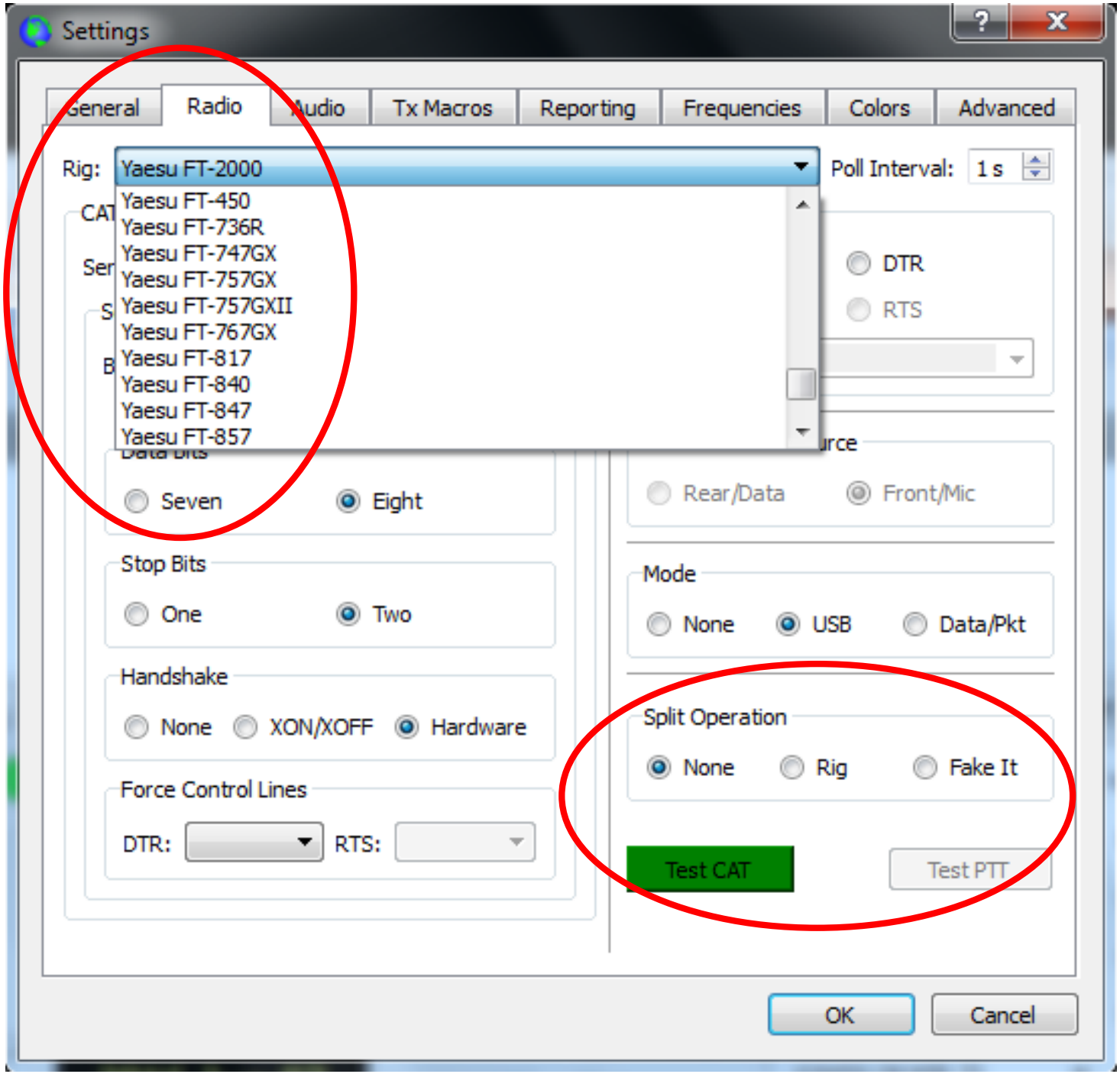
… Brief guided tour, mostly EME …

WSJT-X Configuration

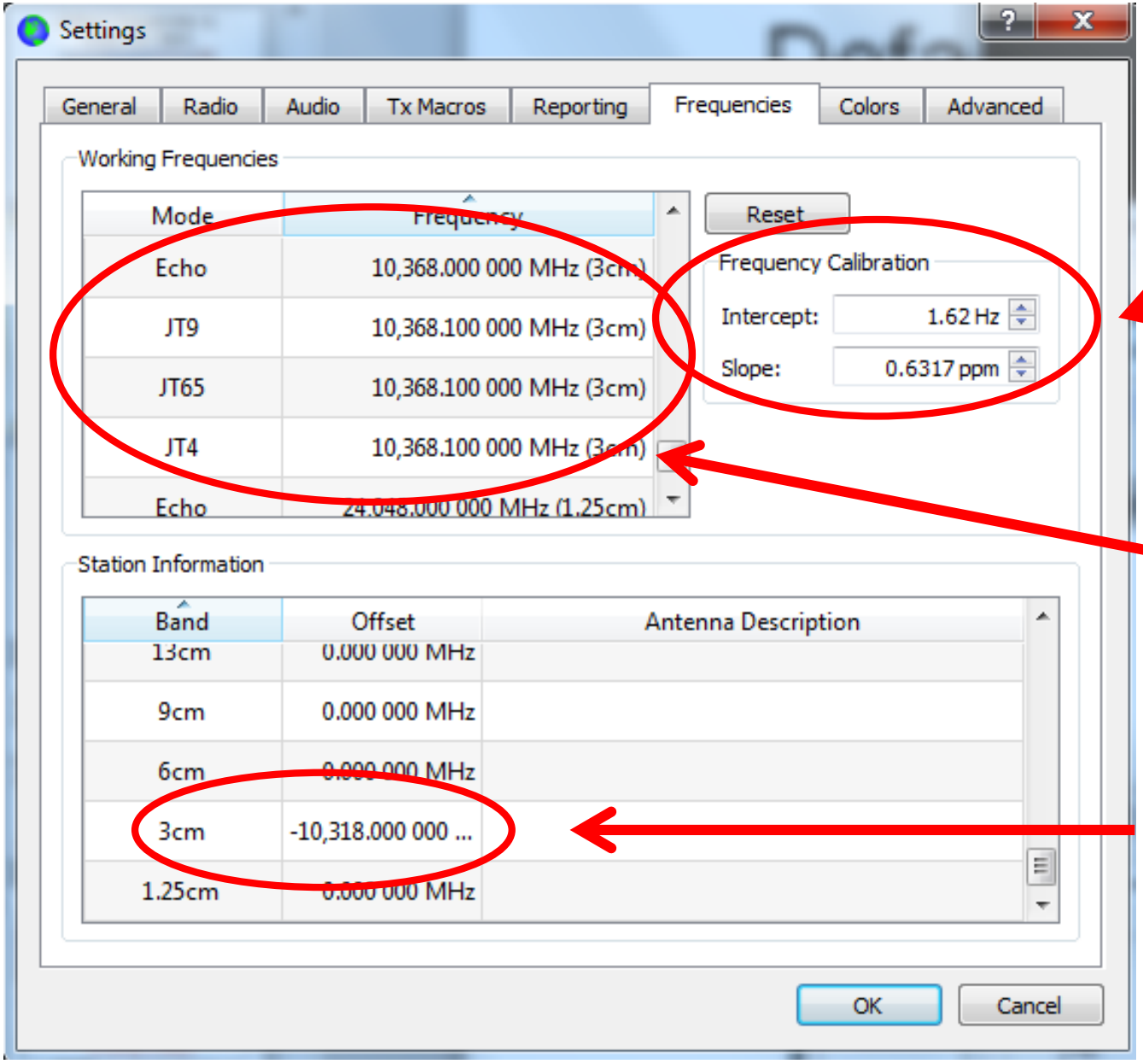




Rig Control


Settings
General
Radio
Audio
Tx Macros
Reporting
Frequencies
Colors
Advanced
Rig:
Yaesu FT-2000
Poll Interval:
1 s
Yaesu FT-450
Yaesu FT-736R
Yaesu FT-747GX
Yaesu FT-757GX
Yaesu FT-757GXII
Yaesu FT-767GX
Yaesu FT-817
Yaesu FT-840
Yaesu FT-847
Yaesu FT-857
DTR
RTS
Seven
Eight
Stop Bits
One
Two
Handshake
None
XON/XOFF
Hardware
Force Control Lines
DTR:
RTS:
Rear/Data
Front/Mic
Mode
None
USB
Data/Pkt
Split Operation
None
Rig
Fake It
Test CAT
Test PTT
OK
Cancel

Frequency Settings

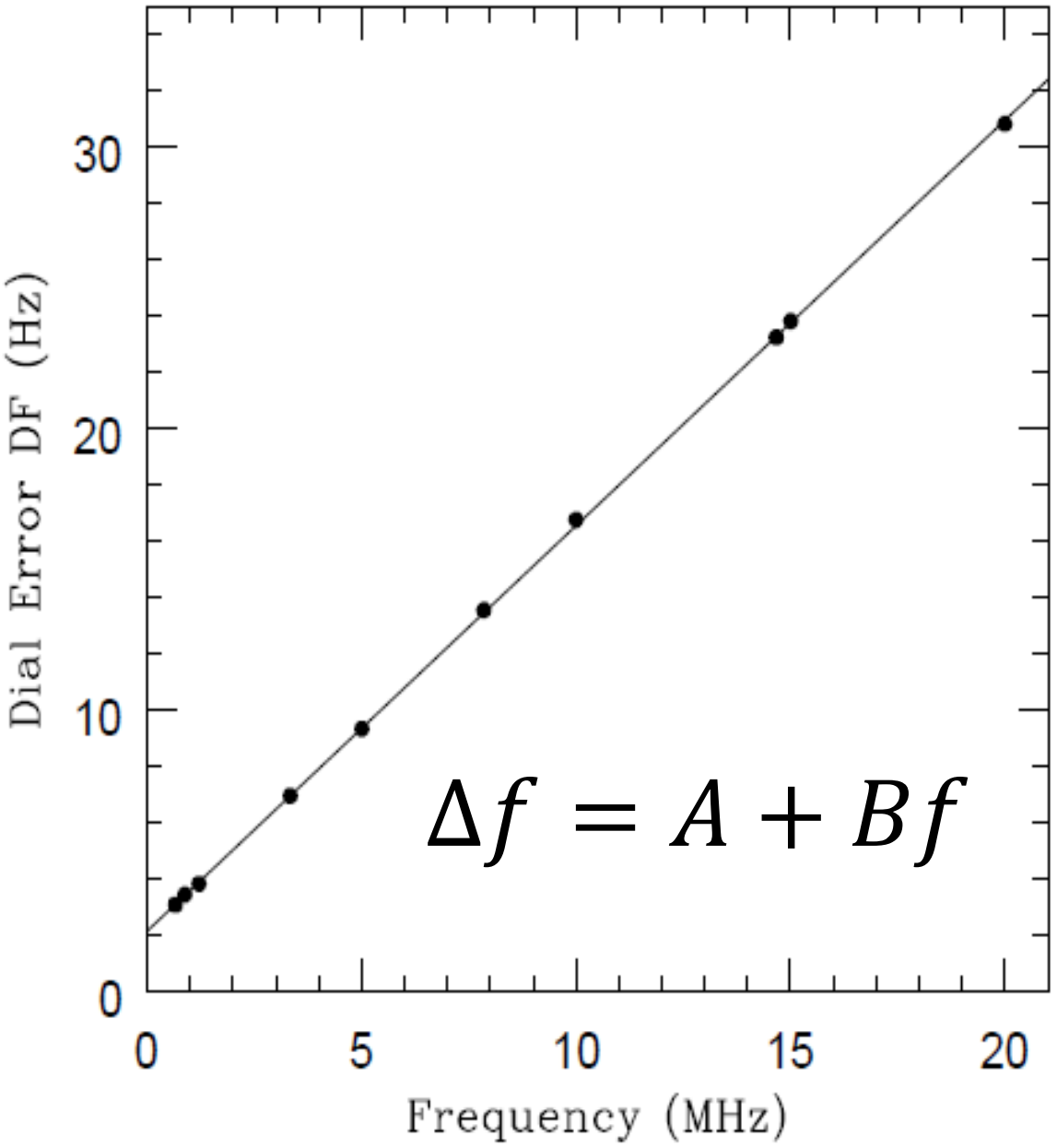


Calibration parameters

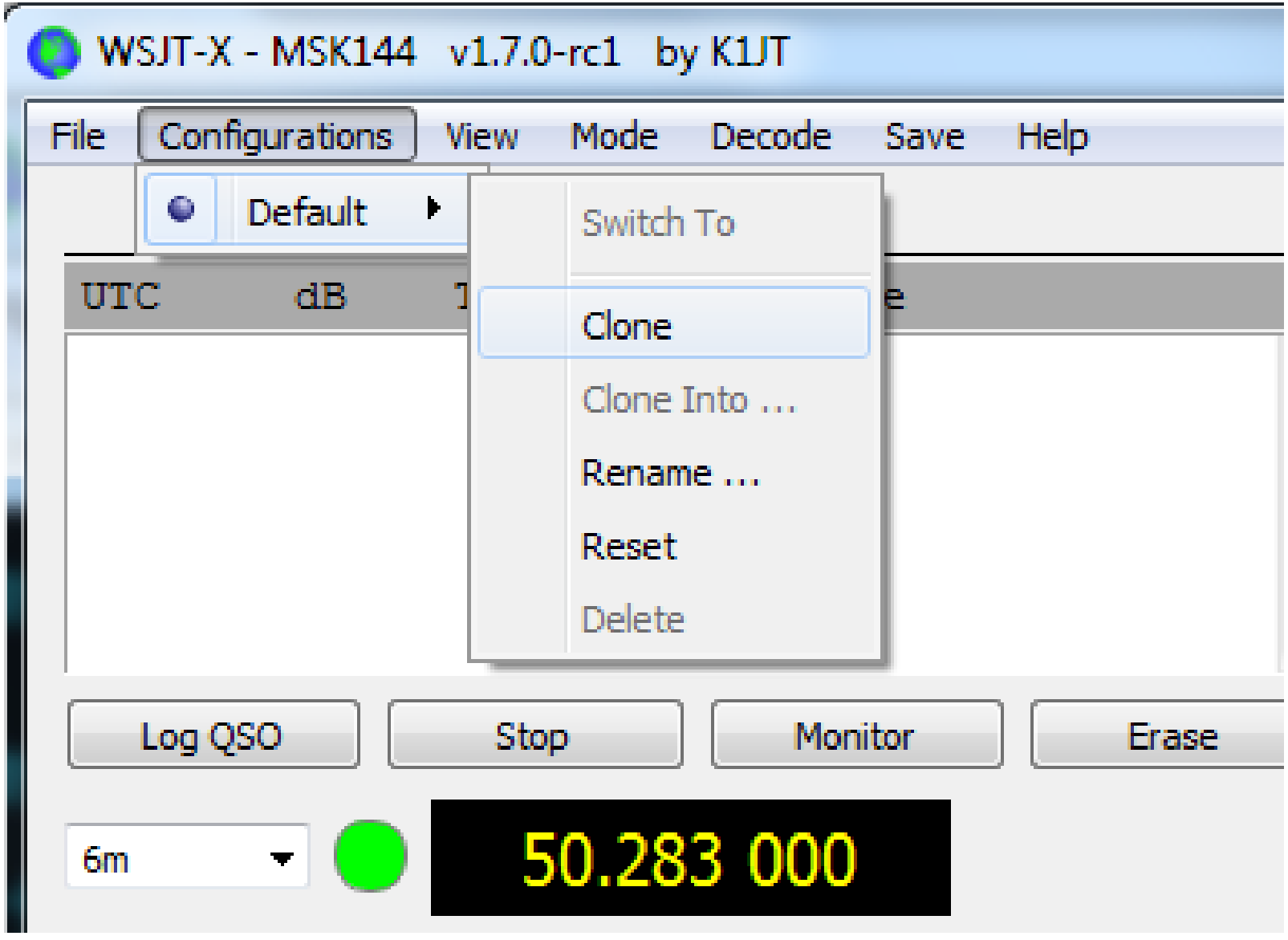
Frequencies by Mode & Band

Transverter offsets

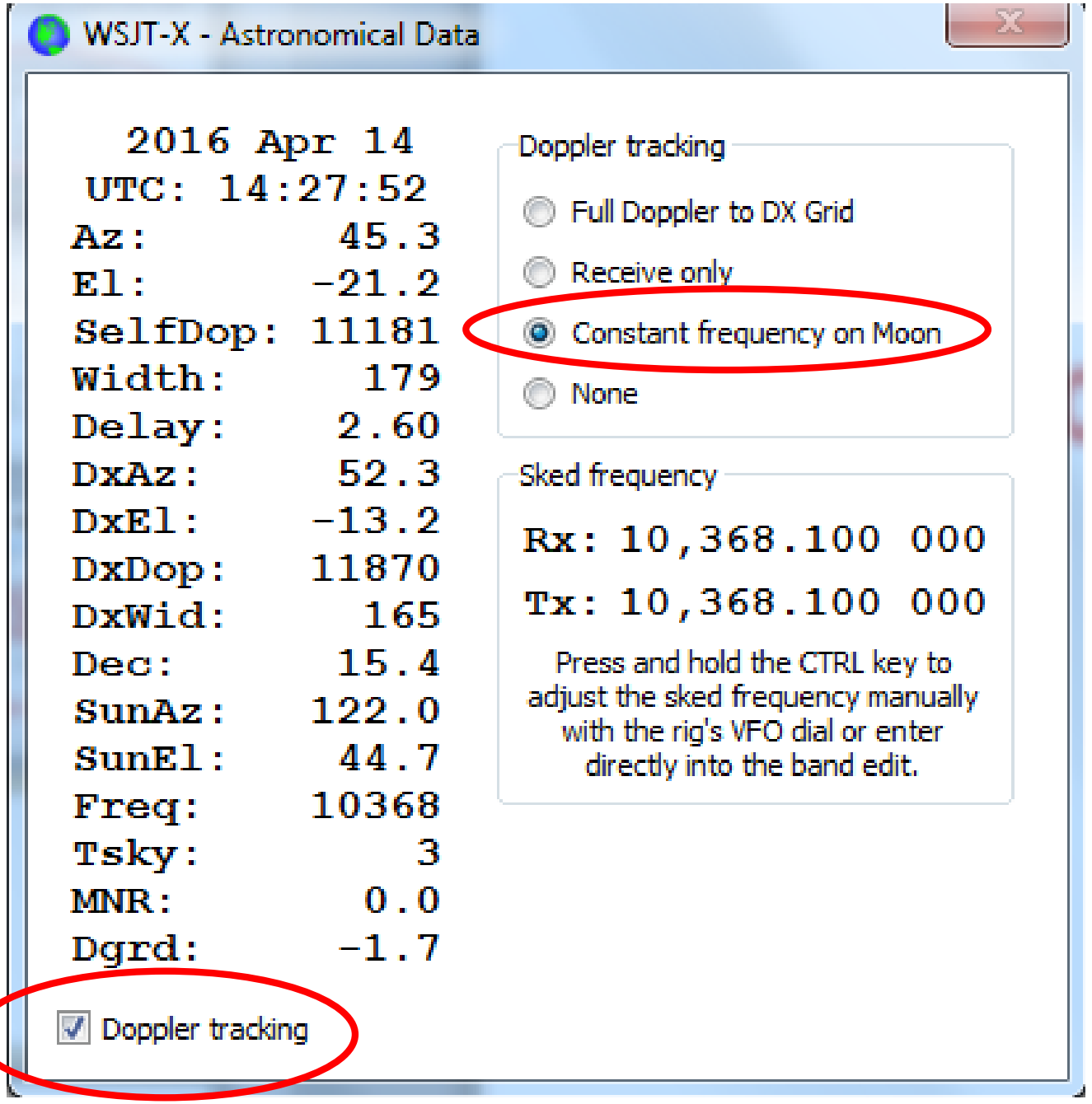
TS-2000X Frequency Calibration



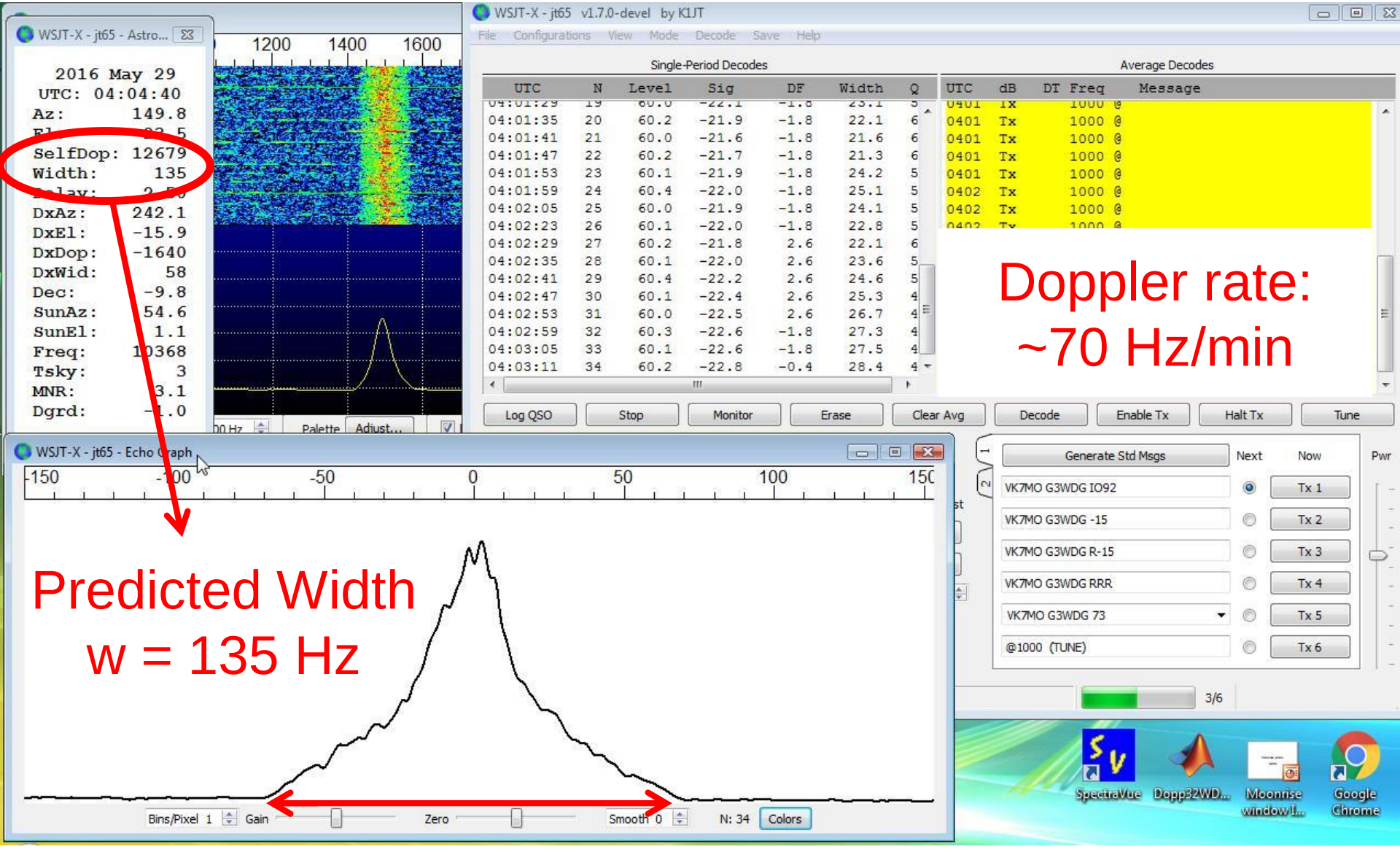
Save/Restore Configurations



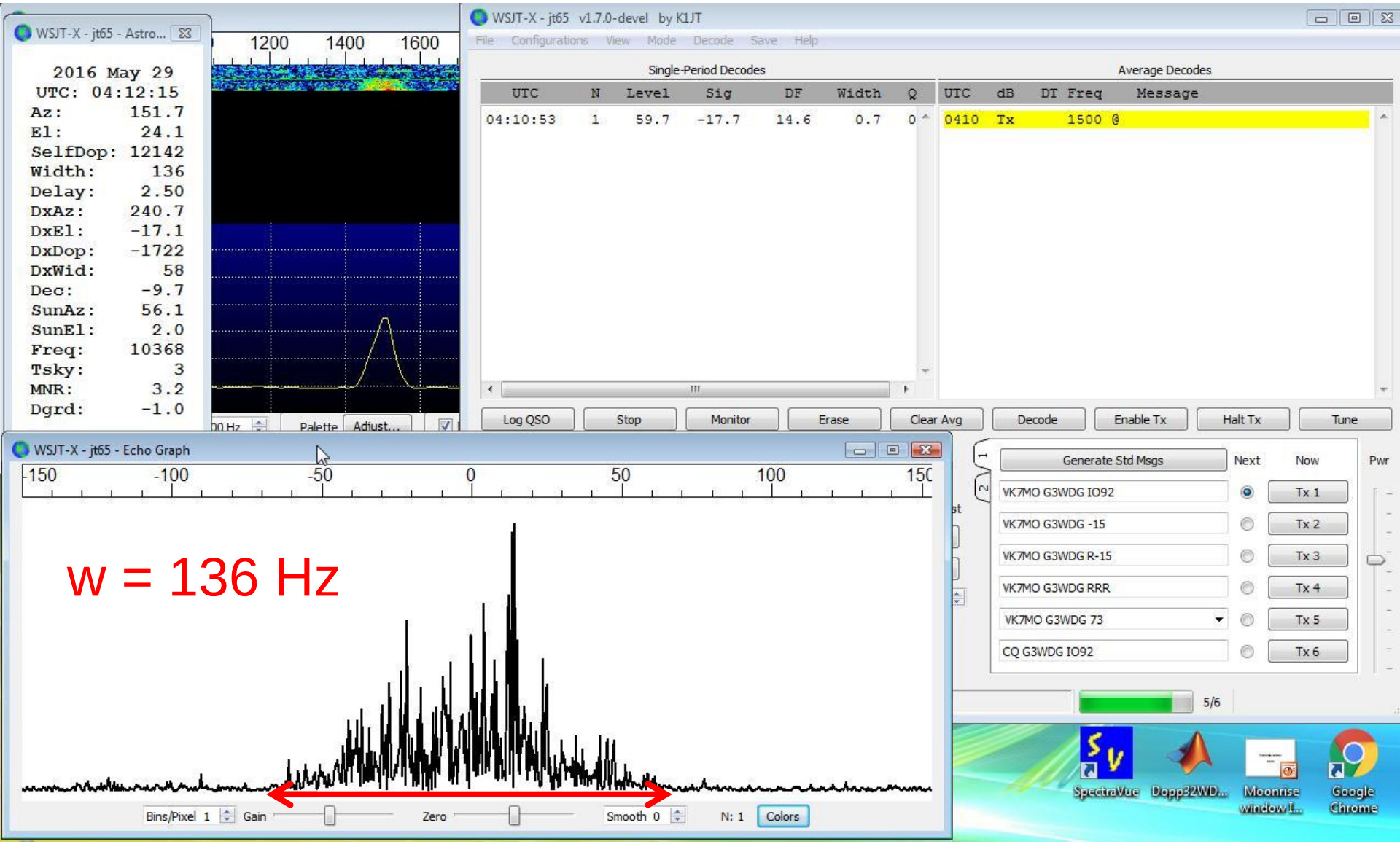
Automatic Doppler tracking



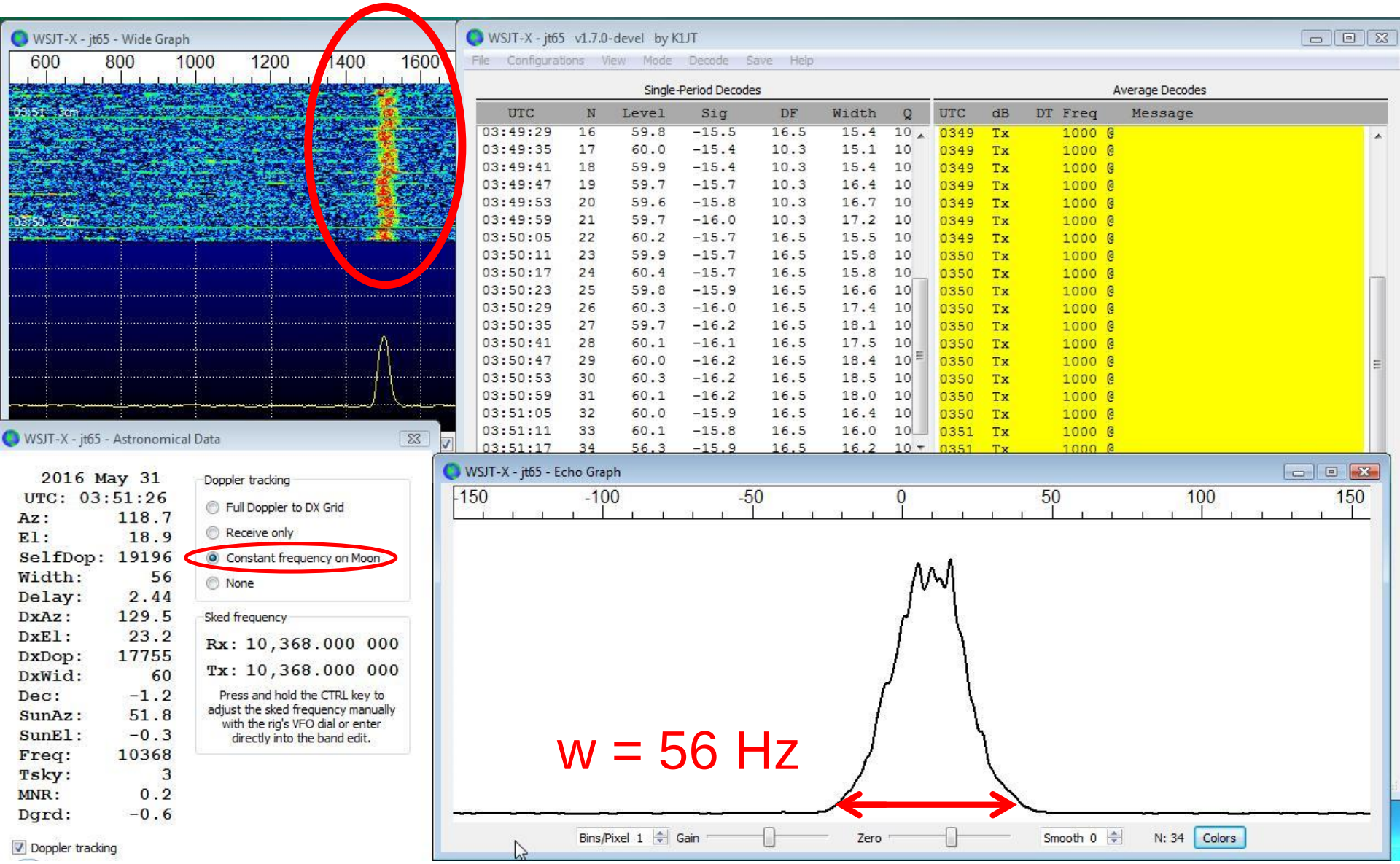
Echo Mode: G3WDG, 10 GHz



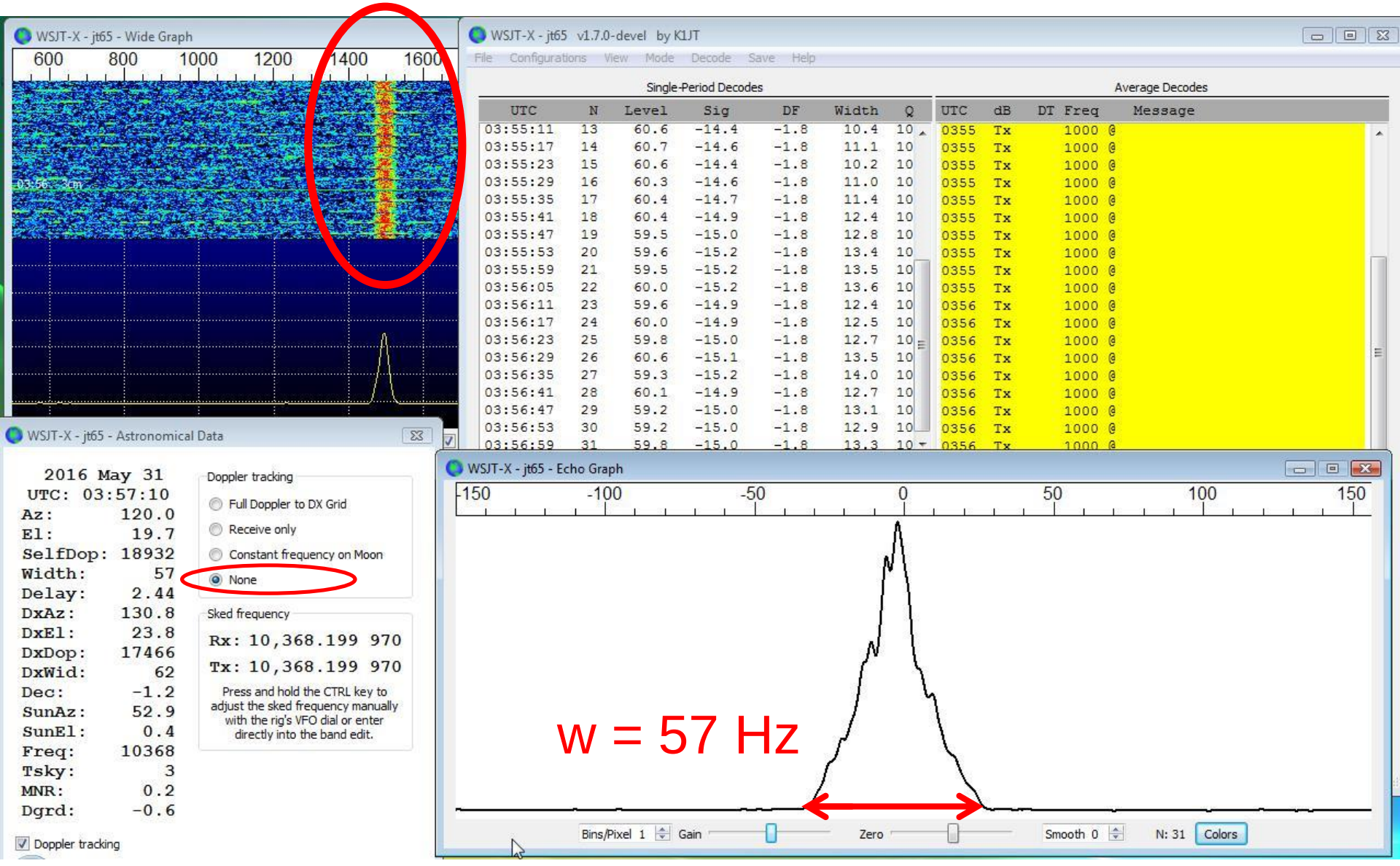
Single-pulse Echo



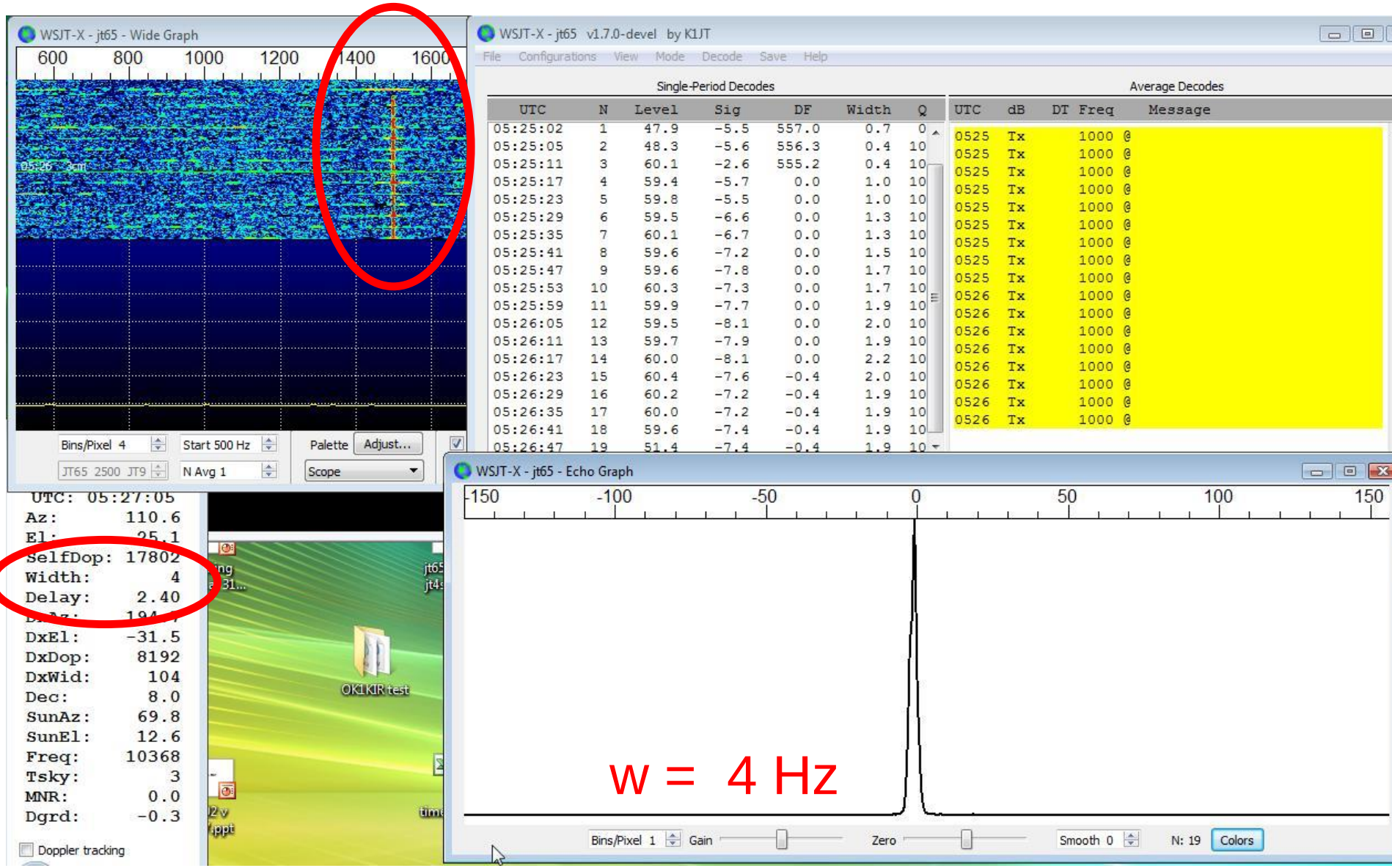
Doppler steering via Rig Control



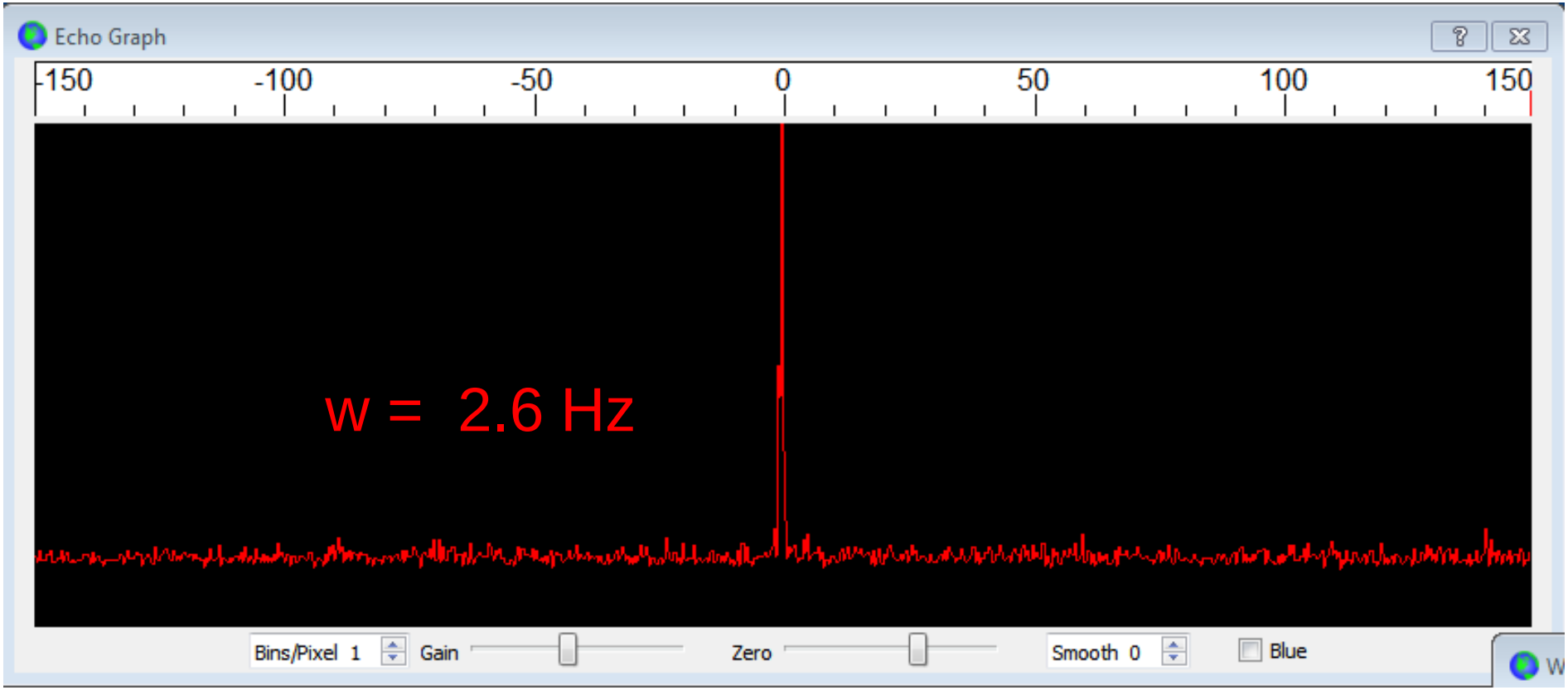
Doppler steering via transverter LO



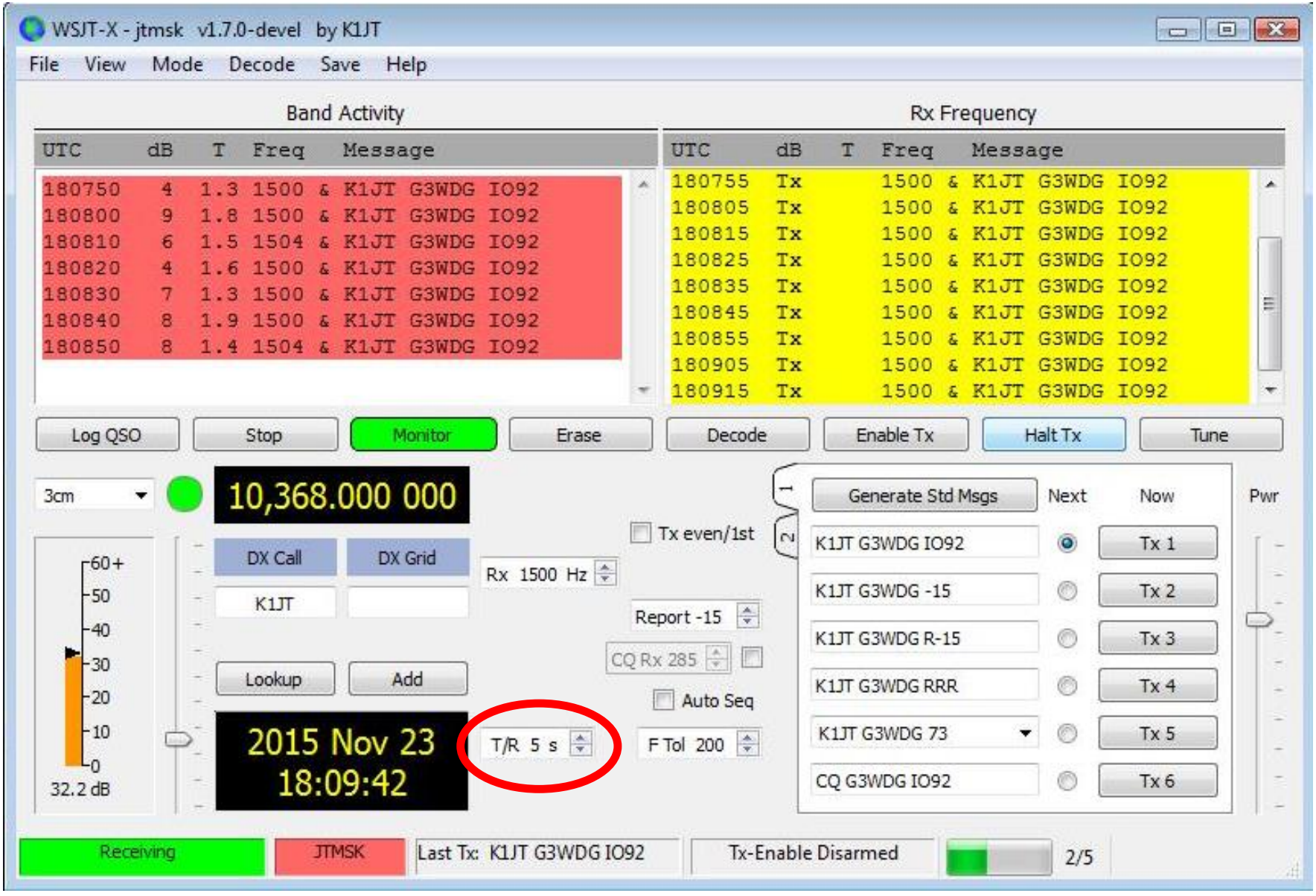
Close to libration minimum



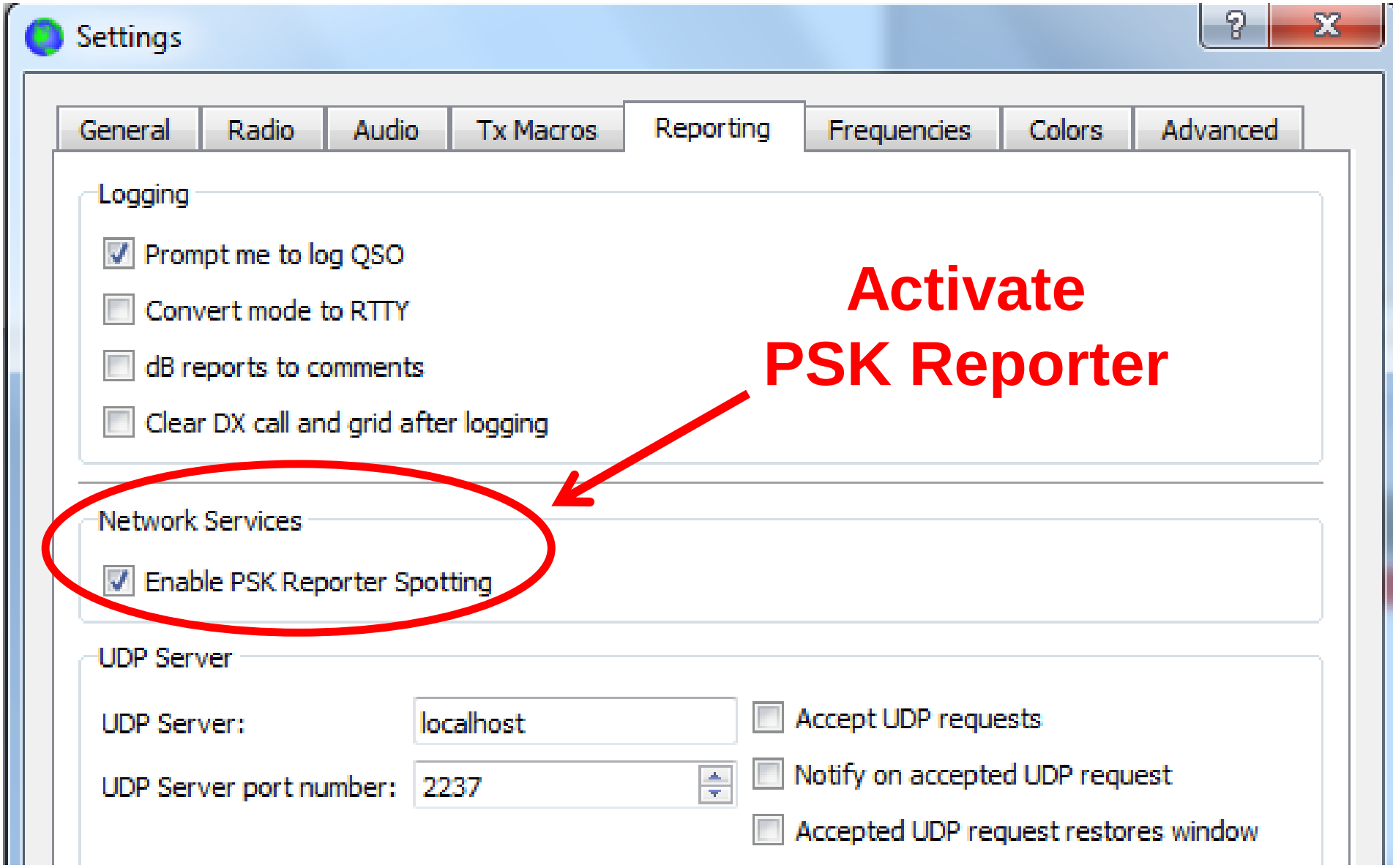
Echo Mode: K1JT, 144 MHz



Comic relief: JTMSK self-echoes



Logging, Reporting, UDP Server



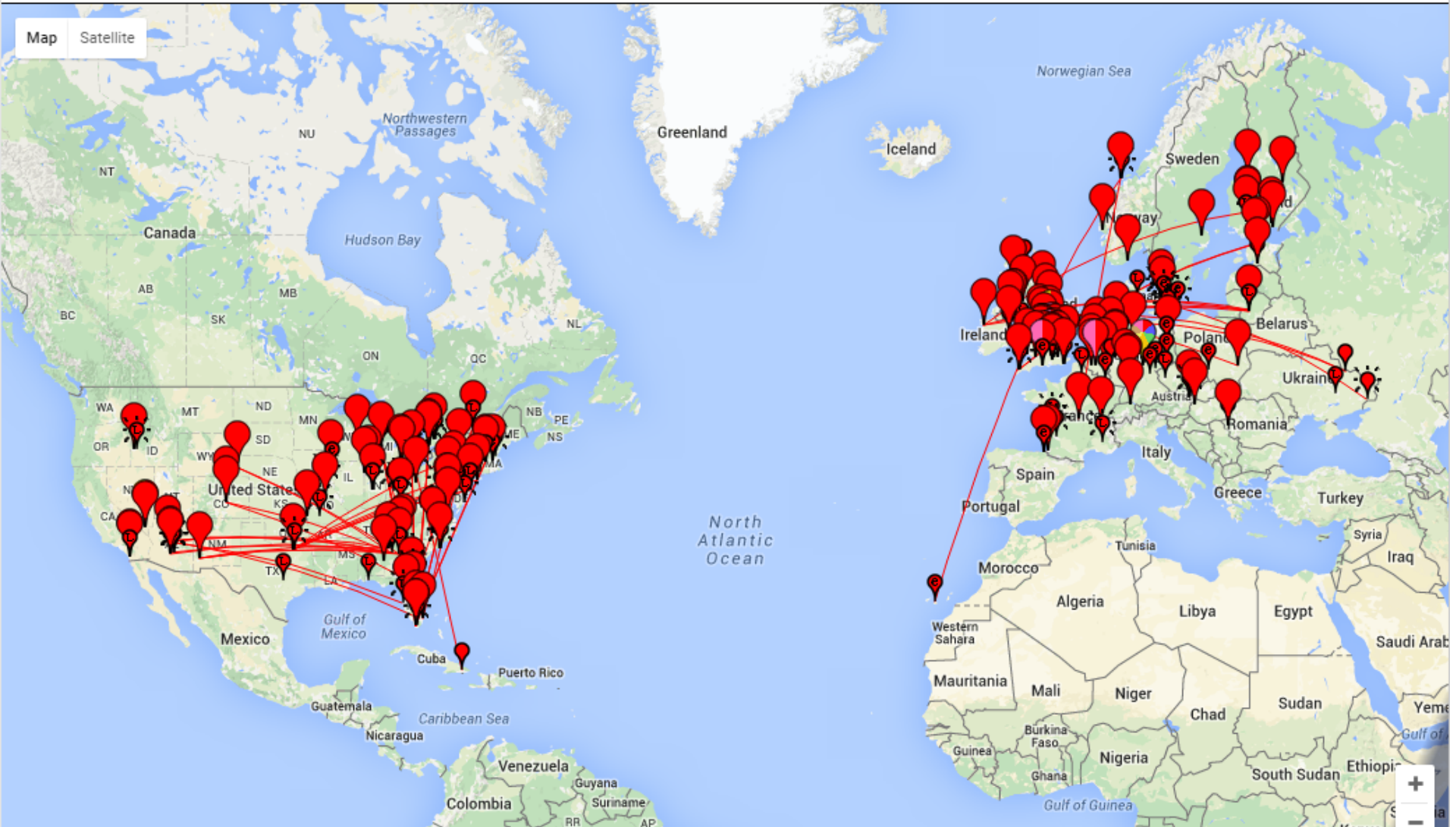
PSK Reporter: 6 m, JT modes

On 6m, show signals sent by anyone using JT over the last 1 hour Go!

Display options Permalink

Automatic refresh in 4 minutes. Large markers are monitors. Display all reports.

There are 121 active JT monitors on 6m. Show all JT on all bands. Show all on all bands. Legend



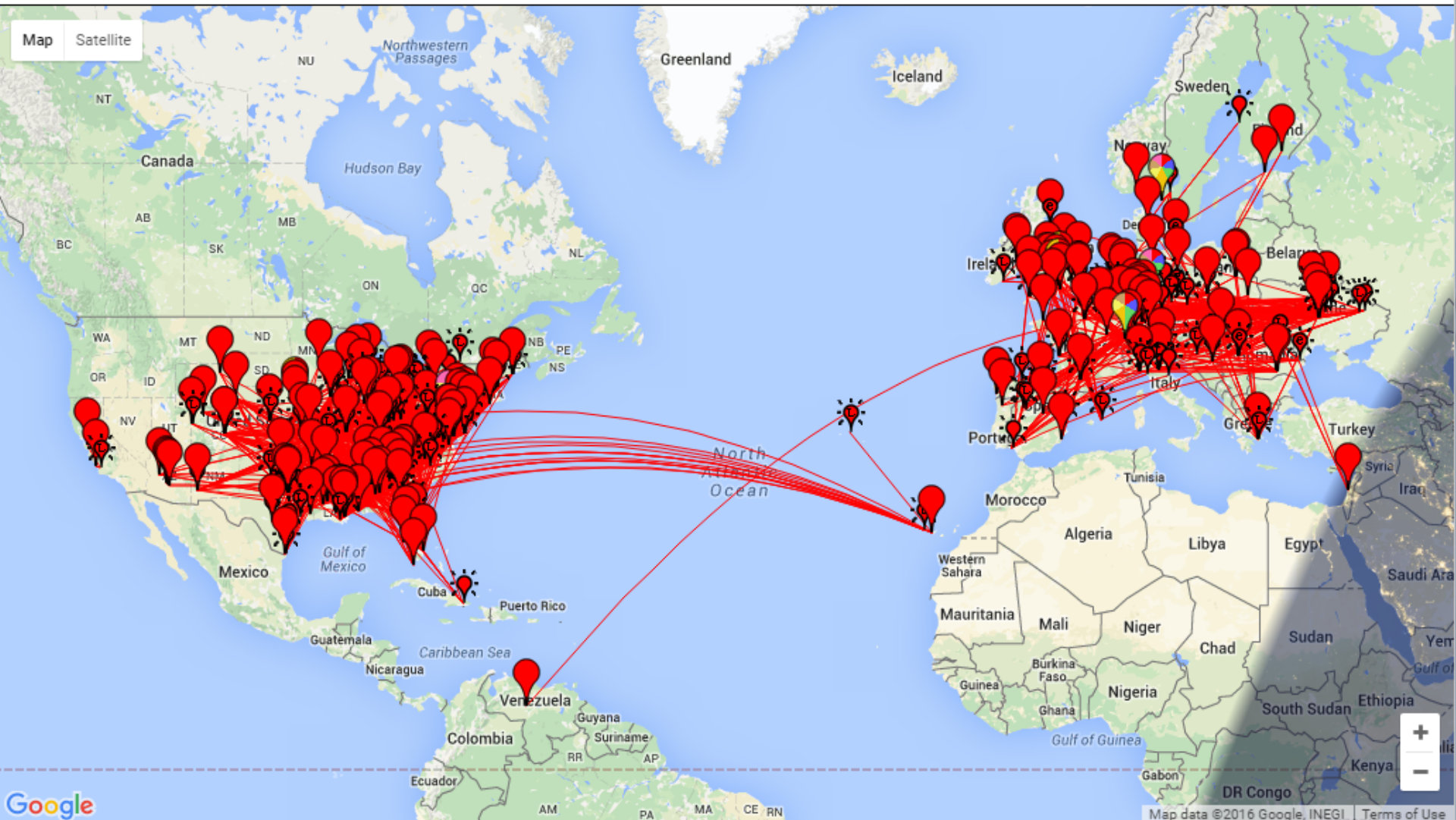
JT modes, 50 MHz

On 6m, show signals, sent by anyone, using JT, over the last 1 hour, Go!

Display options

Automatic refresh in 5 minutes. Large markers are monitors. Display all reports.

There are 202 active JT monitors on 6m. Show all JT on all bands. Show all on all bands. Legend



EME modes

- 50 MHz: **JT65A QRA64**
- 144, 222, 432 MHz: **JT65B QRA64**
- 1296 MHz: **JT65C QRA64**
- 2.3+ GHz (depends on Doppler spread)

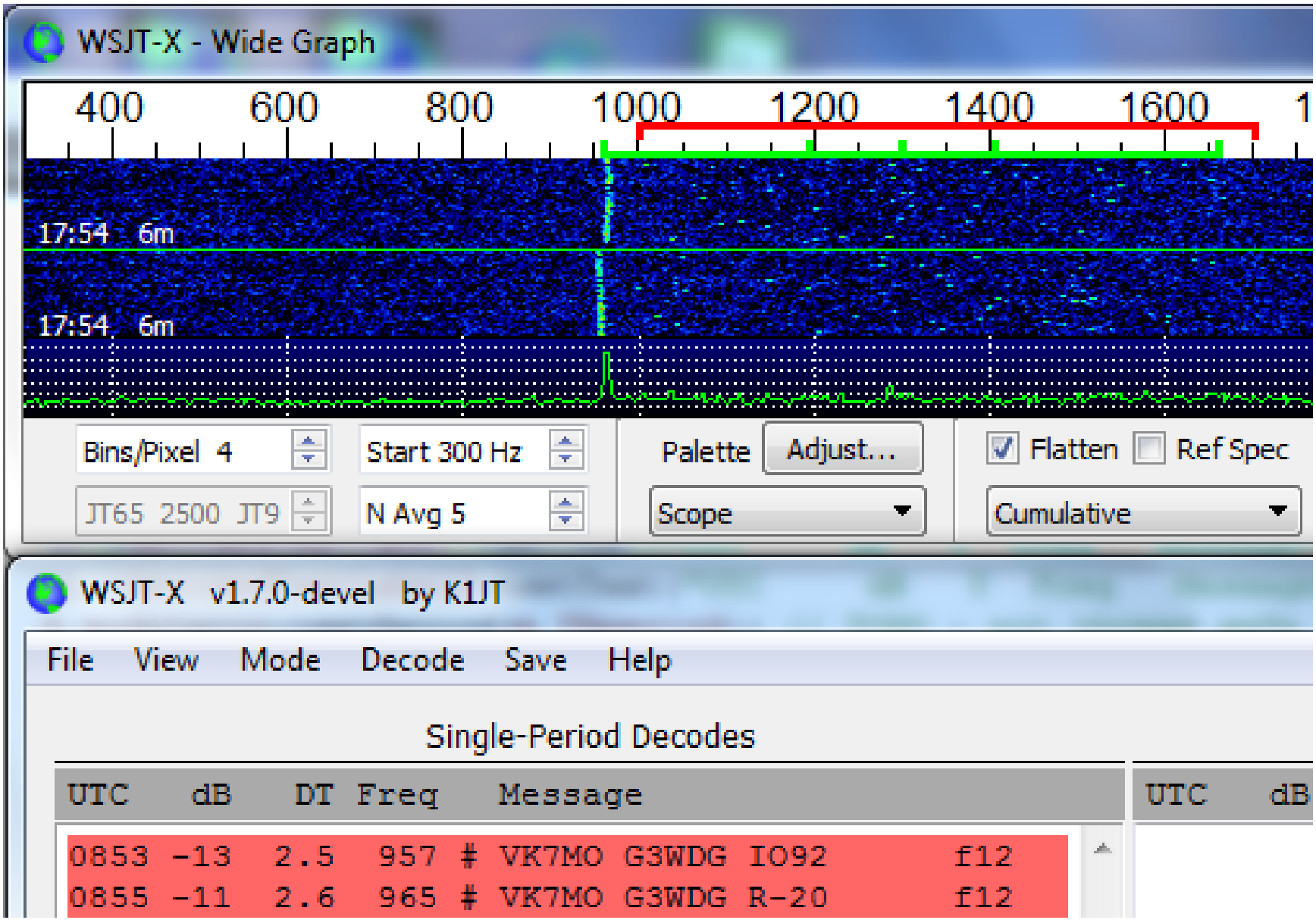
➔ **JT65C, JT4F, JT9F, QRA64**

Don't forget: In some ways,

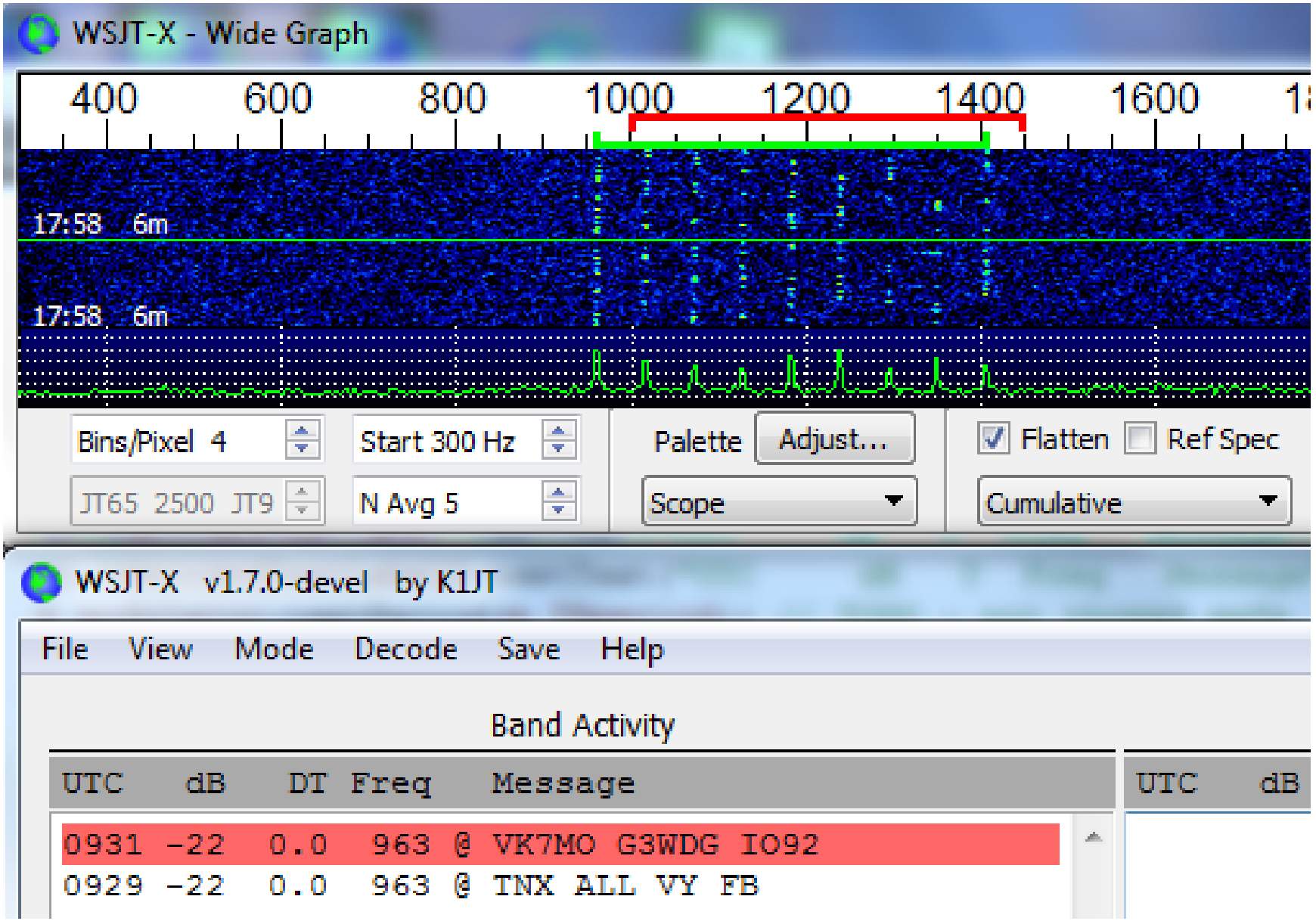
➔ EME is easier at higher frequencies!

VK7MO: 10 GHz, 76 cm dish

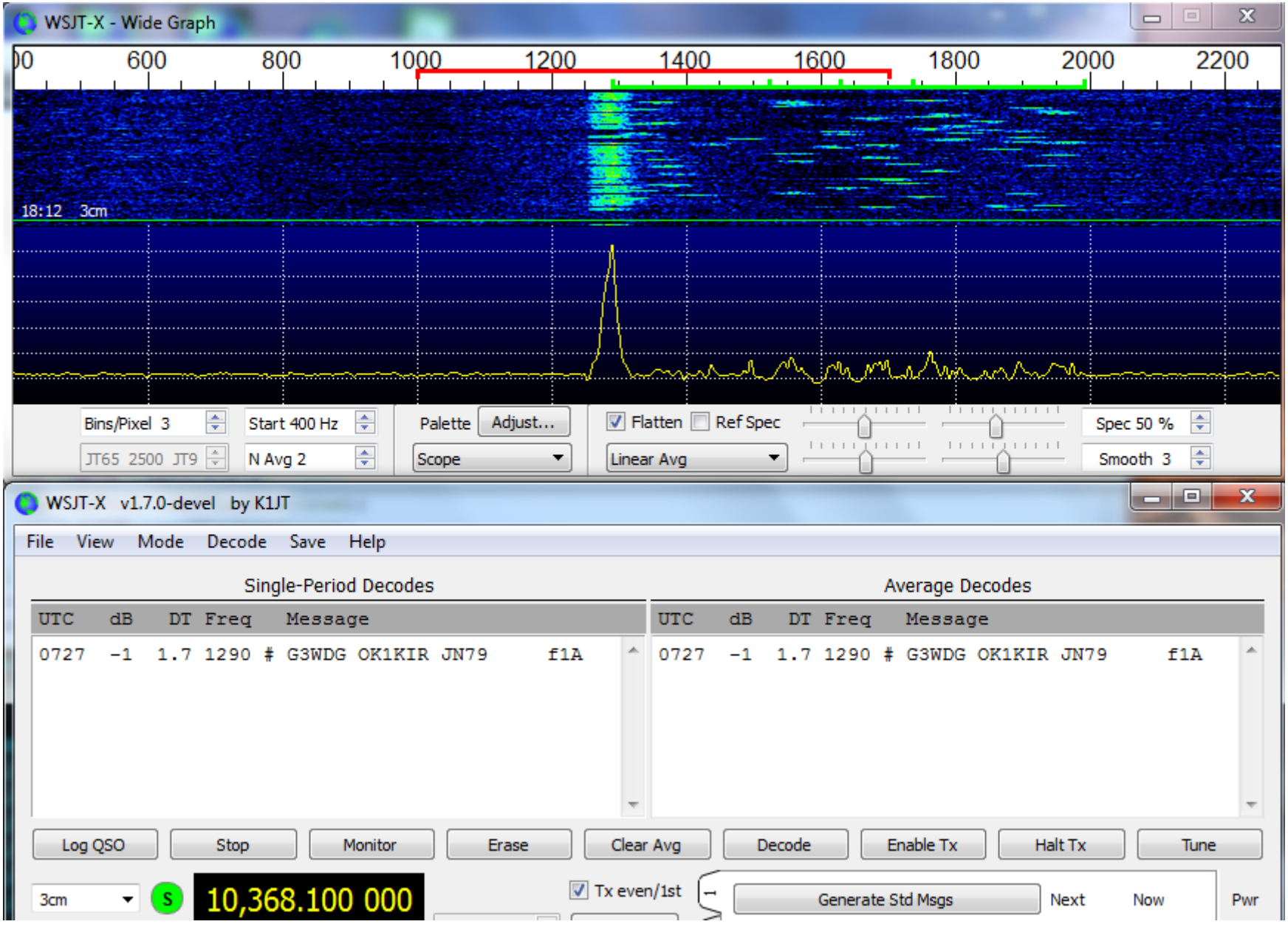
VK7MO: 10 GHz, JT65C



VK7MO: 10 GHz, JT9F



G3WDG: 10 GHz, JT65C



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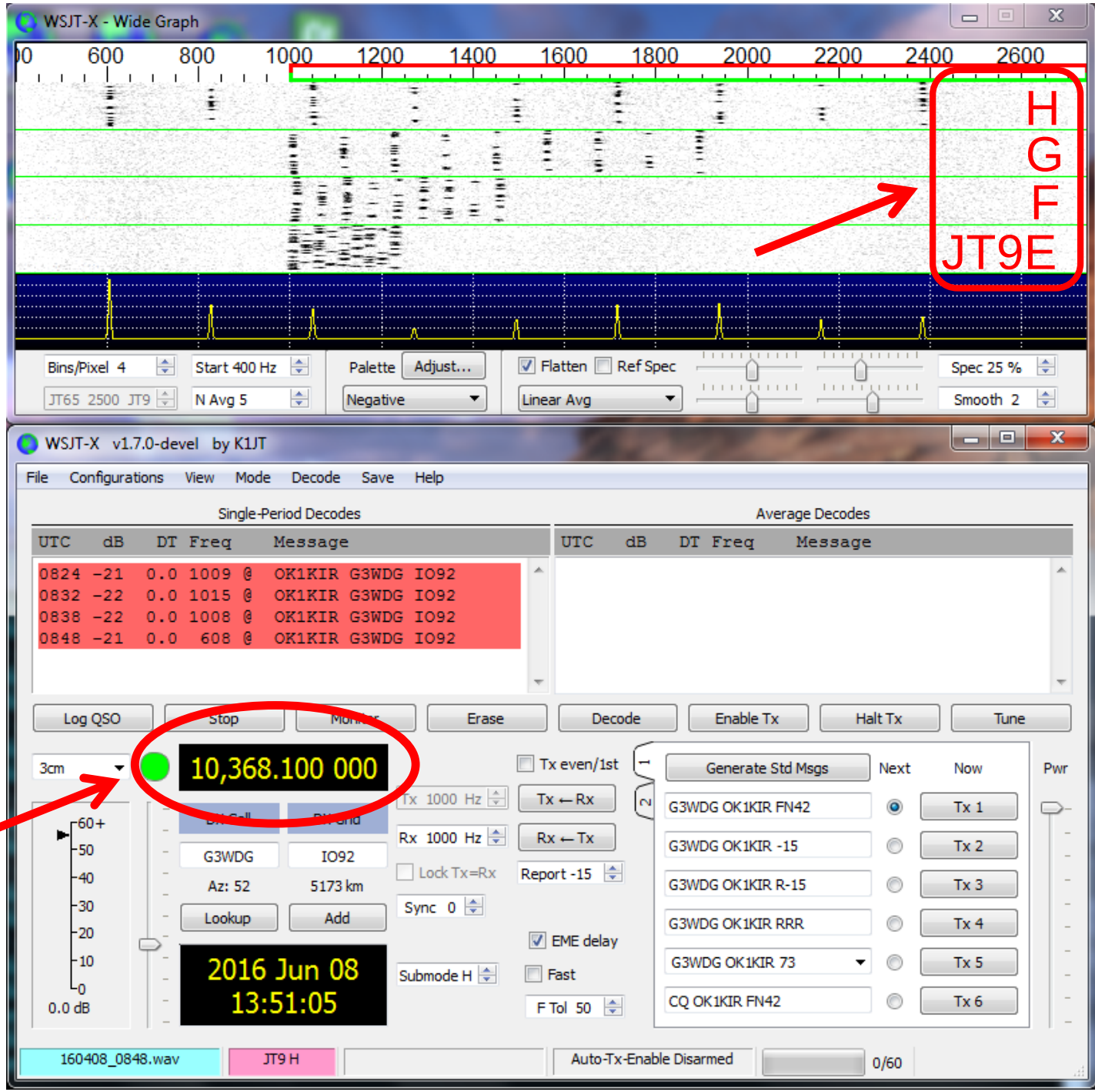
G3WDG received at OK1KIR

10 GHz



QRA64

- Details in next talk: **IV3NWV**
- Q-ary (63,12) repeat-accumulate code
- Operationally similar to JT65
- Three 7×7 Costas arrays for sync
- Thousands of simulation tests
- Many QSOs, HF through 10 GHz

QRA64: Better than JT65!

- Better code: +1.0 to +1.5 dB
- Better sync scheme: +1.9 dB
- Additional +0.5, +1.1, +2.3, +4.2 dB
  using *a priori* information
- No callsign database
- Very low undetected error rate (UER)

Standard minimal QSO

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC –22

K1ABC W9XYZ R–19

W9XYZ K1ABC RRR

K1ABC W9XYZ 73

Underline ➔ *a priori* “known”

QRA64: Measured Sensitivity

Thresholds for 50% decode probability

Full 72-bit message:	–28.1 dB
Locator or report:	–30.4 dB
Sync only:	–32.6 dB

Scatter Modes: Quick Overview

- Ionospheric scatter (6m, 4m) **JT9G,H**
- Meteor scatter (6m, 4m, 2m, …) **JTMSK**

  ➔ 800 – 2100 km, any time! **MSK144**

- Aircraft scatter (10 GHz) **ISCAT, JT9H**

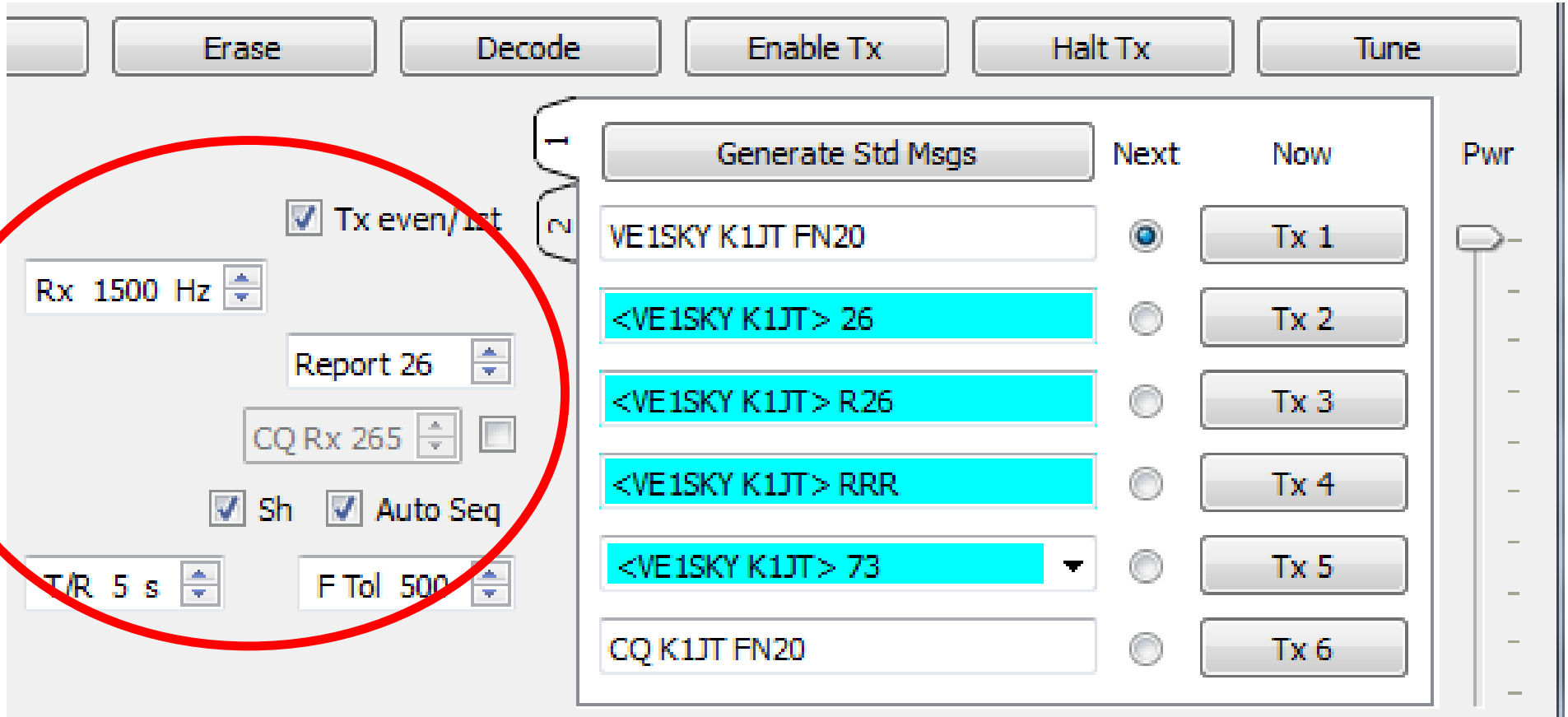
  (up to ~800 km)

Meteor Scatter: Message duration

FSK441: 122 ms (18 char msg)

JTMSK: 117 or 17.5 ms

MSK144: 72 or 20 ms



MSK144 short messages

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC –03

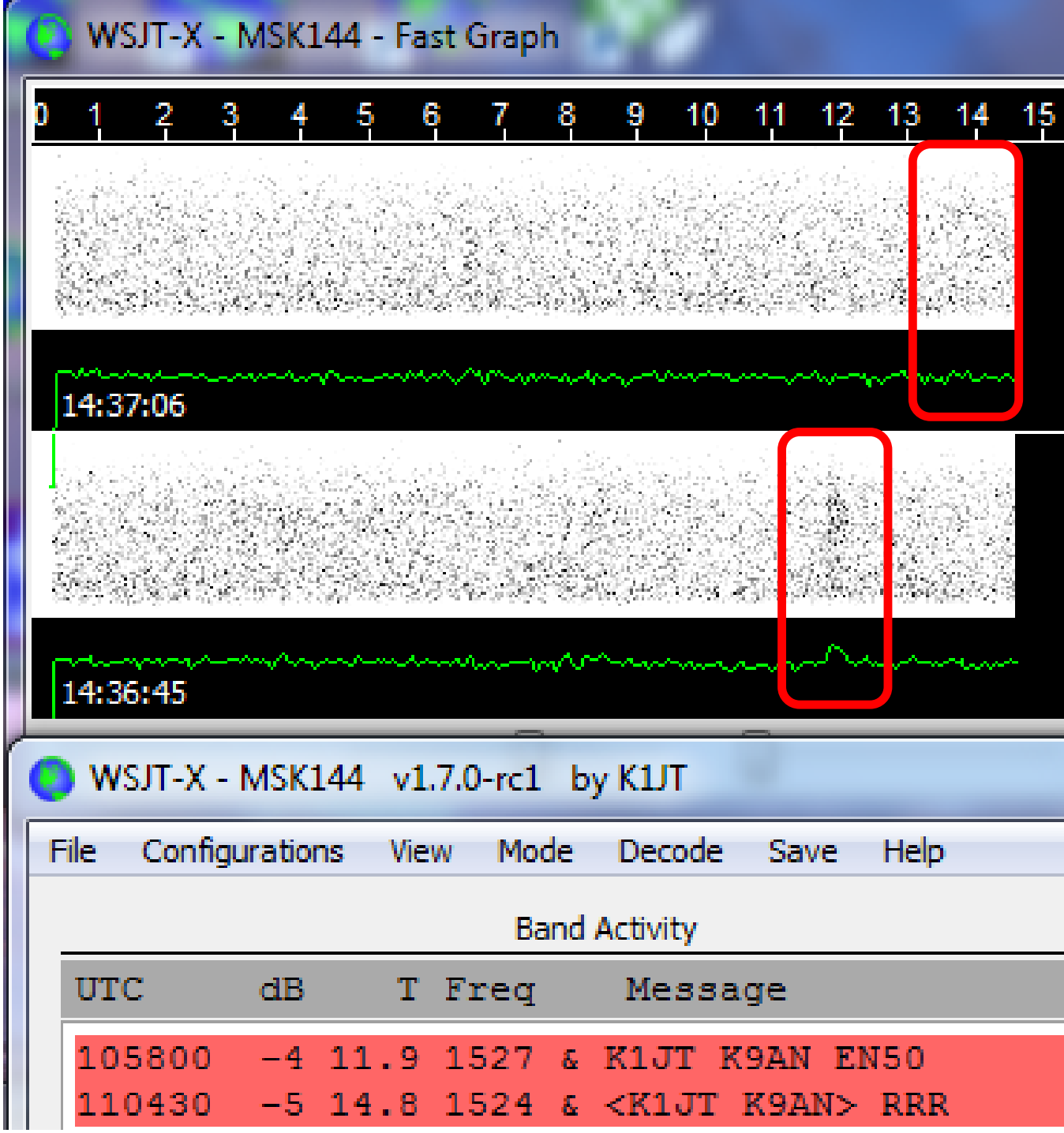
<K1ABC W9XYZ> R+03

<W9XYZ K1ABC> RRR

<K1ABC W9XYZ> 73

MSK144

Copy at S/N = –4, –5 dB



Still to Come …

WSJT-X Version 1.7

- Updated User Guide
- WSJT-X v1.7-rc2
- v1.7 General Release

MAP64

- Inclusion of QRA64

Operating Advice

- Meteor scatter: MSK144
- Other scatter modes: MSK144, Fast JT9, ISCAT

- EME at VHF/UHF: QRA64
- EME (w > 50 Hz): JT4, JT9

Special Acknowledgments

WSJT-X has **many** contributors!

Special thanks for recent efforts to:

G4WJS: Rig control, program structure

K9AN: FT decoder, MSK144

IV3NWV: QRA64 internals

KI7MT: Software developers kit

VE1SKY, G3WDG, VK7MO, OK1KIR: Tests