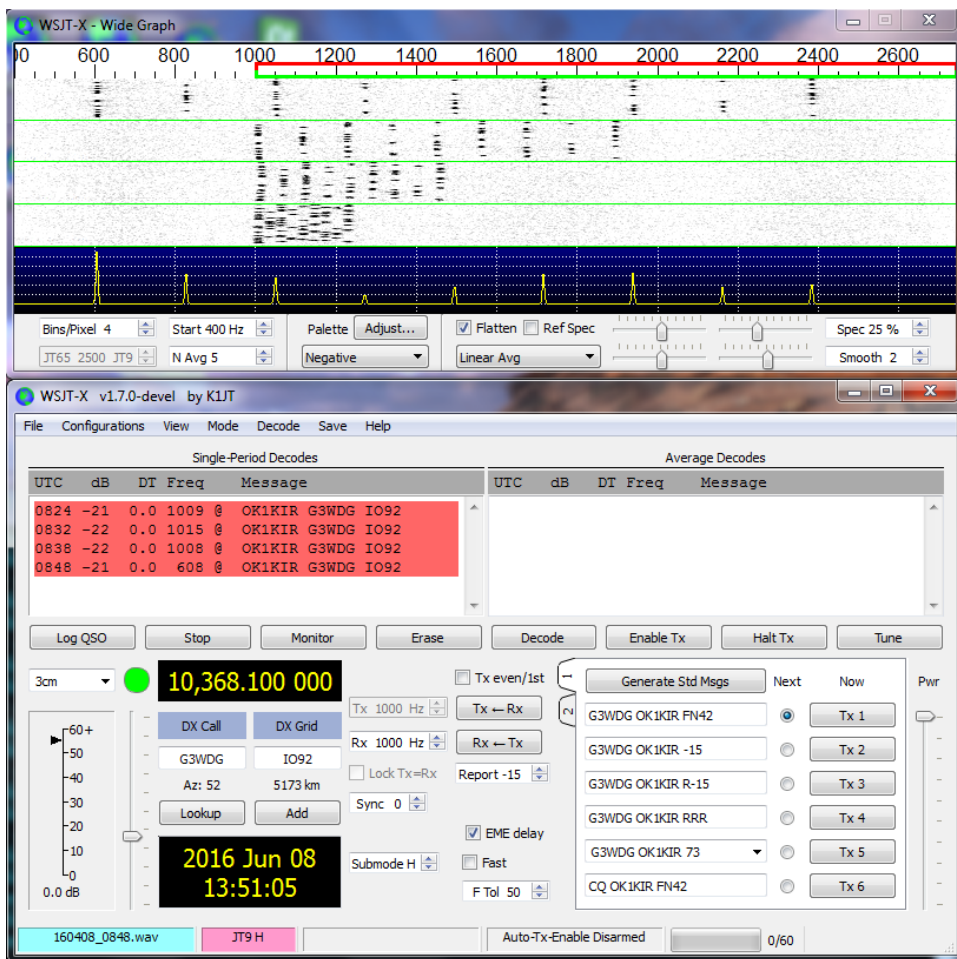


WSJT-X

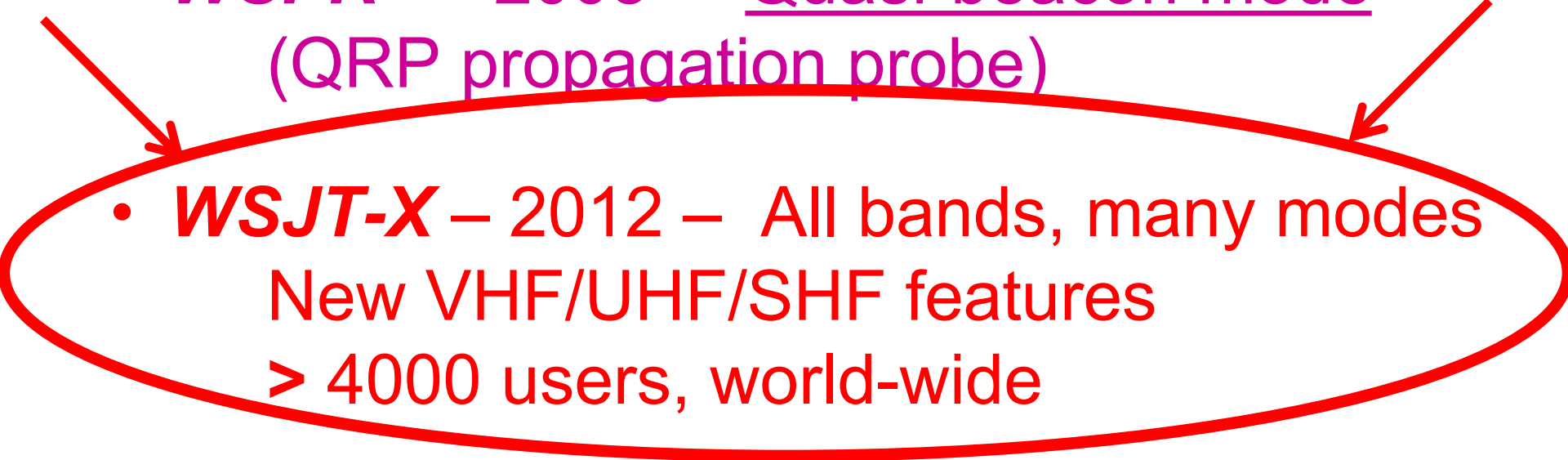
New Codes, Modes and Tools for Weak-Signal Communication

Joe Taylor
K1JT

EME Conference
Venice
Aug 21, 2016



“JT” Weak-Signal Software

- **WSJT** – 2001 – VHF-and-up (meteor scatter, EME, ionosscatter, 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

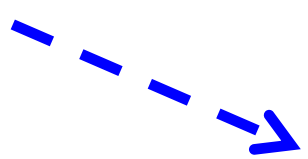
Scatter → “Fast”

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

EME, QRP → “Slow”

- JT65
- JT4
- JT9
- QRA64
- WSPR

Echo



Mode	Decode
	JT9
<input checked="" type="radio"/>	JT65
	JT9+JT65
	JT4
	WSPR-2
	WSPR-15
	Echo
	ISCAT
	JTMSK
	MSK144
	QRA

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

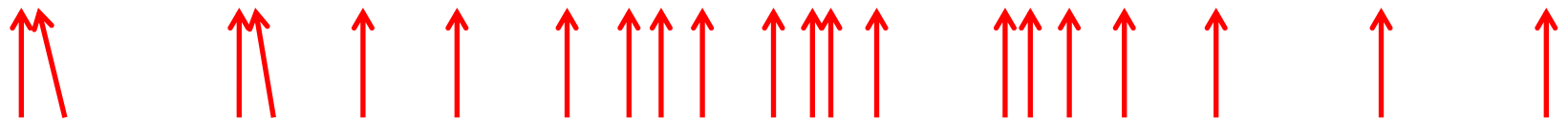
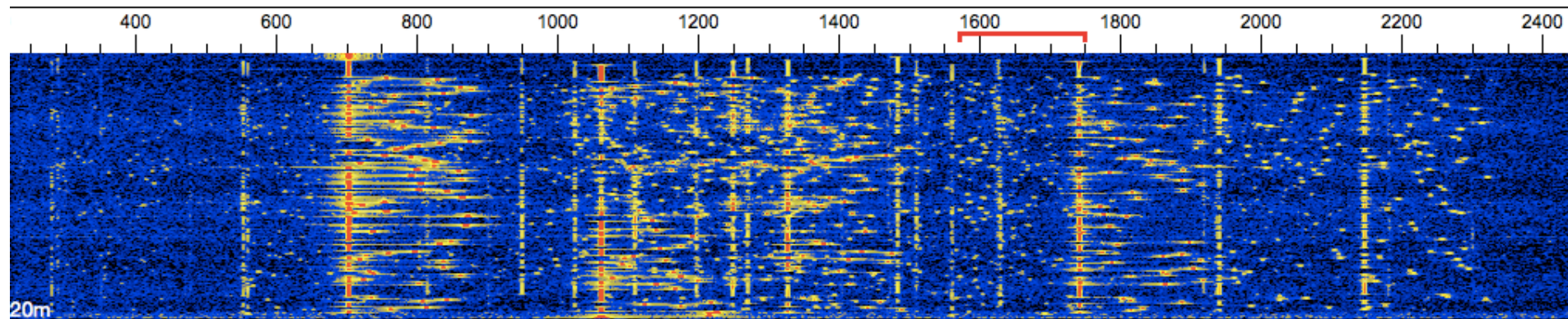
- Platform independence (Windows, Linux, OS X, ...)
- Rig control for nearly all radios
- Accurate frequency calibration
- Franke-Taylor decoder for JT65
- Other decoder improvements
- Added modes: WSPR, fast/wide JT9, JT4, (JTMSK), MSK144, QRA64

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

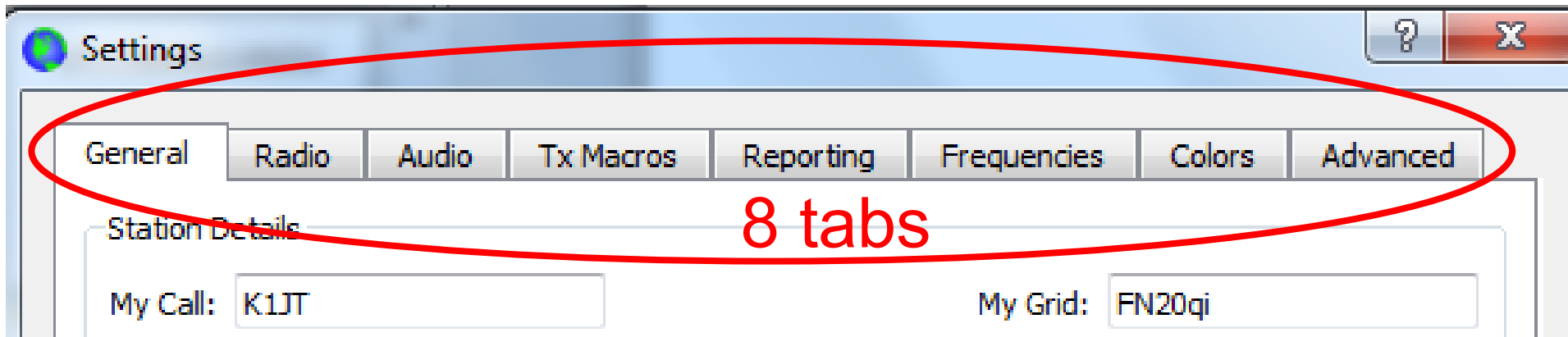
21 JT65A signals, all decoded !

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

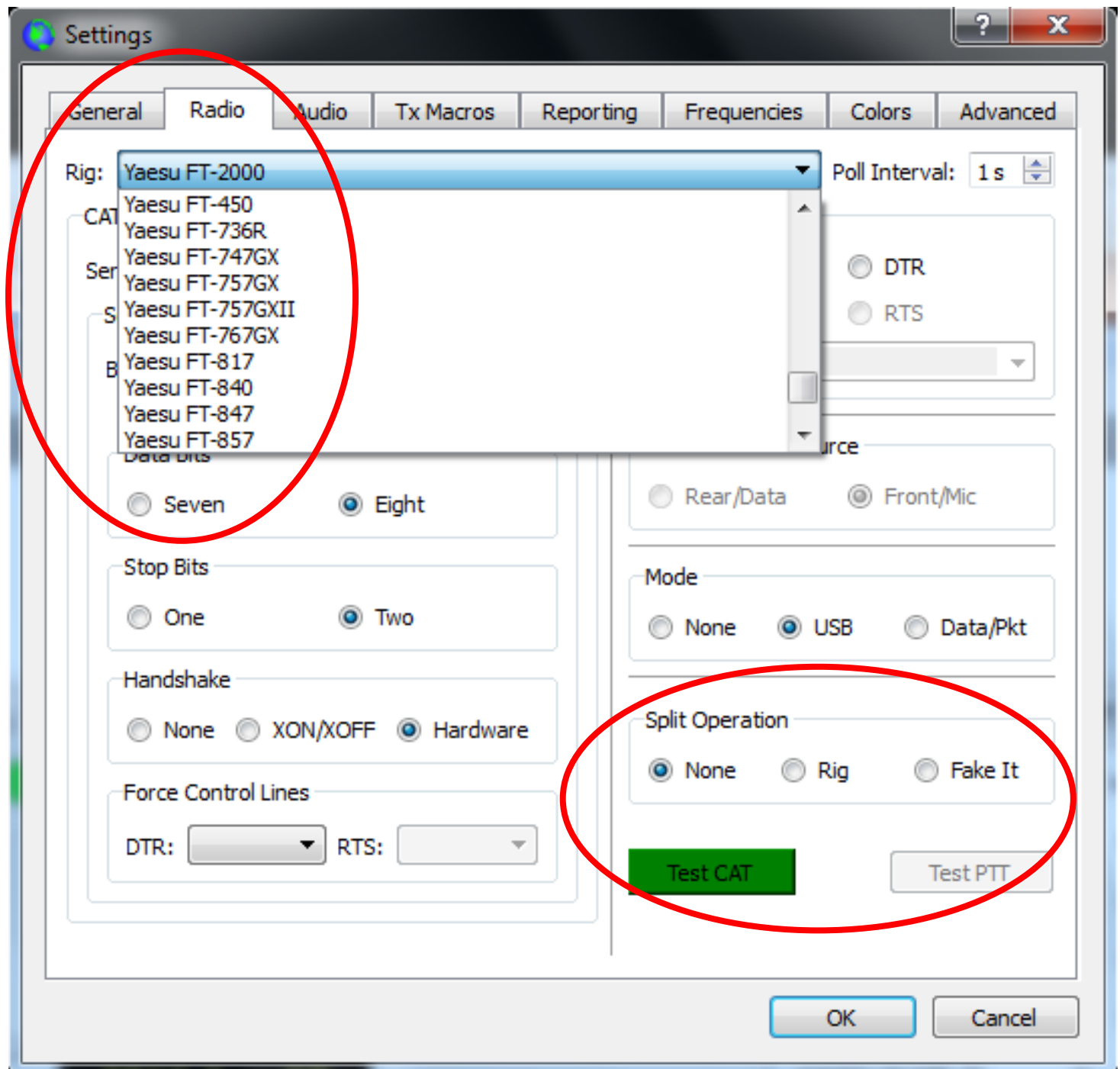


8 tabs

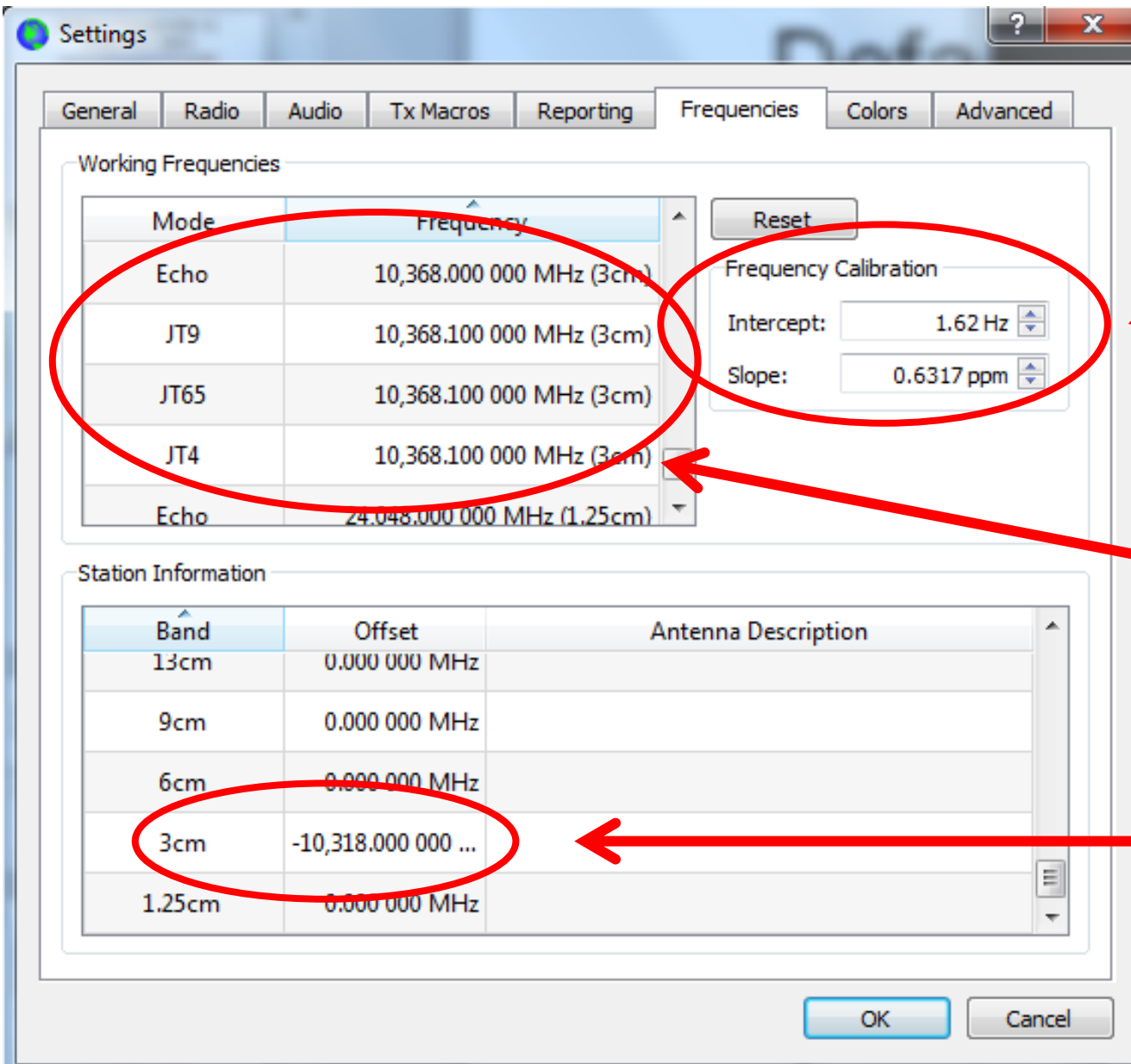
- Enable VHF/UHF/Microwave features
- Allow Tx frequency changes while transmitting
- Single decode
- Decode at t = 52 s
- Rx frequency offset with "CQ nnn ..."

VHF+ items

Rig Control



Frequency Settings

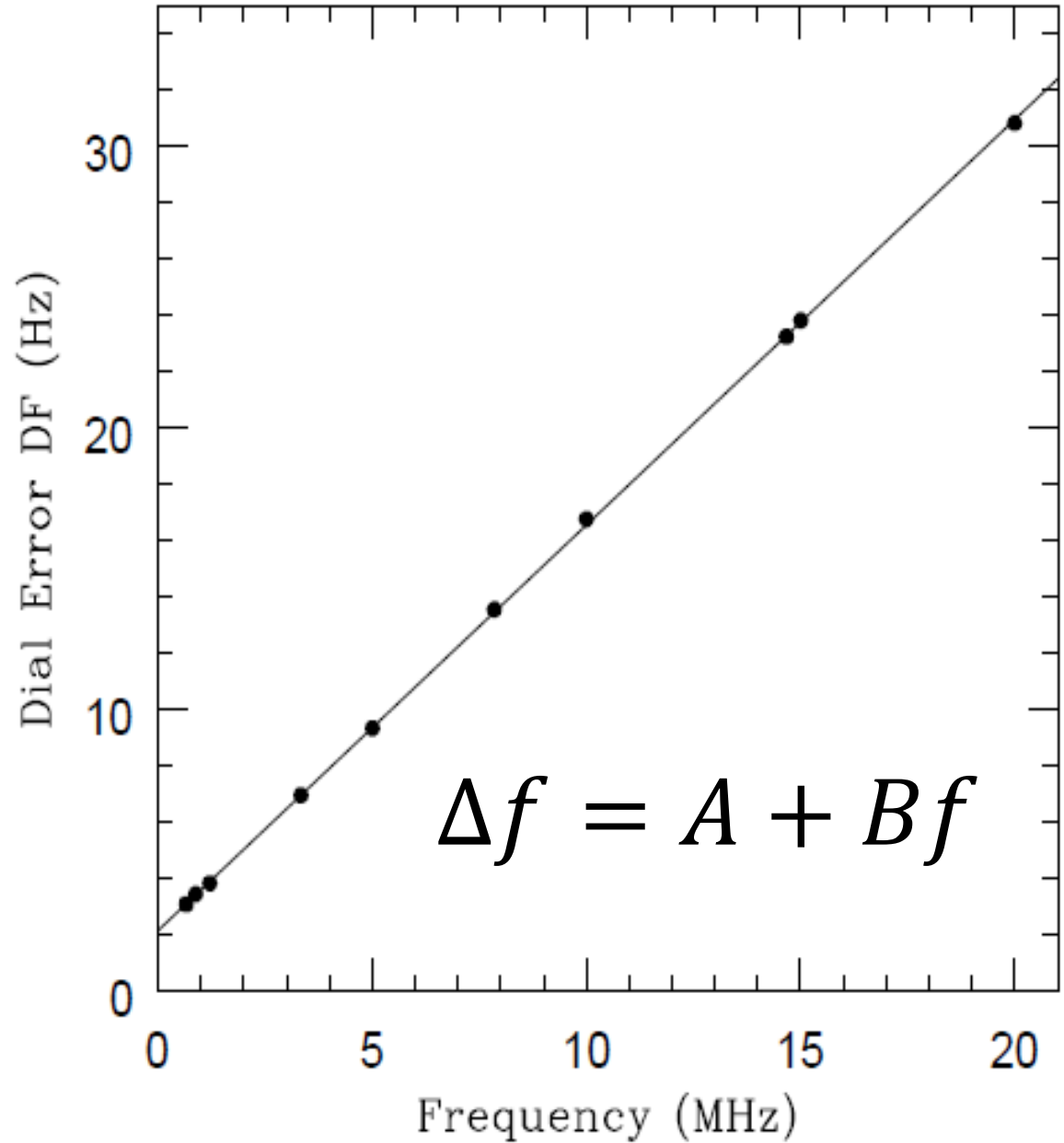


Calibration parameters

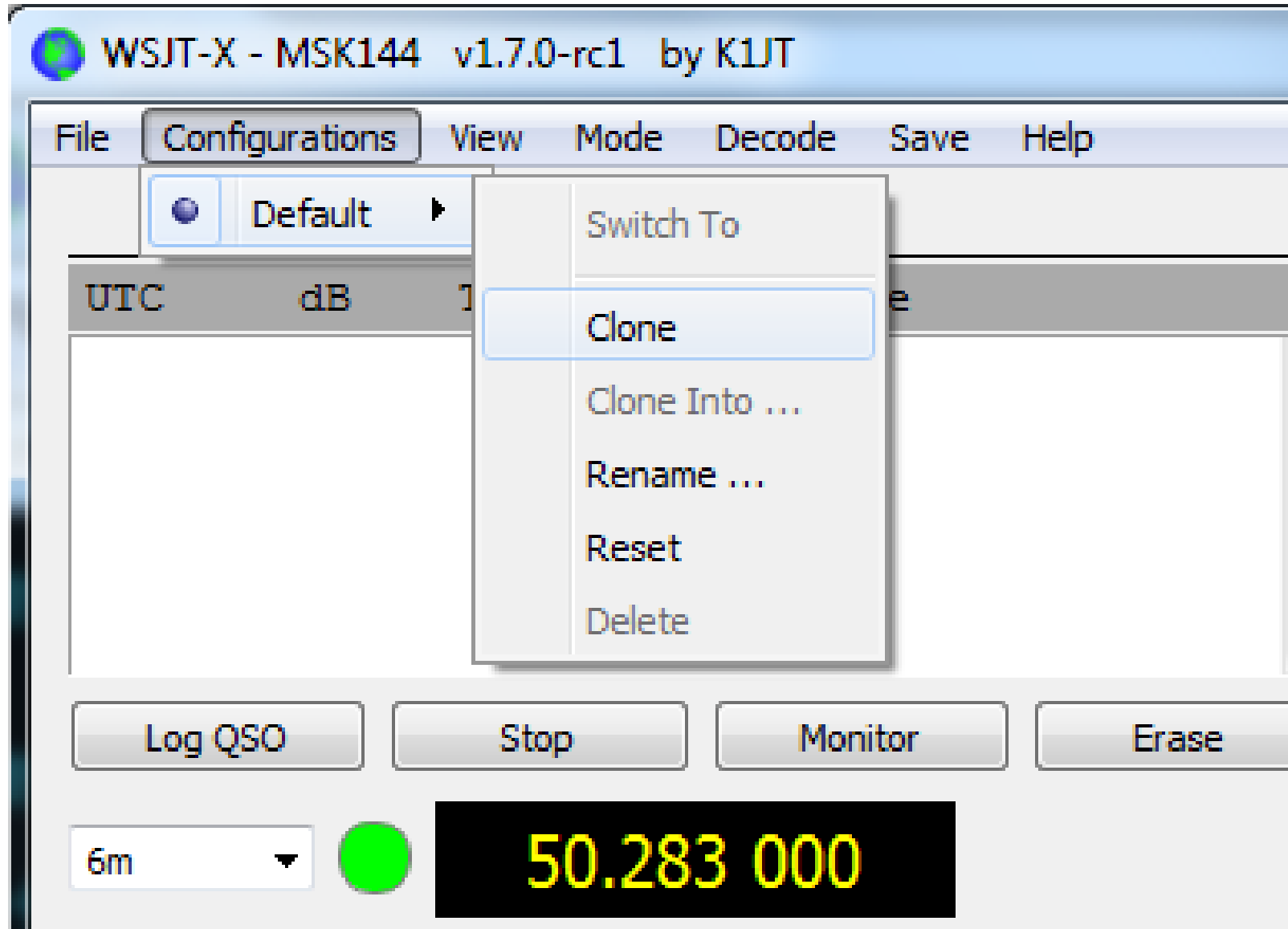
Frequencies by Mode & Band

Transverter offsets

TS-2000X
Frequency
Calibration



Save/Restore Configurations



Automatic Doppler tracking

WSJT-X - Astronomical Data

2016 Apr 14
UTC: 14:27:52
Az: 45.3
El: -21.2
SelfDop: 11181
Width: 179
Delay: 2.60
DxAz: 52.3
DxEI: -13.2
DxDop: 11870
DxWid: 165
Dec: 15.4
SunAz: 122.0
SunEl: 44.7
Freq: 10368
Tsky: 3
MNR: 0.0
Dgrd: -1.7

Doppler tracking

Doppler tracking

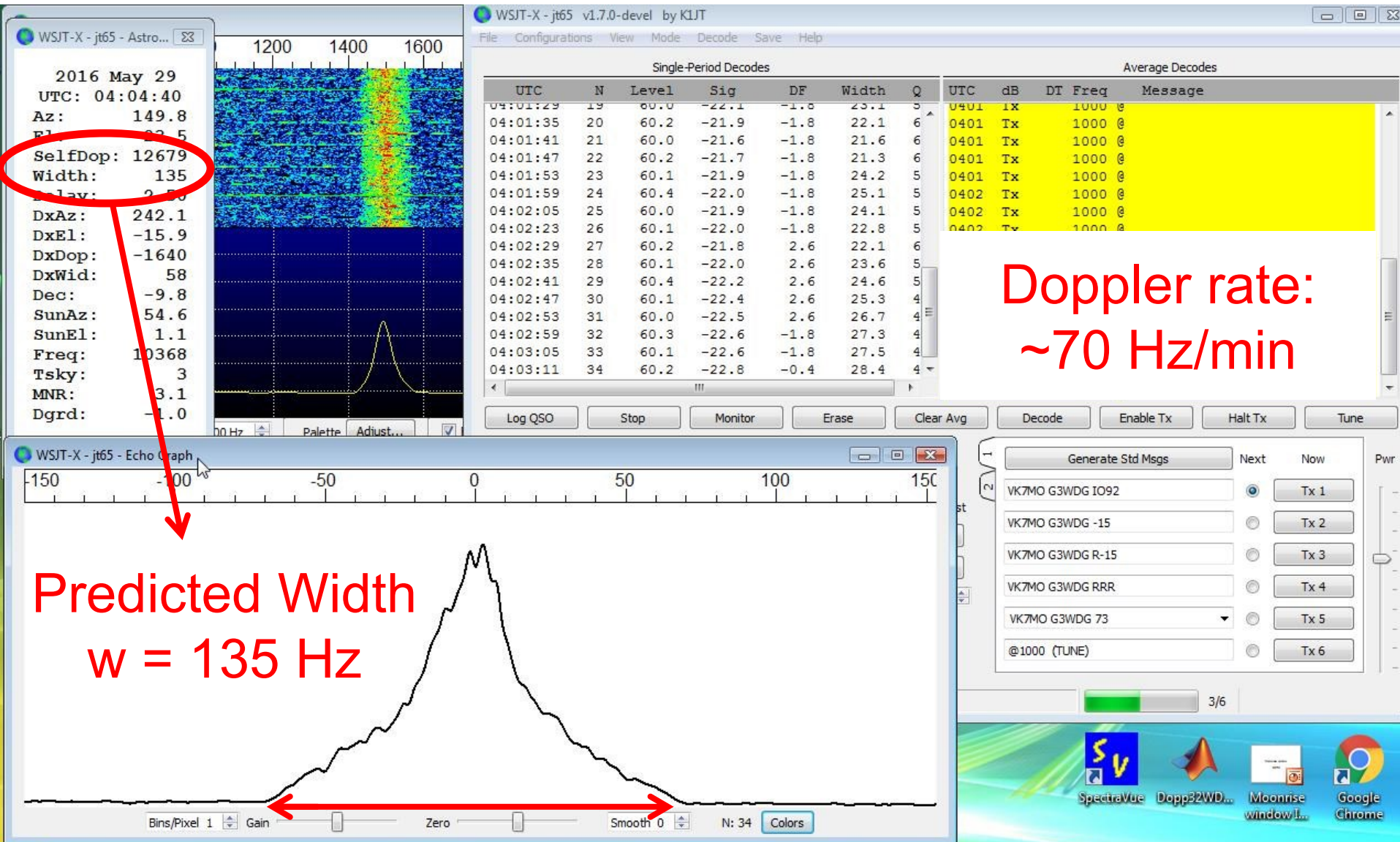
- Full Doppler to DX Grid
- Receive only
- Constant frequency on Moon
- None

Sked frequency

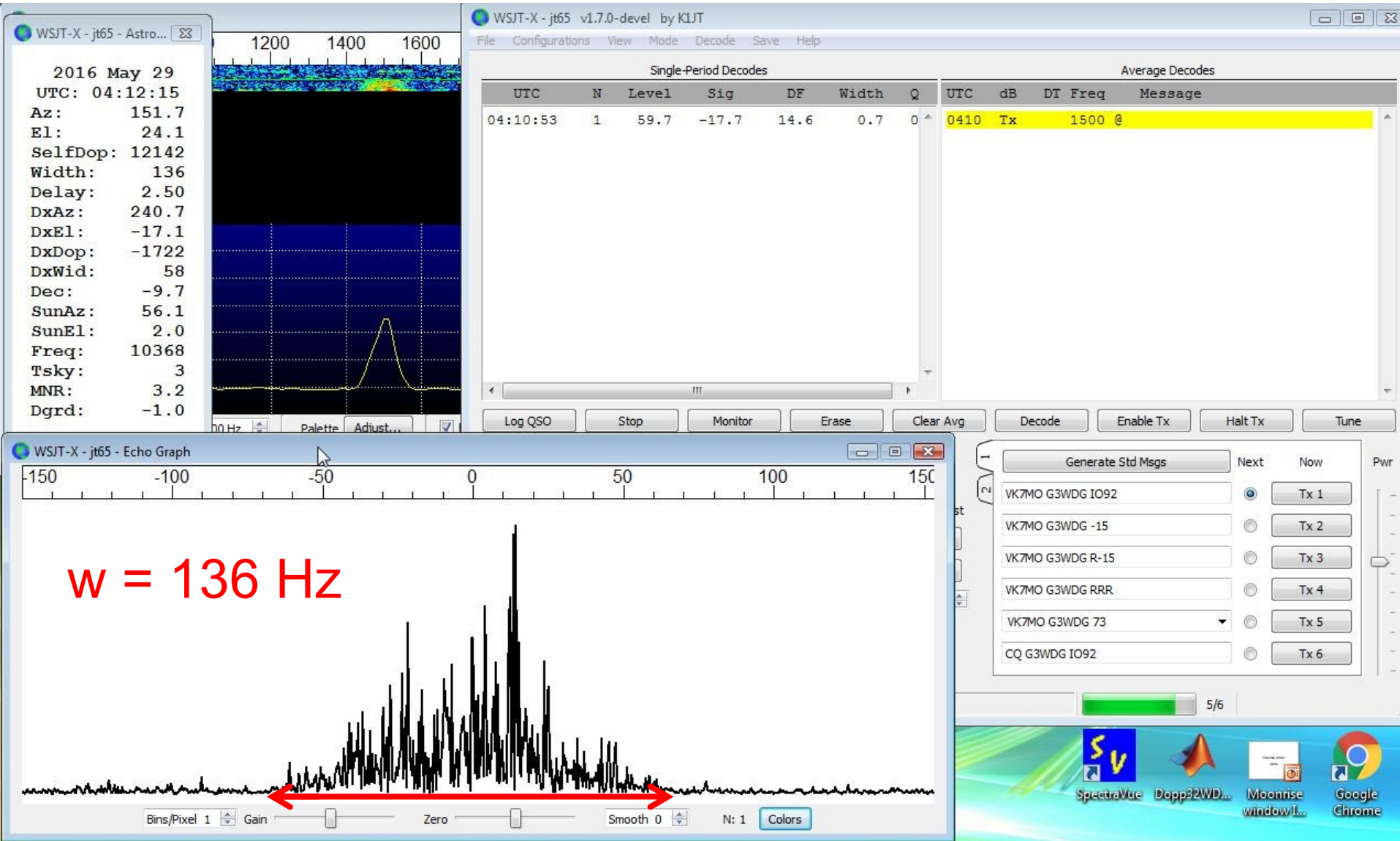
Rx: 10,368.100 000
Tx: 10,368.100 000

Press and hold the CTRL key to adjust the sked frequency manually with the rig's VFO dial or enter directly into the band edit.

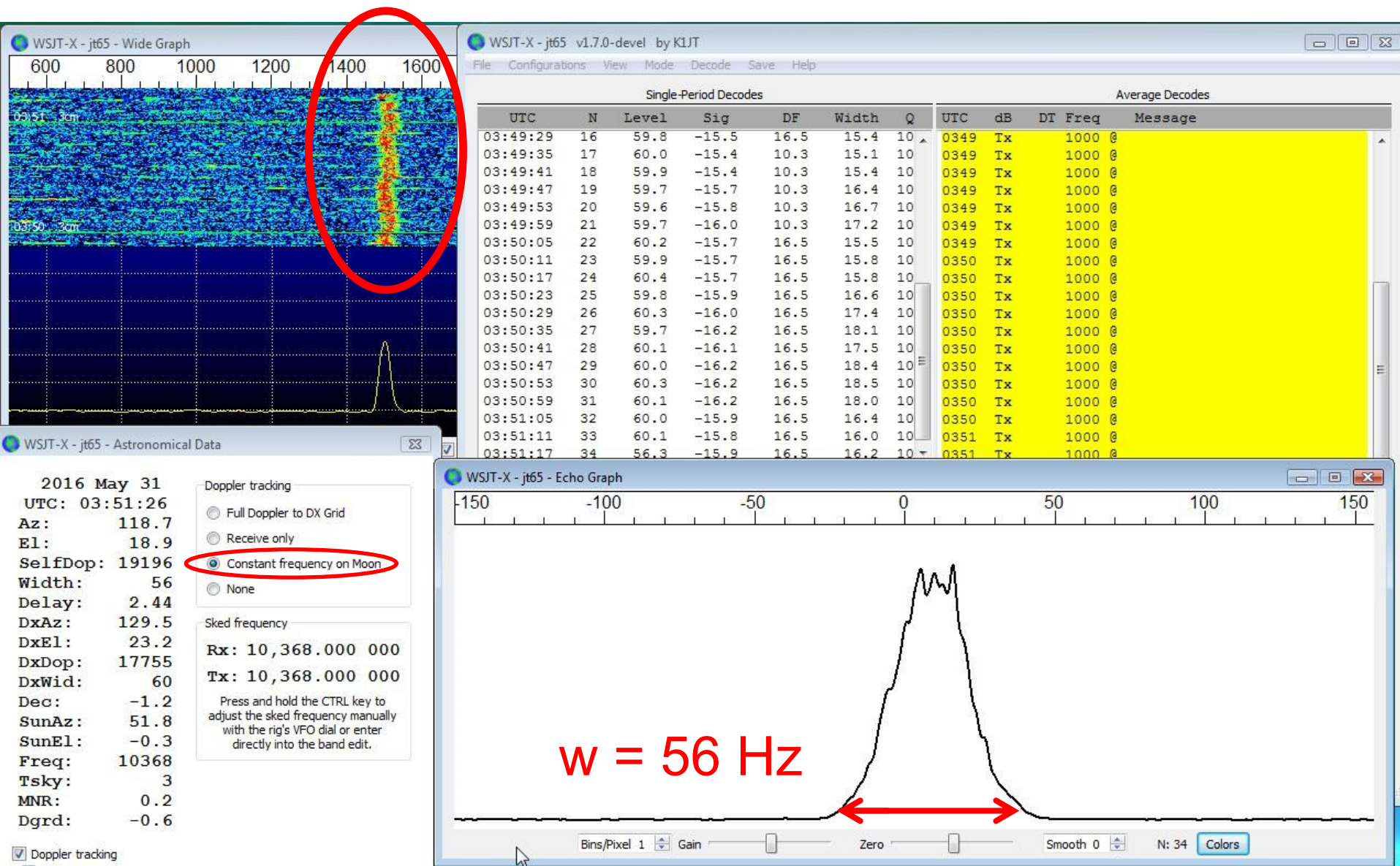
Echo Mode: G3WDG, 10 GHz



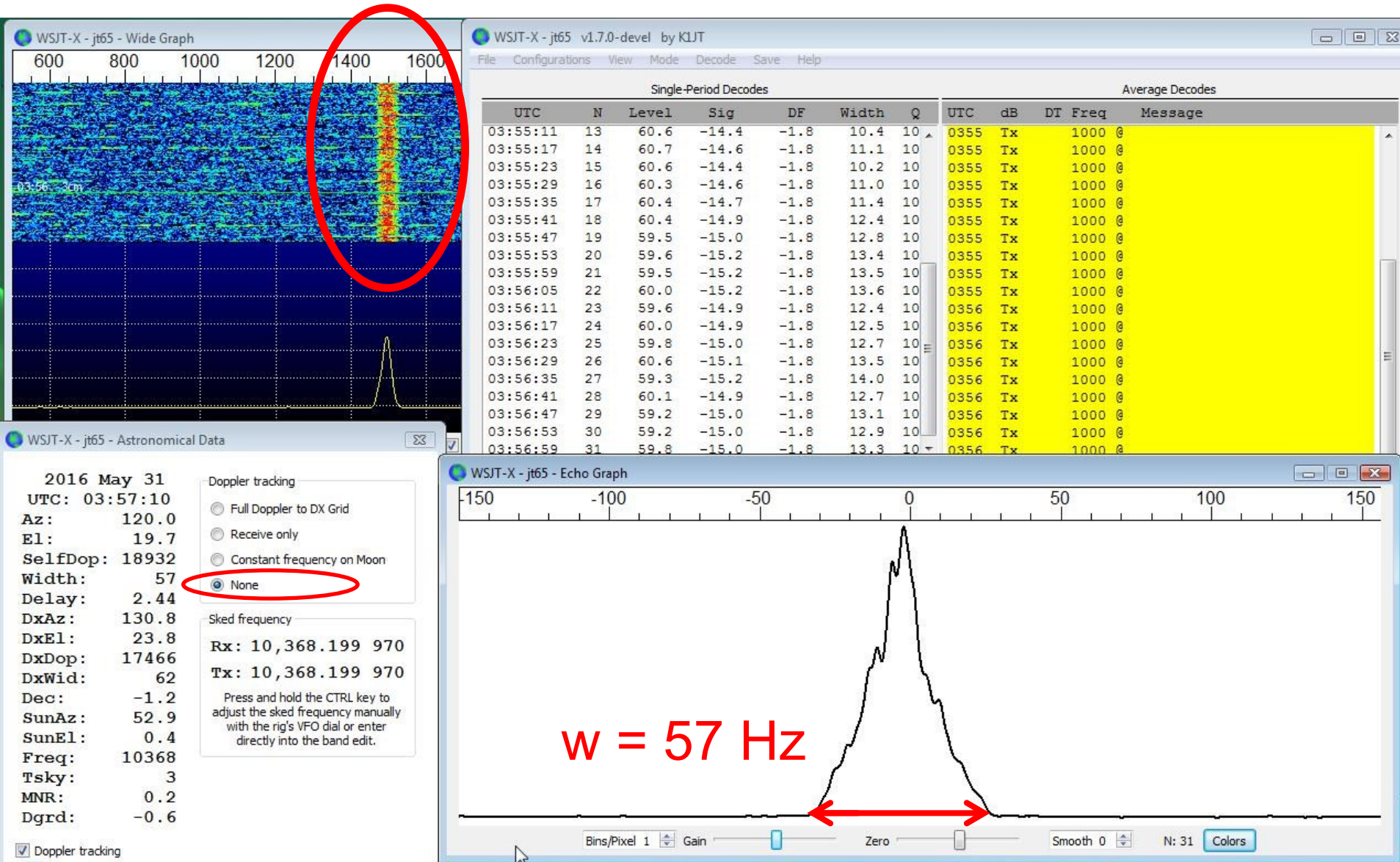
Single-pulse Echo



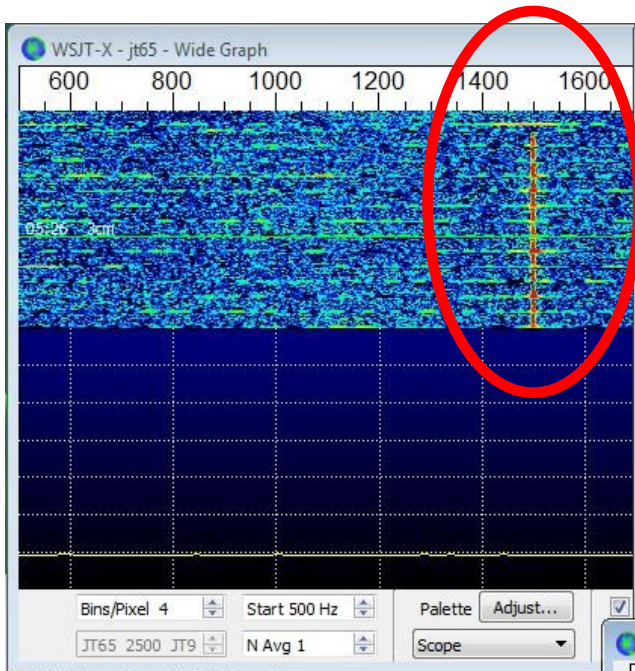
Doppler steering via Rig Control



Doppler steering via transverter LO



Close to libration minimum



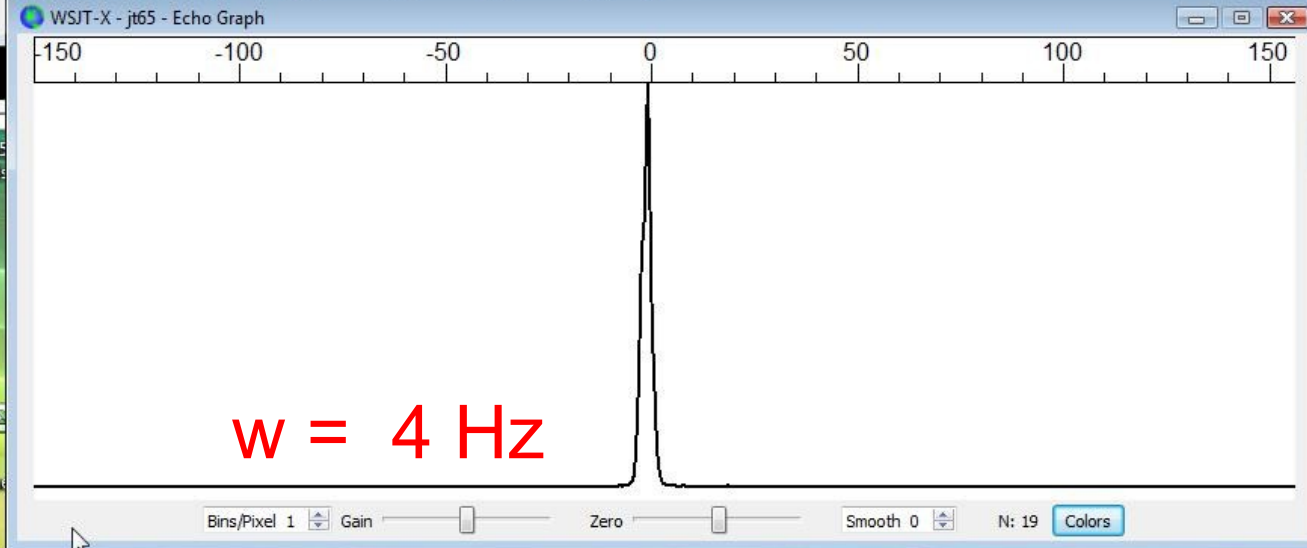
WSJT-X - jt65 v1.7.0-devel by K1JT

File Configurations View Mode Decode Save Help

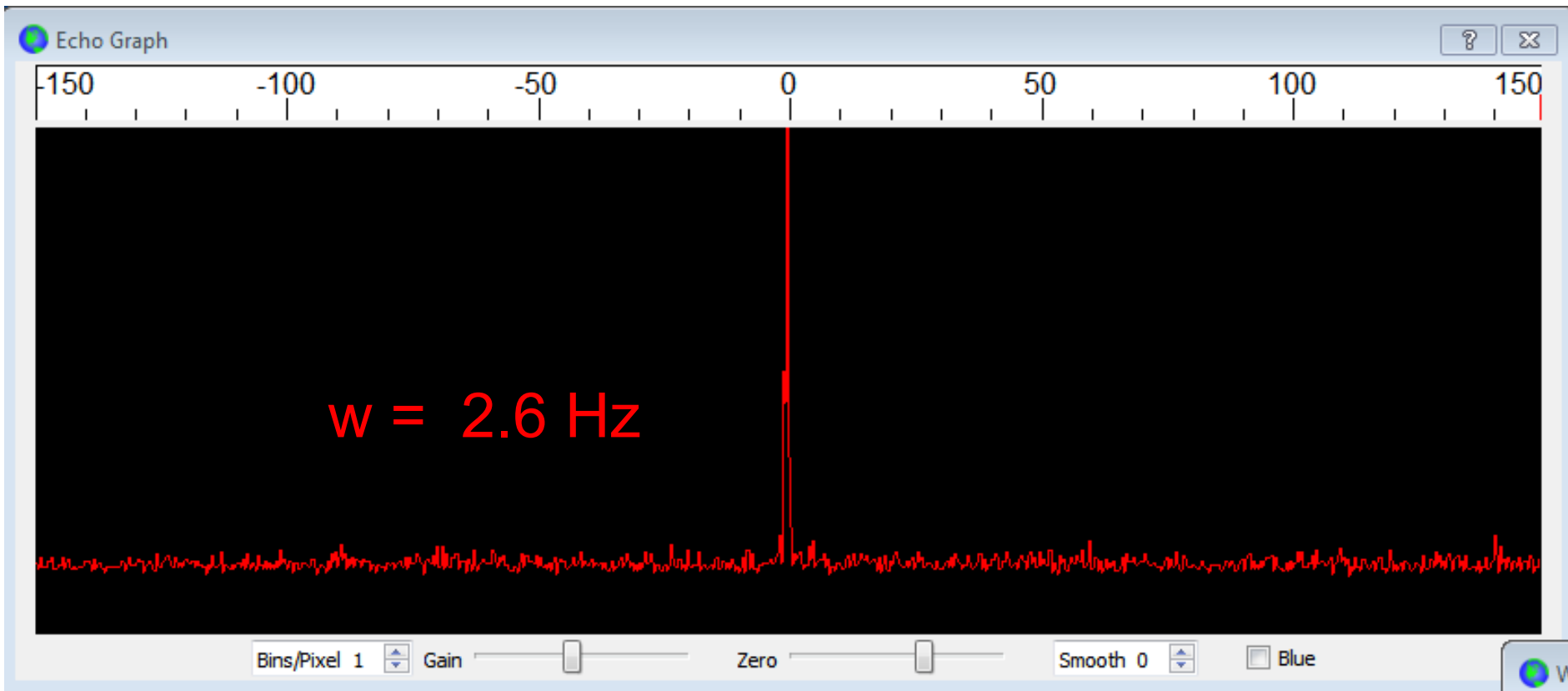
Single-Period Decodes							Average Decodes				
UTC	N	Level	Sig	DF	Width	Q	UTC	dB	DT	Freq	Message
05:25:02	1	47.9	-5.5	557.0	0.7	0	0525	Tx		1000	@
05:25:05	2	48.3	-5.6	556.3	0.4	10	0525	Tx		1000	@
05:25:11	3	60.1	-2.6	555.2	0.4	10	0525	Tx		1000	@
05:25:17	4	59.4	-5.7	0.0	1.0	10	0525	Tx		1000	@
05:25:23	5	59.8	-5.5	0.0	1.0	10	0525	Tx		1000	@
05:25:29	6	59.5	-6.6	0.0	1.3	10	0525	Tx		1000	@
05:25:35	7	60.1	-6.7	0.0	1.3	10	0525	Tx		1000	@
05:25:41	8	59.6	-7.2	0.0	1.5	10	0525	Tx		1000	@
05:25:47	9	59.6	-7.8	0.0	1.7	10	0525	Tx		1000	@
05:25:53	10	60.3	-7.3	0.0	1.7	10	0525	Tx		1000	@
05:25:59	11	59.9	-7.7	0.0	1.9	10	0525	Tx		1000	@
05:26:05	12	59.5	-8.1	0.0	2.0	10	0526	Tx		1000	@
05:26:11	13	59.7	-7.9	0.0	1.9	10	0526	Tx		1000	@
05:26:17	14	60.0	-8.1	0.0	2.2	10	0526	Tx		1000	@
05:26:23	15	60.4	-7.6	-0.4	2.0	10	0526	Tx		1000	@
05:26:29	16	60.2	-7.2	-0.4	1.9	10	0526	Tx		1000	@
05:26:35	17	60.0	-7.2	-0.4	1.9	10	0526	Tx		1000	@
05:26:41	18	59.6	-7.4	-0.4	1.9	10	0526	Tx		1000	@
05:26:47	19	51.4	-7.4	-0.4	1.9	10	0526	Tx		1000	@

UTC: 05:27:05
Az: 110.6
El: 25.1
SelfDop: 17802
Width: 4
Delay: 2.40
DxEl: -31.5
DxDop: 8192
DxWid: 104
Dec: 8.0
SunAz: 69.8
SunEl: 12.6
Freq: 10368
Tsky: 3
MNR: 0.0
Dgrd: -0.3

Doppler tracking



Echo Mode: K1JT, 144 MHz



Comic relief: JTMSK self-echoes

The screenshot shows the WSJT-X software interface. The title bar reads "WSJT-X - jtmsk v1.7.0-devel by K1JT". The menu bar includes "File", "View", "Mode", "Decode", "Save", and "Help".

There are two main data tables:

Band Activity					Rx Frequency				
UTC	dB	T	Freq	Message	UTC	dB	T	Freq	Message
180750	4	1.3	1500	& K1JT G3WDG IO92	180755	Tx		1500	& K1JT G3WDG IO92
180800	9	1.8	1500	& K1JT G3WDG IO92	180805	Tx		1500	& K1JT G3WDG IO92
180810	6	1.5	1504	& K1JT G3WDG IO92	180815	Tx		1500	& K1JT G3WDG IO92
180820	4	1.6	1500	& K1JT G3WDG IO92	180825	Tx		1500	& K1JT G3WDG IO92
180830	7	1.3	1500	& K1JT G3WDG IO92	180835	Tx		1500	& K1JT G3WDG IO92
180840	8	1.9	1500	& K1JT G3WDG IO92	180845	Tx		1500	& K1JT G3WDG IO92
180850	8	1.4	1504	& K1JT G3WDG IO92	180855	Tx		1500	& K1JT G3WDG IO92
					180905	Tx		1500	& K1JT G3WDG IO92
					180915	Tx		1500	& K1JT G3WDG IO92

Below the tables are several control buttons: "Log QSO", "Stop", "Monitor" (highlighted in green), "Erase", "Decode", "Enable Tx", "Halt Tx", and "Tune".

The central control panel shows a frequency of 10,368.000 000 MHz and a mode of 3cm. The call sign is K1JT. The date and time are 2015 Nov 23 18:09:42. A red circle highlights the "T/R 5 s" setting. Other settings include "R x 1500 Hz", "Report -15", "CQ Rx 285", "Auto Seq", and "F Tol 200".

On the right, there is a "Generate Std Msgs" section with a list of messages and their transmission status:

Message	Next	Now
K1JT G3WDG IO92	<input checked="" type="radio"/>	Tx 1
K1JT G3WDG -15	<input type="radio"/>	Tx 2
K1JT G3WDG R-15	<input type="radio"/>	Tx 3
K1JT G3WDG RRR	<input type="radio"/>	Tx 4
K1JT G3WDG 73	<input type="radio"/>	Tx 5
CQ G3WDG IO92	<input type="radio"/>	Tx 6

At the bottom, there are status indicators: "Receiving" (green), "JTMSK" (red), "Last Tx: K1JT G3WDG IO92", "Tx-Enable Disarmed", and a progress indicator showing 2/5.

Logging, Reporting, UDP Server

Settings

General Radio Audio Tx Macros **Reporting** Frequencies Colors Advanced

Logging

- Prompt me to log QSO
- Convert mode to RTTY
- dB reports to comments
- Clear DX call and grid after logging

Activate PSK Reporter

Network Services

- Enable PSK Reporter Spotting

UDP Server

UDP Server: localhost Accept UDP requests

UDP Server port number: 2237 Notify on accepted UDP request

Accepted UDP request restores window

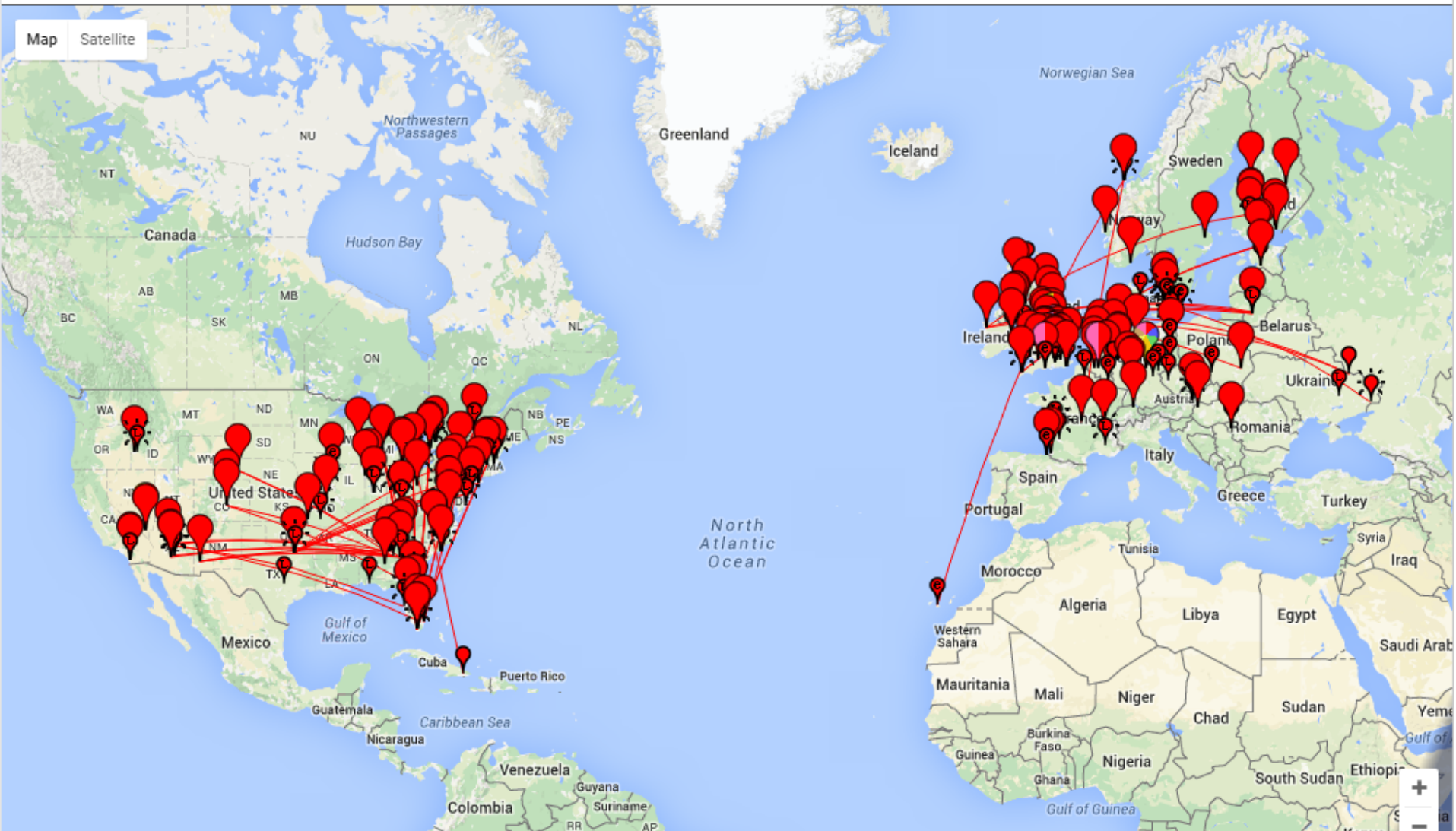
PSK Reporter: 6 m, JT modes

On , show sent by using over the last

[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](#)



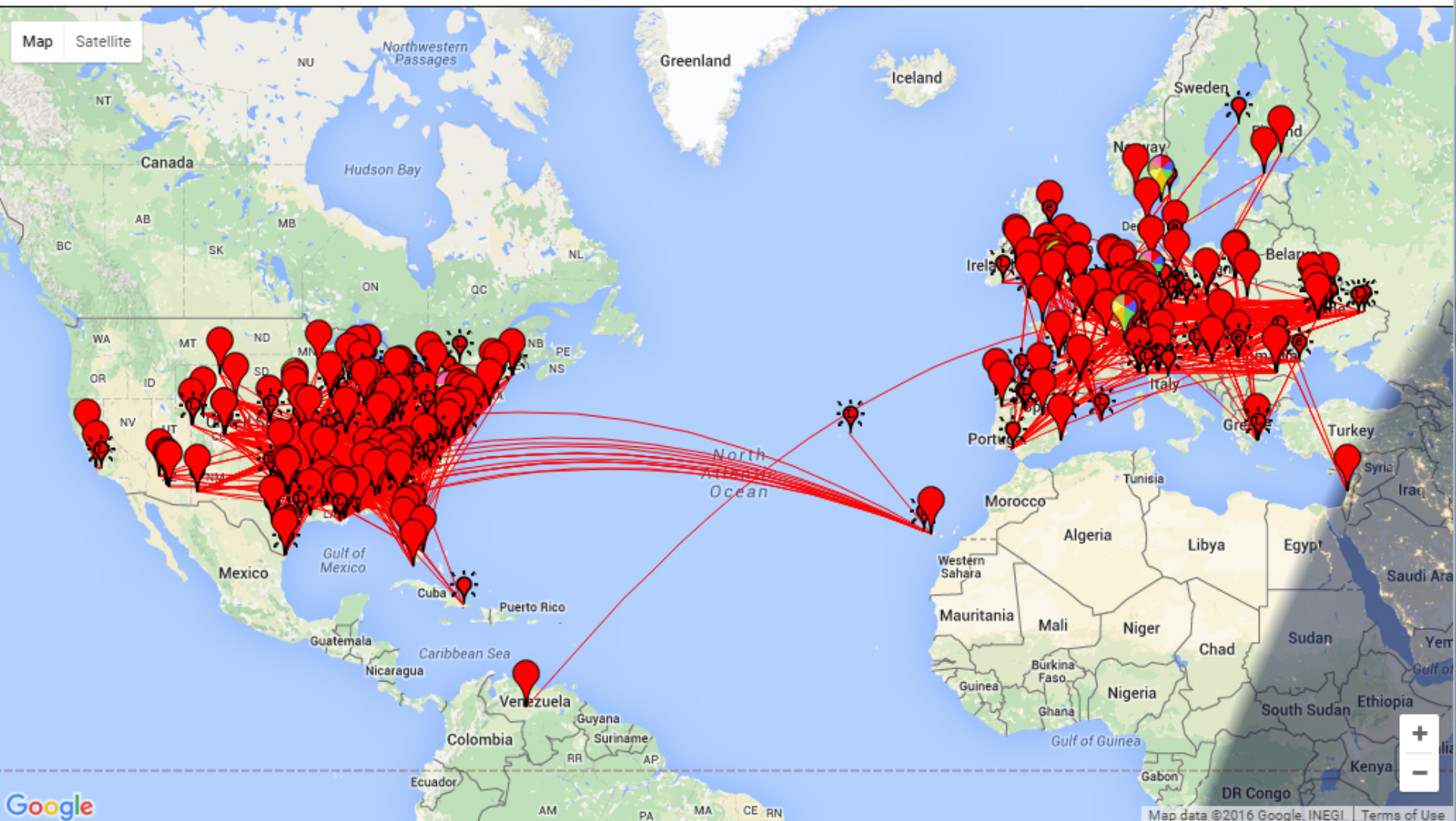
JT modes, 50 MHz

On show sent by using over the last

[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

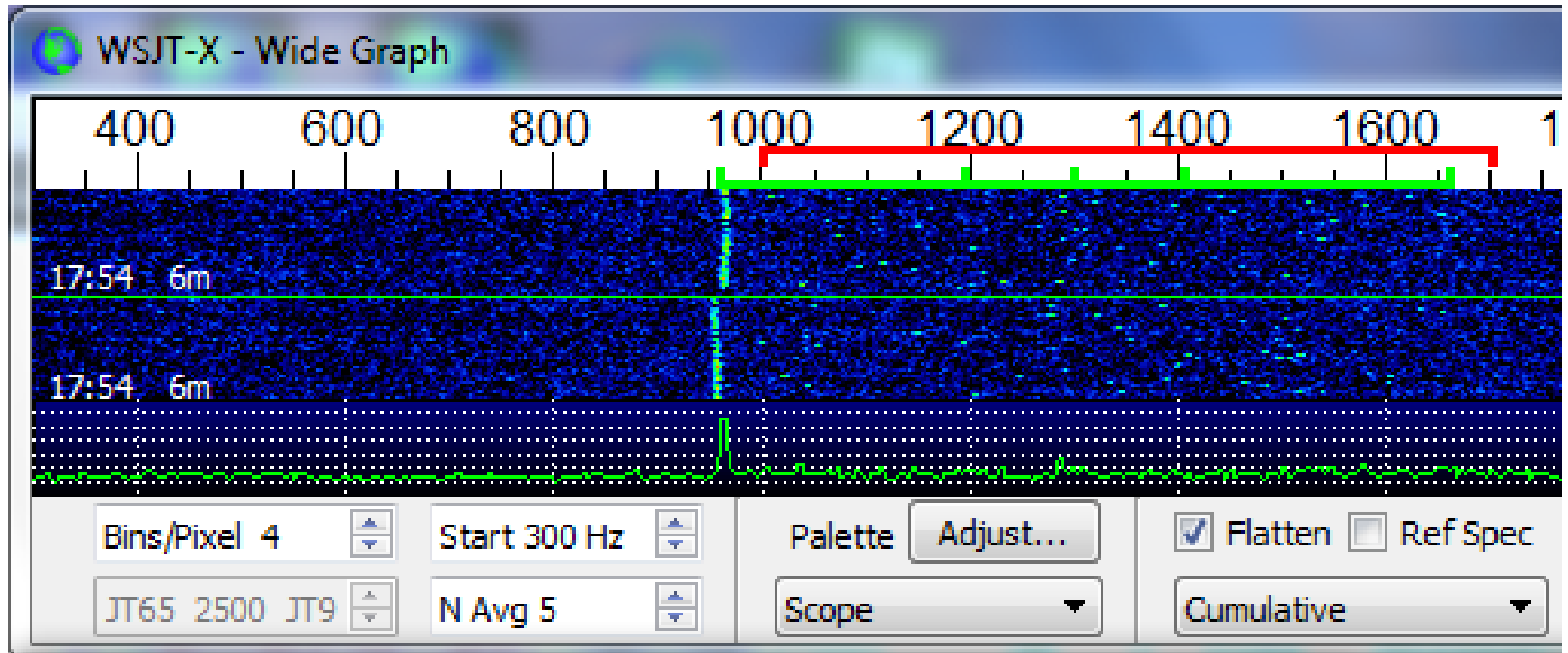
- 50 MHz: **JT65A QRA64**
- 144, 222, 432 MHz: **JT65B QRA64**
- 1296 MHz: **JT65C QRA64**
- 2.3+ GHz (depends on Doppler spread)
→ **JT65C, JT4F, JT9F, QRA64**

Don't forget: In some ways,
→ EME is easier at higher frequencies!

VK7MO: 10 GHz, 76 cm dish



VK7MO: 10 GHz, JT65C



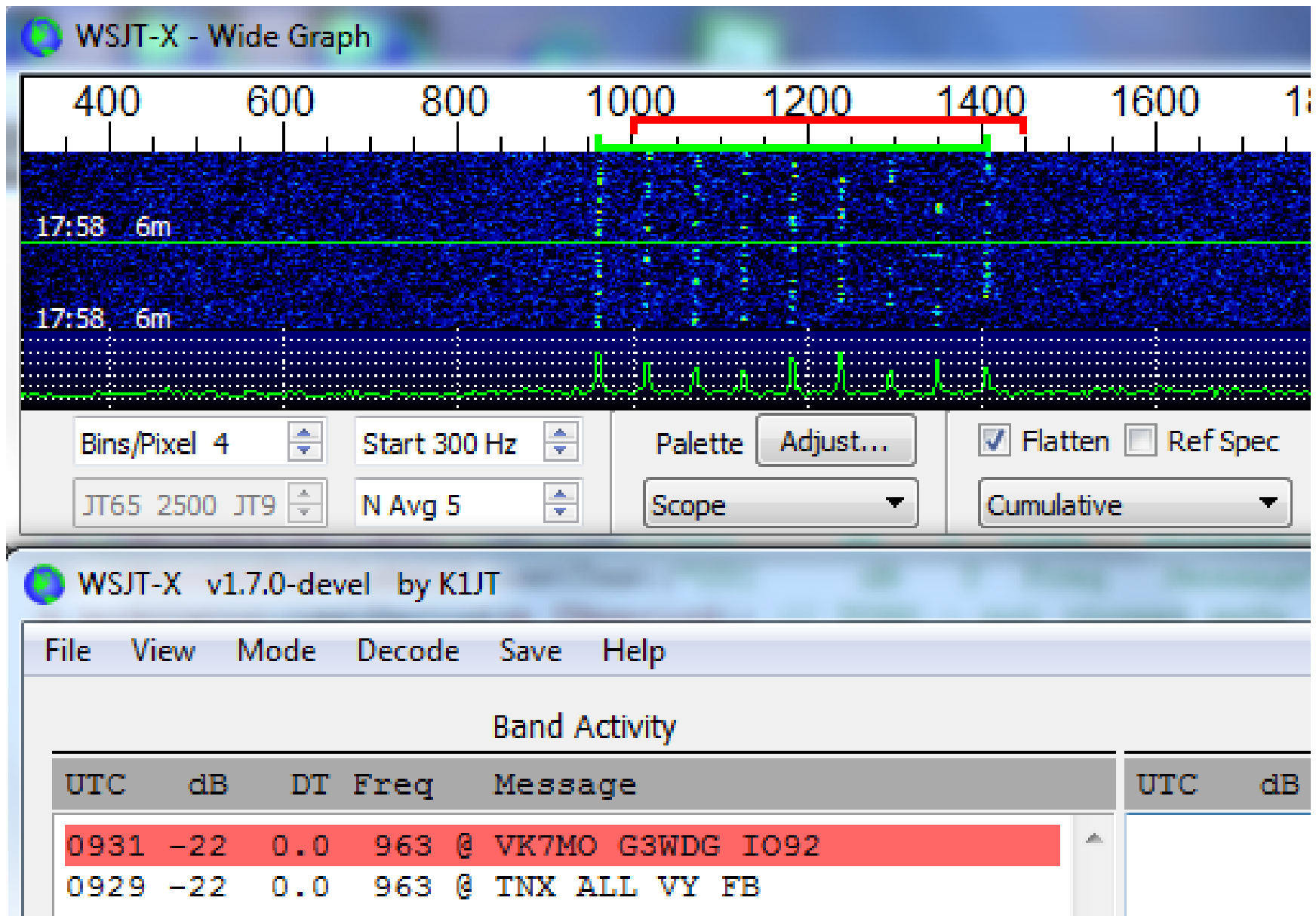
WSJT-X v1.7.0-devel by K1JT

File View Mode Decode Save Help

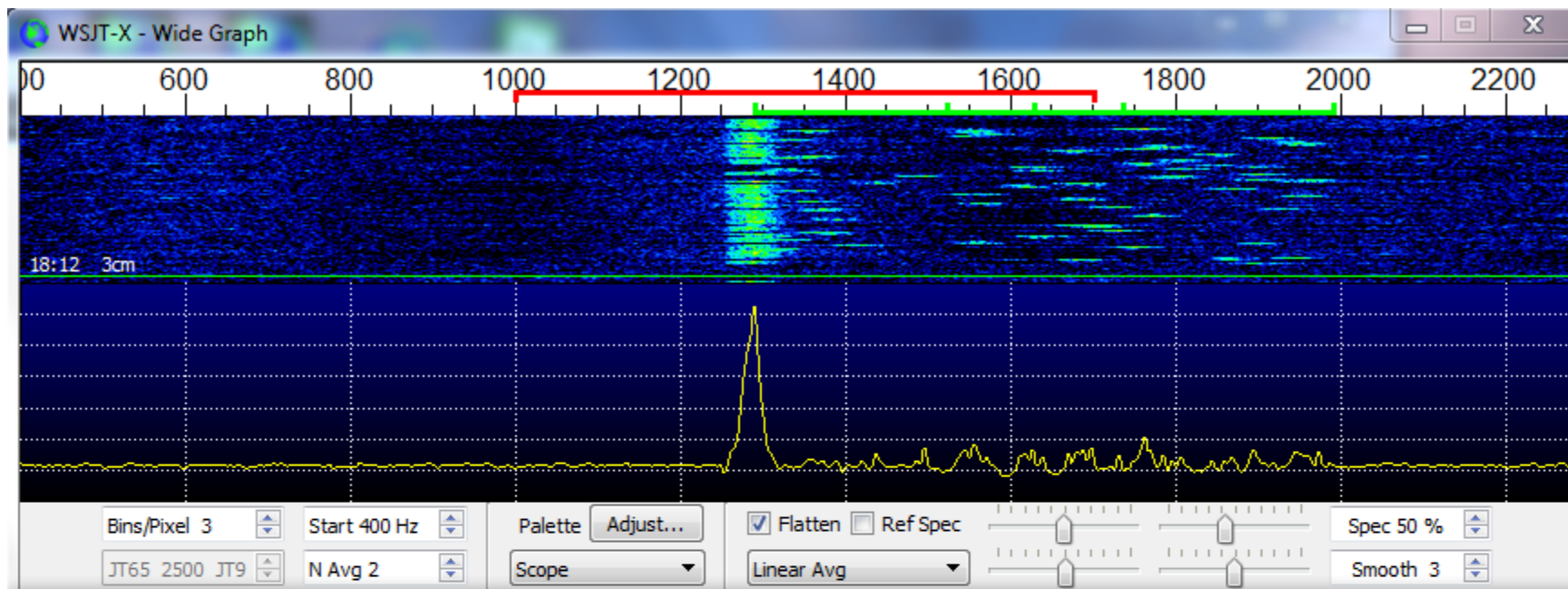
Single-Period Decodes

UTC	dB	DT	Freq	Message	UTC	dB
0853	-13	2.5	957	# VK7MO G3WDG IO92 f12		
0855	-11	2.6	965	# VK7MO G3WDG R-20 f12		

VK7MO: 10 GHz, JT9F



G3WDG: 10 GHz, JT65C



WSJT-X v1.7.0-devel by K1JT

File View Mode Decode Save Help

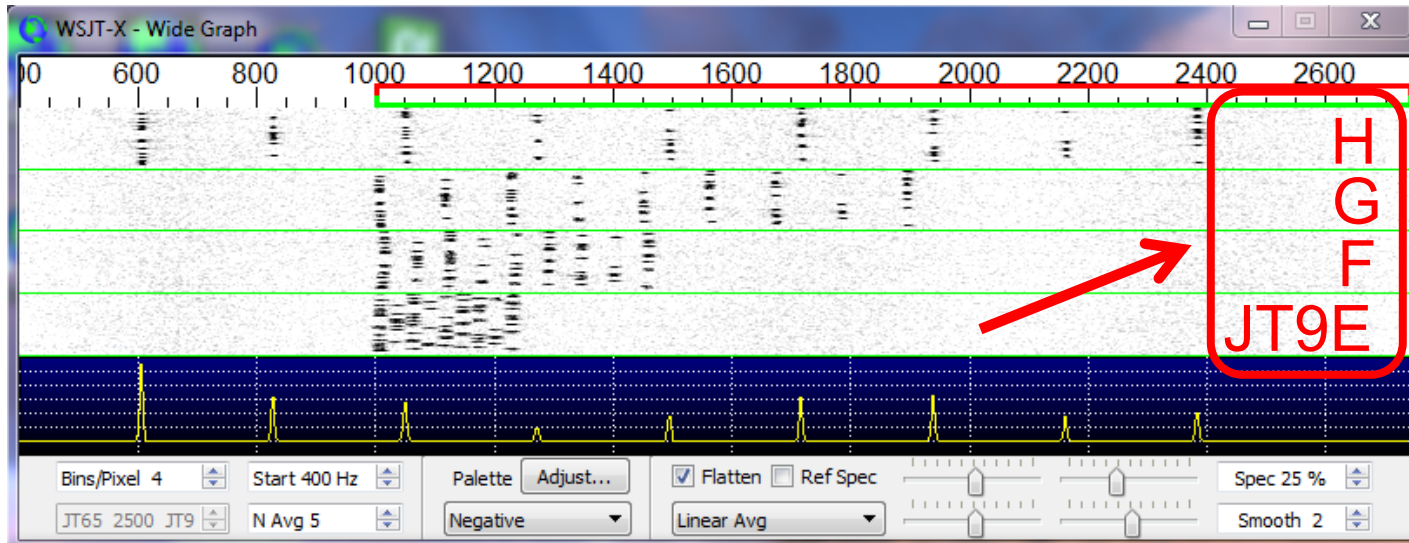
Single-Period Decodes						Average Decodes					
UTC	dB	DT	Freq	Message		UTC	dB	DT	Freq	Message	
0727	-1	1.7	1290	#	G3WDG OK1KIR JN79 f1A	0727	-1	1.7	1290	#	G3WDG OK1KIR JN79 f1A

Log QSO Stop Monitor Erase Clear Avg Decode Enable Tx Halt Tx Tune

3cm **S** **10,368.100 000** Tx even/1st Generate Std Msgs Next Now Pwr

WSJT-X

G3WDG
received at
OK1KIR



WSJT-X v1.7.0-devel by K1JT

File Configurations View Mode Decode Save Help

Single-Period Decodes					Average Decodes				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
0824	-21	0.0	1009 @	OK1KIR G3WDG IO92					
0832	-22	0.0	1015 @	OK1KIR G3WDG IO92					
0838	-22	0.0	1008 @	OK1KIR G3WDG IO92					
0848	-21	0.0	608 @	OK1KIR G3WDG IO92					

Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune

3cm 10,368.100 000

60+
50
40
30
20
10
0
0.0 dB

G3WDG IO92
Az: 52 5173 km
Lookup Add

2016 Jun 08
13:51:05

Submode H EME delay Fast F Tol 50

Generate Std Msgs Next Now Pwr

Message	Next	Now	Pwr
G3WDG OK1KIR FN42	<input checked="" type="radio"/>	Tx 1	
G3WDG OK1KIR -15	<input type="radio"/>	Tx 2	
G3WDG OK1KIR R-15	<input type="radio"/>	Tx 3	
G3WDG OK1KIR RRR	<input type="radio"/>	Tx 4	
G3WDG OK1KIR 73	<input type="radio"/>	Tx 5	
CQ OK1KIR FN42	<input type="radio"/>	Tx 6	

160408_0848.wav JT9 H Auto-Tx-Enable Disarmed 0/60

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, ...)
→ 800 – 2100 km, any time! **JTMSK**
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

The screenshot shows a software interface for Meteor Scatter. At the top, there are five buttons: Erase, Decode, Enable Tx, Halt Tx, and Tune. Below these, there is a section for message generation. A red circle highlights the following settings:

- Tx even/1st
- Rx 1500 Hz
- Report 26
- CQ Rx 265
- Sh
- Auto Seq
- T/R 5 s
- F Tol 500

To the right of these settings is a table with columns for 'Next', 'Now', and 'Pwr'. The 'Next' column contains a 'Generate Std Msgs' button. The 'Now' column contains a list of messages, each with a radio button and a 'Tx' button. The messages are:

Next	Now	Pwr
Generate Std Msgs		
VE1SKY K1JT FN20	<input checked="" type="radio"/> Tx 1	
<VE1SKY K1JT> 26	<input type="radio"/> Tx 2	
<VE1SKY K1JT> R26	<input type="radio"/> Tx 3	
<VE1SKY K1JT> RRR	<input type="radio"/> Tx 4	
<VE1SKY K1JT> 73	<input type="radio"/> Tx 5	
CQ K1JT FN20	<input type="radio"/> Tx 6	

MSK144 short messages

CQ K1ABC FN42

K1ABC W9XYZ EN37

W9XYZ K1ABC +06

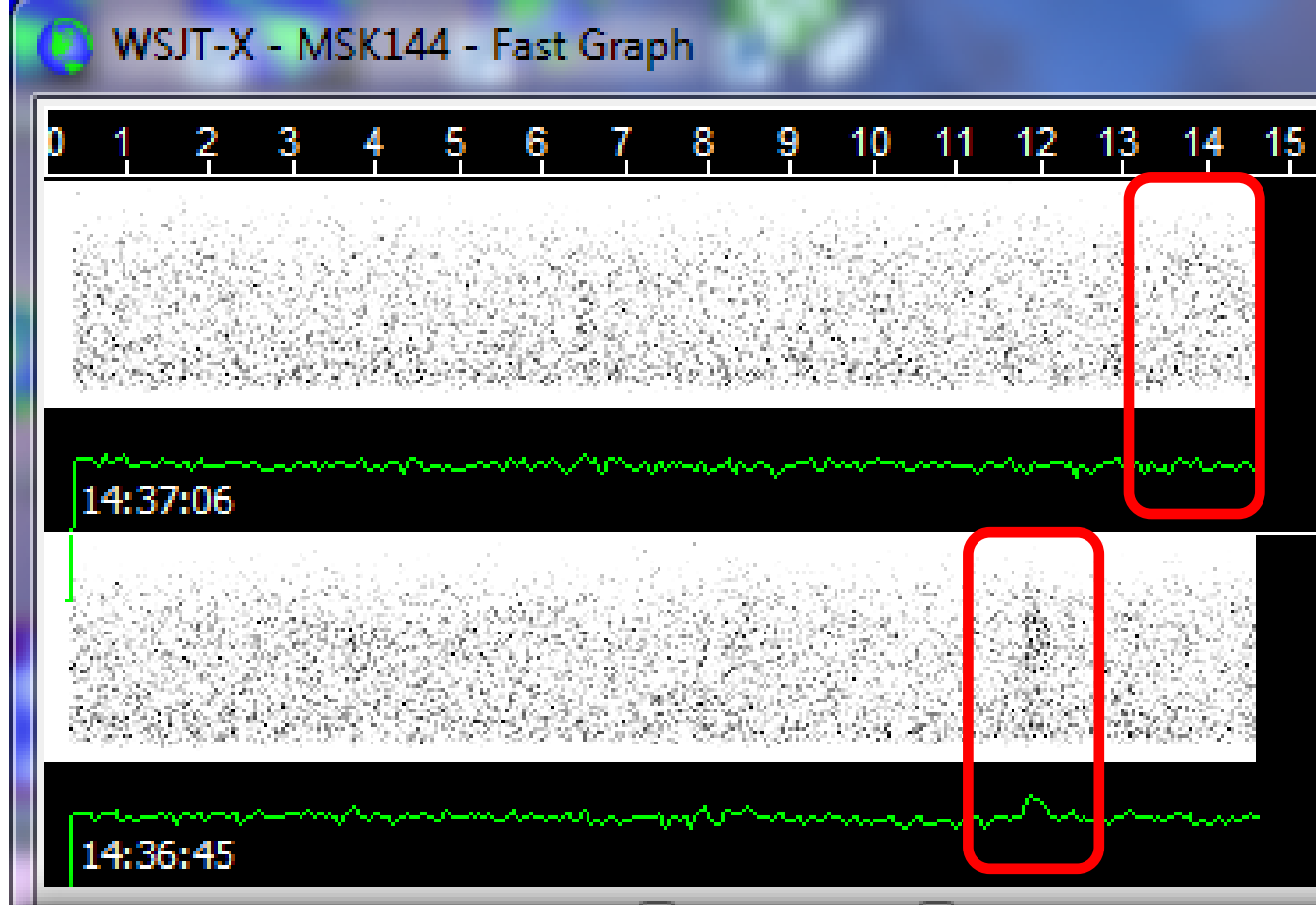
<K1ABC W9XYZ> R-03

<W9XYZ K1ABC> RRR

<K1ABC W9XYZ> 73

MSK144

Copy at
S/N = -4,
-5 dB



WSJT-X - MSK144 v1.7.0-rc1 by K1JT

File Configurations View Mode Decode Save Help

Band Activity

UTC	dB	T	Freq	Message
105800	-4	11.9	1527	& K1JT K9AN EN50
110430	-5	14.8	1524	& <K1JT K9AN> RRR

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