

Deep space communications – on earth?

2020-01-08

Presentation at SK7DX
by Björn Ekelund SM7IUN

The back story

- When Joe Taylor was approaching 60 in the late 90's, he got an urge to return to the hobby of his teens: ham radio.
- A childhood dream was to communicate using moon-bounce but he was also fascinated by intermittent propagations, such as meteor scatter.
- Having extensive experience from weak signal detection (radio astronomy) and deep space communications he wanted to try this also for himself.
- In 2001 the DOS-based software WSJT was released.
- He later joined forces with remote sensing Professor Steve Franke and brilliant British software designer Bill Somerville.

Two professors and a software guru



Prof. Joe Taylor, K1JT
Former Dean of the
Physics Department,
Princeton.
Nobel Laureate

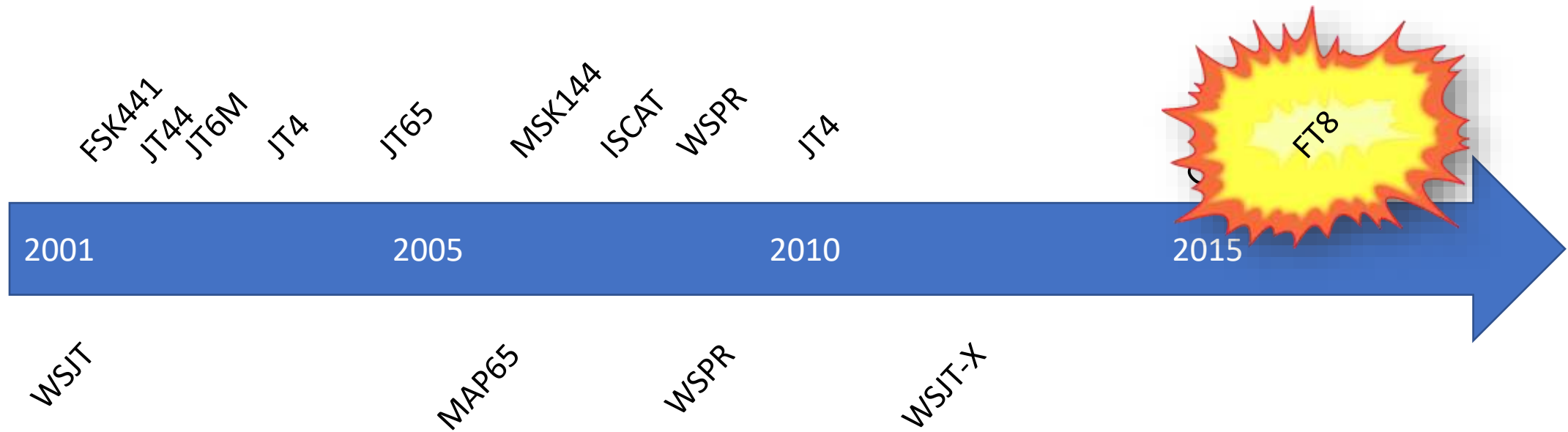


Prof. Steven J. Franke, K3AN
Electrical and Computer
Engineering
University of Illinois at
Urbana

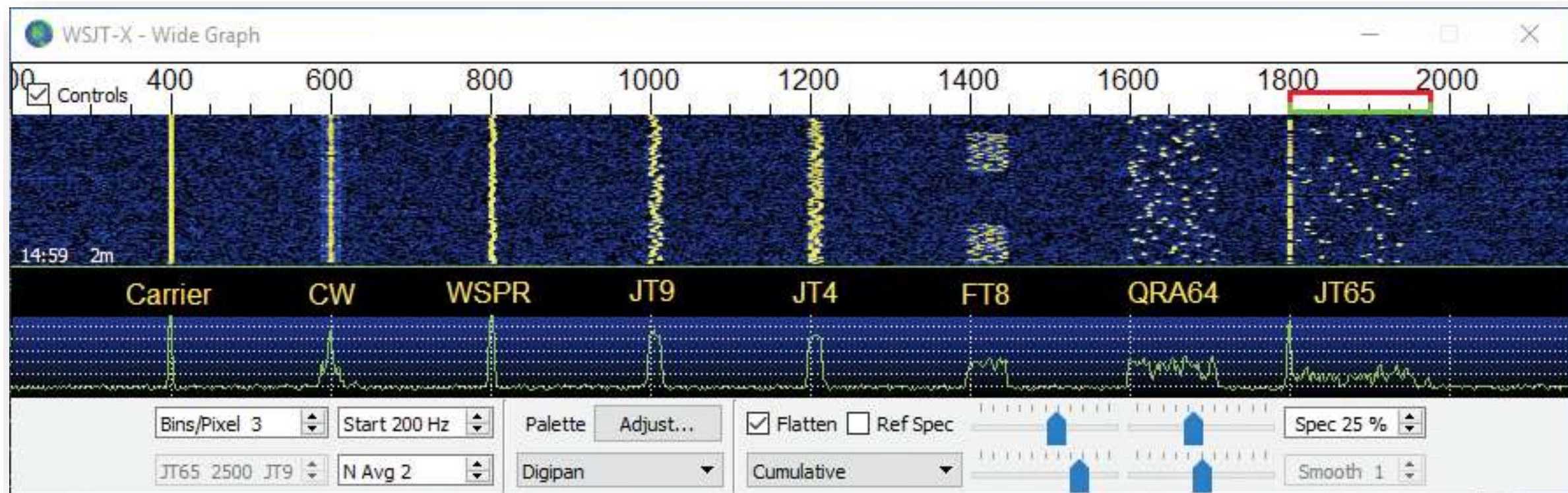


Bill Somerville, G4WJS
Freelance software engineer
Stokenchurch, UK

Evolution



Modulation characteristics



Better than CW? Only a little...

| Modulation + protocol | SNR @ 2.5kHz |
|-----------------------|--------------|
| SSB (telephony) | ~10dB |
| MSK441 | -8dB |
| FT4 | -16dB |
| Human Morse code | ~-18dB |
| FT8 | -20dB |
| JT65 | -25dB |
| QRA64 | -27dB |
| WSPR | -31dB |

FT8: DXing on Dead Bands

Some Say: The Greatest Thing Since...



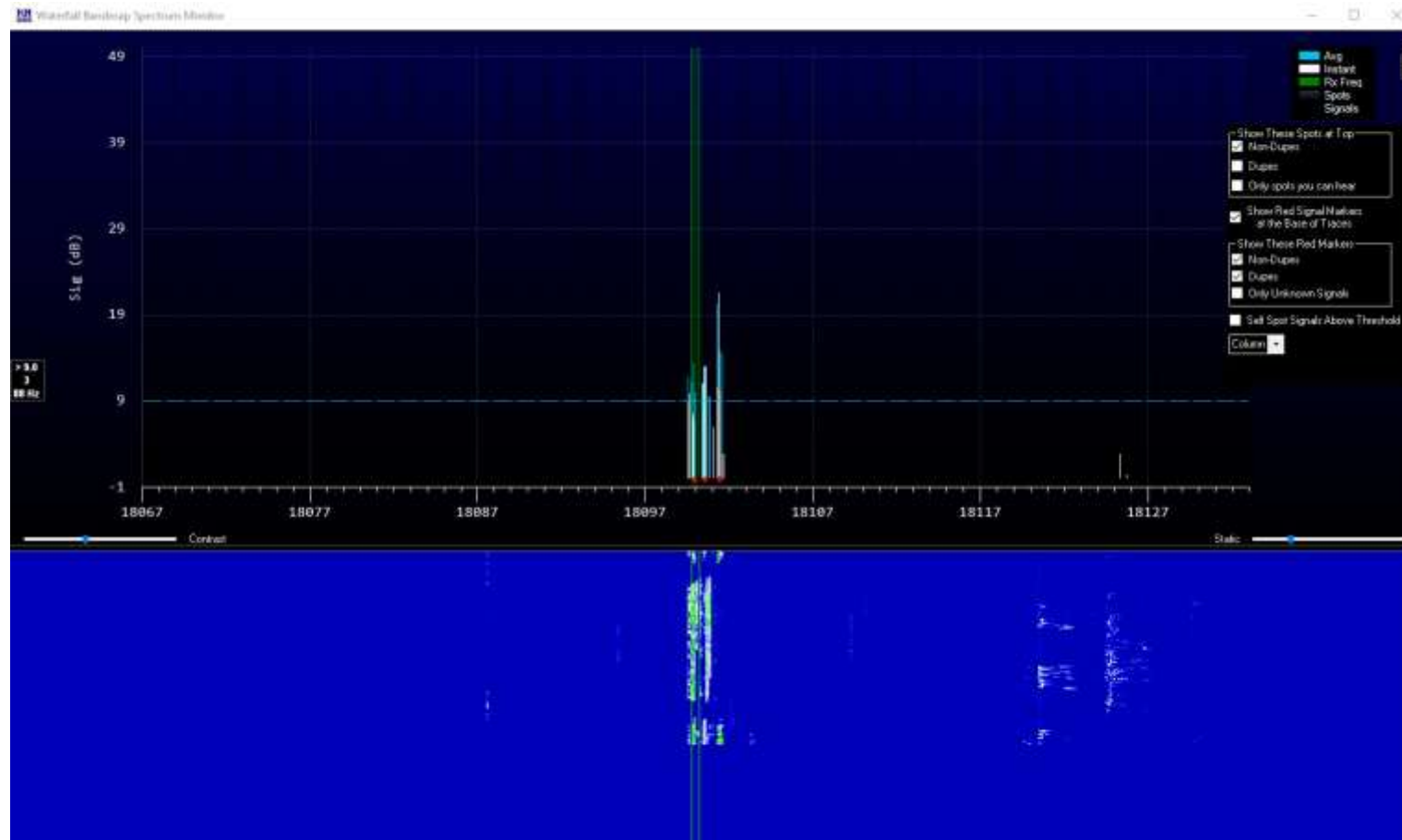
FT8: DXing on Dead Bands

Others Say: The End of Ham Radio as We Know It



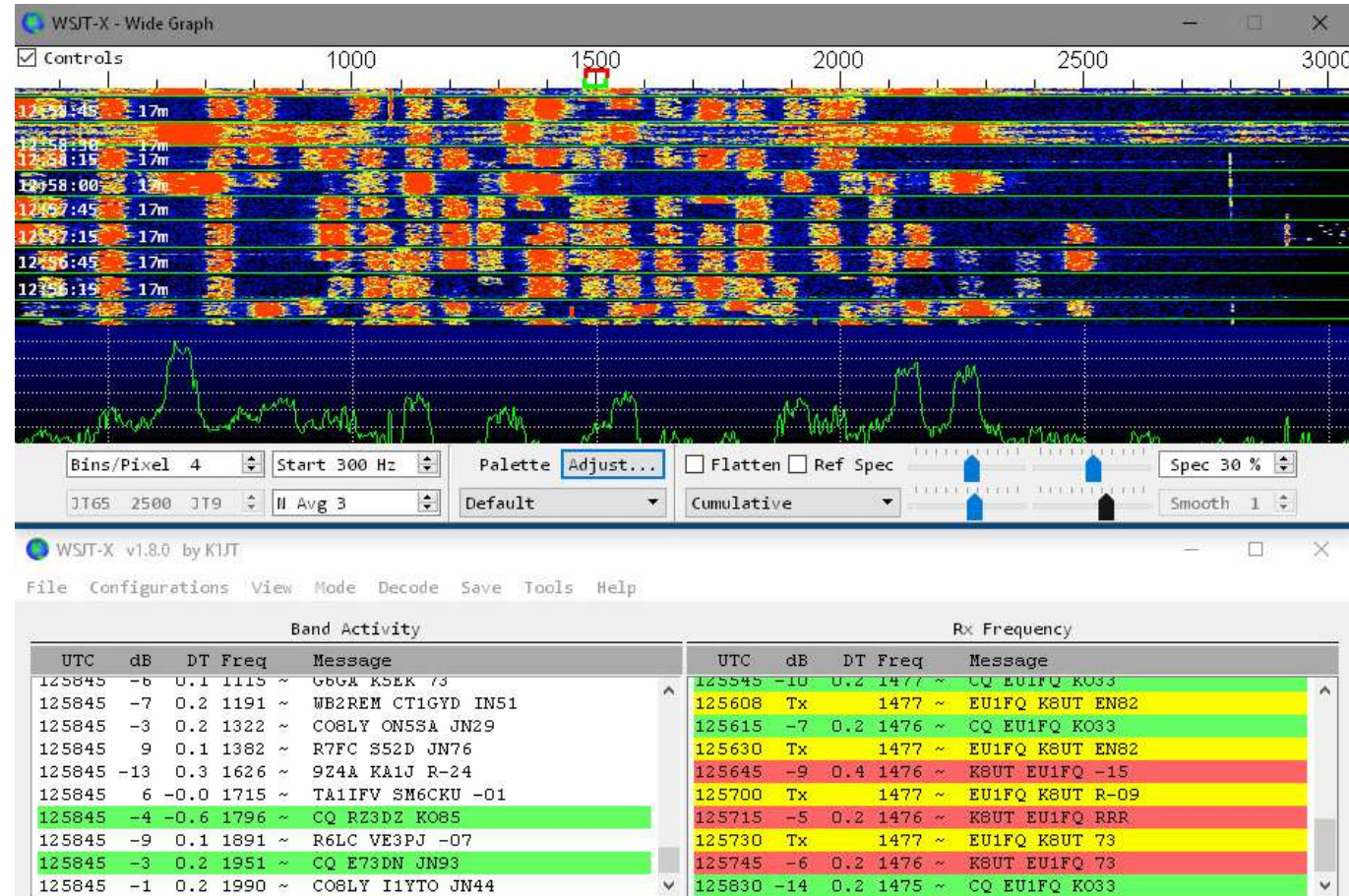
Slide courtesy of Larry Gauthier, K8UT

FT8: 17 Meters, Monday 8am



Slide courtesy of Larry Gauthier, K8UT

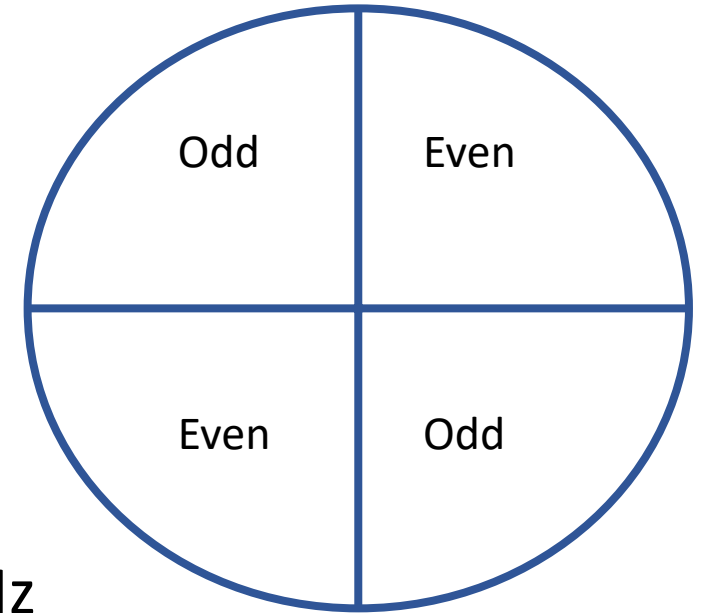
FT8: 17 Meters, Monday 8am



Slide courtesy of Larry Gauthier, K8UT

FT8 – Franke-Taylor-8FSK

- T/R sequence period: 15s
- Message length: 75 bits + 12-bit CRC
- FEC code: (174,87) LDPC
- Modulation: 8-FSK, keying rate = tone spacing = 6.25Hz
- Waveform: Continuous phase, constant envelope
- Occupied bandwidth: 50Hz
- Synchronization: Three 7 x 7 Costas arrays (start, middle, end of transmission)
- Transmission duration: $79 \times 1920 / 12000 = 12.64\text{s}$
- Decoding threshold: -20dB SNR (down to -24dB with a priori decoding)
- Multi-decoding: Finds and decodes all FT8 signals in passband



Equipment



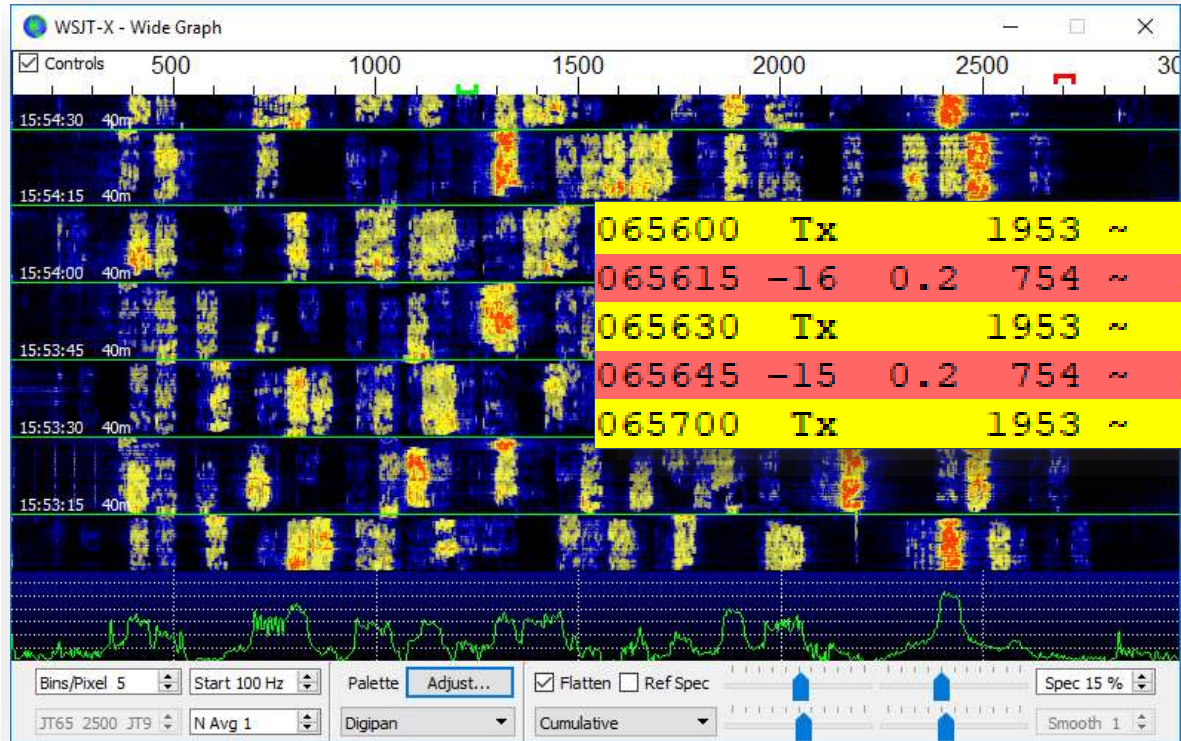
Audio



CAT



Using the software



WSJT-X v2.0.0 by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity

| UTC | dB | DT | Freq | Message |
|--------|-----|------|------|-------------------|
| 065615 | 0 | -0.2 | 2212 | CQ F5REQ IN97 |
| 065615 | -16 | 0.2 | 754 | SM7IUN ZL2LW -18 |
| 065615 | -10 | -0.4 | 1071 | DK7IX F5PVJ R+00 |
| 065615 | 7 | 0.1 | 1243 | CQ DX ON3MK JO21 |
| 065615 | -14 | 0.1 | 1488 | CQ 555GR JN75 |
| 065645 | -15 | 0.2 | 754 | SM7IUN ZL2LW RR73 |

Rx Frequency

| UTC | dB | DT | Freq | Message |
|--------|-----|-----|------|-------------------|
| 065315 | -33 | 0.1 | 800 | CQ GM4CXP IO85 |
| 065315 | -17 | 0.2 | 754 | FE50 ZL2LW R-11 |
| 065345 | -15 | 0.2 | 754 | FE50 ZL2LW R-12 |
| 065400 | Tx | | 1953 | ZL2LW SM7IUN JO65 |
| 065430 | Tx | | 1953 | ZL2LW SM7IUN JO65 |
| 065415 | -14 | 0.2 | 754 | FE50 ZL2LW 73 |
| 065500 | Tx | | 1953 | ZL2LW SM7IUN JO65 |
| 065515 | -24 | 0.2 | 754 | DL7KL ZL2LW R-14 |
| 065530 | Tx | | 1953 | ZL2LW SM7IUN JO65 |
| 065600 | Tx | | 1953 | ZL2LW SM7IUN JO65 |
| 065615 | -16 | 0.2 | 754 | SM7IUN ZL2LW -18 |
| 065630 | Tx | | 1953 | ZL2LW SM7IUN R-16 |
| 065645 | -15 | 0.2 | 754 | SM7IUN ZL2LW RR73 |
| 065700 | Tx | | 1953 | ZL2LW SM7IUN 73 |
| 065715 | -13 | 0.2 | 754 | CQ ZL2LW RF80 |

065715 1 0.1 702 - DF1KAG DB1OK JN48

065715 -12 -0.4 1071 - DK7IX F5PVJ 73

065715 -6 -0.5 1787 - CQ PF3X JO21

065715 9 0.1 2140 - LA3VL LB8MG -04

065715 -2 -0.2 2211 - CQ F5REQ IN97

065715 11 0.2 2379 - AA1XQ EA2DP -07

065715 -15 0.2 754 - CQ ZL2LW RF80

☐ CQ only Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune ☒ Menus

80m 3,573 000

DX Call DX Grid

ZL2LW

Az: 251 16553 km

Lookup Add

Report -15

Auto Seq Call list

2019 feb 22 06:57:32

Receiving FT8 Last Tx: ZL2LW SM7IUN 73

2/15 WD: 10m

Basic set-up of WSJT-X

WSJT-X v2.1.2 by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity

| UTC | dB | DT | Freq | Message |
|-----------------|-----|-----|------|----------------------|
| 200245 | -17 | 0.1 | 1327 | ~ CQ SV1TN KM18 |
| 200245 | 1 | 0.2 | 1570 | ~ HA8LN EI9KF -08 |
| 200245 | -8 | 0.1 | 1894 | ~ DL9HD UA2FF -13 |
| 200245 | 0 | 0.1 | 1952 | ~ E75JD ON7DE JO20 |
| 200245 | -14 | 0.1 | 2244 | ~ CQ RA3WII KO71 |
| 200245 | -7 | 0.6 | 2345 | ~ EC5CFV G4DBW -15 |
| 200245 | -10 | 0.1 | 2558 | ~ OY5ET US1IK KN88 |
| 200245 | -9 | 0.2 | 2855 | ~ CQ MORCM IO94 |
| 200245 | -1 | 0.3 | 2920 | ~ YB6HAI R6KX -21 |
| 200245 | -8 | 0.3 | 201 | ~ EC5CFV SV3AQT -07 |
| 200245 | 0 | 0.9 | 645 | ~ YO3GD GD3YUM -16 |
| 200245 | -16 | 1.0 | 729 | ~ PA3FRZ F6BHK JN24 |
| 200245 | -18 | 0.3 | 1095 | ~ MW0CSO TA7LZB KN90 |
| 200245 | -14 | 1.8 | 1414 | ~ ZS6GTK EALAGP IN73 |
| 200245 | -9 | 0.5 | 1563 | ~ TF3PPN M7RKK IO93 |
| 200245 | -21 | 0.3 | 2204 | ~ ZS6GTK GOCQZ IO91 |
| 200245 | -19 | 2.1 | 2601 | ~ F4ERS RV6HEG R-10 |
| 200245 | -10 | 0.1 | 662 | ~ UR3EO HA8RC RR73 |
| ----- 40m ----- | | | | |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200315 | -10 | 0.4 | 201 | ~ EC5CFV SV3AQT RR73 |
| 200315 | 2 | 0.6 | 325 | ~ CQ RW6AIC KN96 |
| 200315 | 1 | 0.1 | 377 | ~ 9K2OD EW4C -05 |
| 200315 | 3 | 0.8 | 800 | ~ CQ AF LA3WJA JP32 |
| 200315 | -19 | 2.4 | 916 | ~ BI6KAE IZ0XYX JN62 |

Rx Frequency

| UTC | dB | DT | Freq | Message |
|--------|-----|------|------|--------------------------|
| 195915 | -3 | 0.0 | 1374 | ~ CQ OY5ET IP62 |
| 195936 | Tx | | 1374 | ~ OY5ET SM7IUN JO65 |
| 195945 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET R-10 |
| 200000 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200015 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET 73 |
| 200030 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200045 | -6 | 0.1 | 1374 | ~ SM1HOW OY5ET -12 |
| 200100 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200115 | -6 | 0.1 | 1375 | ~ SM1HOW OY5ET RRR |
| 200145 | -4 | 0.0 | 1375 | ~ SM1HOW OY5ET 73 |
| 200200 | Tx | | 1100 | ~ OY5ET SM7IUN JO65 |
| 200215 | -3 | 0.0 | 1374 | ~ SM7IUN OY5ET -08 |
| 200230 | Tx | | 1100 | ~ OY5ET SM7IUN R-03 |
| 200245 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET RRR |
| 200300 | Tx | | 1100 | ~ OY5ET SM7IUN 73 |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200330 | 2 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200345 | -7 | 0.0 | 1375 | ~ G5LP OY5ET -08 |
| 200400 | -1 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200415 | -23 | 0.1 | 2401 | ~ CQ 5Z4/G3AB |
| 200436 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN JO65 |
| 200500 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN JO65 |
| 200530 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN JO65 |
| 200700 | -4 | 0.2 | 2403 | ~ <5Z4/G3AB> IZ8JFA -15 |
| 200730 | -9 | 0.1 | 2401 | ~ <5Z4/G3AB> SV1LIQ KM18 |

40m

7,074 000

TX 2832 Hz

Rx 2901 Hz

Report -19

Auto Seq

Call 1st

2020 jan 07 20:16:07

FT8 Last Tx: <5Z4/G3AB> SM7IUN JO65

Settings

General Radio Audio Tx Macros Reporting Frequencies Colors Advanced

Station Details

My Call: SM7IUN My Grid: JO65MR ☐ AutoGrid IARU Region: Region 1

Message generation for type 2 compound callsign holders: Full call in Tx3

Display

☐ Start new period decodes at top

☒ Blank line between decoding periods

☐ Display distance in miles

☒ Tx messages to Rx frequency window

☐ Show DXCC, grid, and worked-before status ☐ Show principal prefix instead of country name

Behavior

☐ Monitor off at startup ☐ Enable VHF/UHF/Microwave features

☐ Monitor returns to last used frequency ☒ Allow Tx frequency changes while transmitting

☒ Double-click on call sets Tx enable ☐ Single decode

☒ Disable Tx after sending 73 ☐ Decode after EME delay

☐ Calling CQ forces Call 1st

☐ Alternate F1-F6 bindings

☐ CW ID after 73

Tx watchdog: 14 minutes

Periodic CW ID Interval: 0

OK Cancel

Basic set-up of WSJT-X

WSJT-X v2.1.2 by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity

| UTC | dB | DT | Freq | Message |
|-----------|-----|-----|------|----------------------|
| 200245 | -17 | 0.1 | 1327 | ~ CQ SV1TN KM18 |
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| 200245 | 0 | 0.1 | 1952 | ~ E75JD ON7DE JO20 |
| 200245 | -14 | 0.1 | 2244 | ~ CQ RA3WII KO71 |
| 200245 | -7 | 0.6 | 2345 | ~ EC5CFV G4DBW -15 |
| 200245 | -10 | 0.1 | 2558 | ~ OY5ET US1IK KN88 |
| 200245 | -9 | 0.2 | 2855 | ~ CQ M0RCM IO94 |
| 200245 | -1 | 0.3 | 2920 | ~ YB6HAI R6KX -21 |
| 200245 | -8 | 0.3 | 201 | ~ EC5CFV SV3AQT -07 |
| 200245 | 0 | 0.9 | 645 | ~ YO3GD GD3YUM -16 |
| 200245 | -16 | 1.0 | 729 | ~ PA3FRZ F6BHK JN24 |
| 200245 | -18 | 0.3 | 1095 | ~ MW0CSO TA7LZB KN90 |
| 200245 | -14 | 1.8 | 1414 | ~ ZS6GTK EALAGP IN73 |
| 200245 | -9 | 0.5 | 1563 | ~ TF3PPN M7RKK IO93 |
| 200245 | -21 | 0.3 | 2204 | ~ ZS6GTK GOCQZ IO91 |
| 200245 | -19 | 2.1 | 2601 | ~ F4ERS RV6HEG R-10 |
| 200245 | -10 | 0.1 | 662 | ~ UR3EO HA8RC RR73 |
| ----- 40m | | | | |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200315 | -10 | 0.4 | 201 | ~ EC5CFV SV3AQT RR73 |
| 200315 | 2 | 0.6 | 325 | ~ CQ RW6AIC KN96 |
| 200315 | 1 | 0.1 | 377 | ~ 9K2OD EW4C -05 |
| 200315 | 3 | 0.8 | 800 | ~ CQ AF LA3WJA JP32 |
| 200315 | -19 | 2.4 | 916 | ~ BI6KAE IZ0XYX JN62 |

Rx Frequency

| UTC | dB | DT | Freq | Message |
|--------|-----|------|------|---------------------|
| 195915 | -3 | 0.0 | 1374 | ~ CQ OY5ET IP62 |
| 195936 | Tx | | 1374 | ~ OY5ET SM7IUN JO65 |
| 195945 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET R-10 |
| 200000 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200015 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET 73 |
| 200030 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200045 | -6 | 0.1 | 1374 | ~ SM1HOW OY5ET -12 |
| 200100 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200115 | -6 | 0.1 | 1375 | ~ SM1HOW OY5ET RRR |
| 200145 | -4 | 0.0 | 1375 | ~ SM1HOW OY5ET 73 |
| 200200 | Tx | | 1100 | ~ OY5ET SM7IUN JO65 |
| 200215 | -3 | 0.0 | 1374 | ~ SM7IUN OY5ET -08 |
| 200230 | Tx | | 1100 | ~ OY5ET SM7IUN R-03 |
| 200245 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET RRR |
| 200300 | Tx | | 1100 | ~ OY5ET SM7IUN 73 |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200330 | 2 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200345 | -7 | 0.0 | 1375 | ~ G5LP OY5ET -08 |
| 200400 | -1 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200415 | -23 | 0.1 | 2401 | ~ CQ 5Z4/G3AB |
| 200436 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200500 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200530 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200700 | -4 | 0.2 | 2403 | ~ <5Z4/G3AB> IZ8JFA |
| 200730 | -9 | 0.1 | 2401 | ~ <5Z4/G3AB> SV1LIQ |

40m 7,074 000

2020 jan 07 20:16:07

FT8 Last Tx: <5Z4/G3AB> SM7IUN JO65

Settings

General Radio Audio Tx Macros Reporting Frequencies Colors Advanced

Rig: Icom IC-7610 Poll Interval: 1s

CAT Control

Serial Port: COM8

Serial Port Parameters

Baud Rate: 115200

Data Bits

☐ Default ☐ Seven ☒ Eight

Stop Bits

☐ Default ☒ One ☐ Two

Handshake

☐ Default ☒ None ☐ XON/XOFF ☐ Hardware

Force Control Lines

DTR: RTS:

PTT Method

☐ VOX ☐ DTR ☒ CAT ☐ RTS

Port: COM7

Transmit Audio Source

☐ Rear/Data ☒ Front/Mic

Mode

☐ None ☐ USB ☒ Data/Pkt

Split Operation

☐ None ☐ Rig ☒ Fake It

Test CAT Test PTT

OK Cancel

“Split operation”

This setting has nothing to do with transmitting and receiving on different frequencies.

To secure a clean transmission WSJT-X only generates transmit audio signals between 1500kHz and 2000kHz and then modifies the base frequency down or up to achieve the wanted radio frequency.

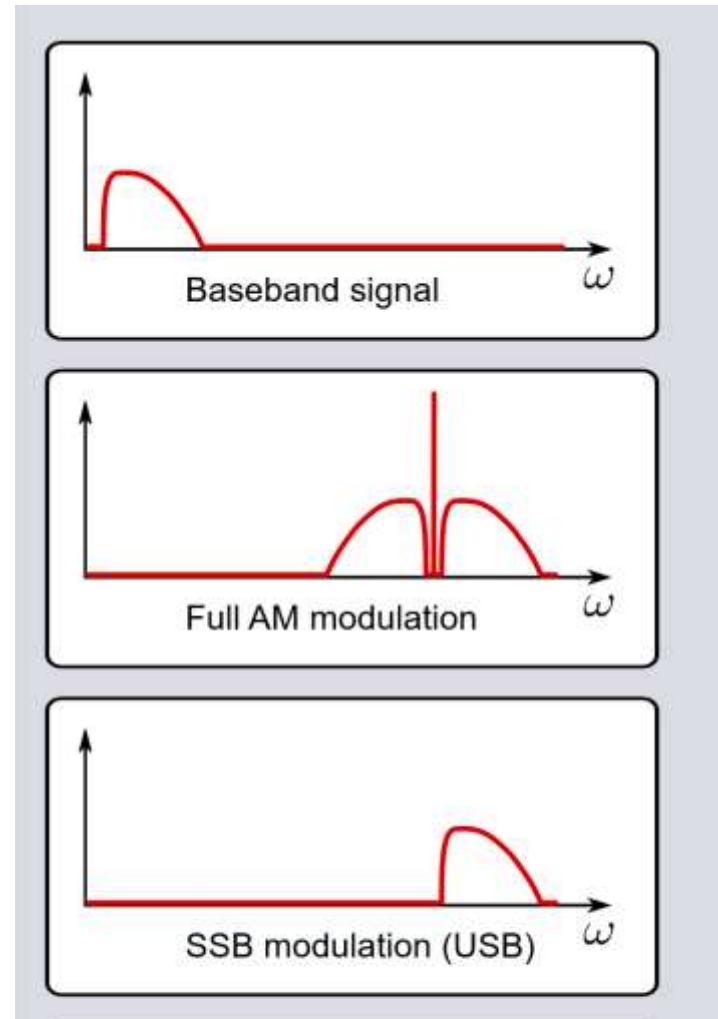
Example: You want to transmit on 3573.5kHz.

1. Radio on 3573kHz + audio 500Hz → RF on 3573.5kHz (bad)
2. Radio on 3572kHz + audio 1500Hz → RF on 3573.5kHz (good).

“**Rig**” puts the modified base frequency for transmission in VFO B and sets “Split operation” on the radio.

“**Fake it**” instead uses CAT commands. (Recommended!)

“None” should never be used unless you restrict transmission to above 1500Hz!



Basic set-up of WSJT-X

WSJT-X v2.1.2 by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity

| UTC | dB | DT | Freq | Message |
|-----------|-----|-----|------|----------------------|
| 200245 | -17 | 0.1 | 1327 | ~ CQ SV1TN KM18 |
| 200245 | 1 | 0.2 | 1570 | ~ HA8LN EI9KF -08 |
| 200245 | -8 | 0.1 | 1894 | ~ DL9HD UA2FF -13 |
| 200245 | 0 | 0.1 | 1952 | ~ E75JD ON7DE JO20 |
| 200245 | -14 | 0.1 | 2244 | ~ CQ RA3WII KO71 |
| 200245 | -7 | 0.6 | 2345 | ~ EC5CFV G4DBW -15 |
| 200245 | -10 | 0.1 | 2558 | ~ OY5ET US1IK KN88 |
| 200245 | -9 | 0.2 | 2855 | ~ CQ M0RCM IO94 |
| 200245 | -1 | 0.3 | 2920 | ~ YB6HAI R6KX -21 |
| 200245 | -8 | 0.3 | 201 | ~ EC5CFV SV3AQT -07 |
| 200245 | 0 | 0.9 | 645 | ~ YO3GD GD3YUM -16 |
| 200245 | -16 | 1.0 | 729 | ~ PA3FRZ F6BHK JN24 |
| 200245 | -18 | 0.3 | 1095 | ~ MW0CSO TA7LZB KN90 |
| 200245 | -14 | 1.8 | 1414 | ~ ZS6GTK EALAGP IN73 |
| 200245 | -9 | 0.5 | 1563 | ~ TF3PPN M7RKK IO93 |
| 200245 | -21 | 0.3 | 2204 | ~ ZS6GTK GOCQZ IO91 |
| 200245 | -19 | 2.1 | 2601 | ~ F4ERS RV6HEG R-10 |
| 200245 | -10 | 0.1 | 662 | ~ UR3EO HA8RC RR73 |
| ----- 40m | | | | |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200315 | -10 | 0.4 | 201 | ~ EC5CFV SV3AQT RR73 |
| 200315 | 2 | 0.6 | 325 | ~ CQ RW6AIC KN96 |
| 200315 | 1 | 0.1 | 377 | ~ 9K2OD EW4C -05 |
| 200315 | 3 | 0.8 | 800 | ~ CQ AF LA3WJA JP32 |
| 200315 | -19 | 2.4 | 916 | ~ BI6KAE IZ0YX JN62 |

Rx Frequency

| UTC | dB | DT | Freq | Message |
|--------|-----|------|------|---------------------|
| 195915 | -3 | 0.0 | 1374 | ~ CQ OY5ET IP62 |
| 195936 | Tx | | 1374 | ~ OY5ET SM7IUN JO65 |
| 195945 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET R-10 |
| 200000 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200015 | -7 | 0.0 | 1374 | ~ G3UEG OY5ET 73 |
| 200030 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200045 | -6 | 0.1 | 1374 | ~ SM1HOW OY5ET -12 |
| 200100 | Tx | | 1693 | ~ OY5ET SM7IUN JO65 |
| 200115 | -6 | 0.1 | 1375 | ~ SM1HOW OY5ET RRR |
| 200145 | -4 | 0.0 | 1375 | ~ SM1HOW OY5ET 73 |
| 200200 | Tx | | 1100 | ~ OY5ET SM7IUN JO65 |
| 200215 | -3 | 0.0 | 1374 | ~ SM7IUN OY5ET -08 |
| 200230 | Tx | | 1100 | ~ OY5ET SM7IUN R-03 |
| 200245 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET RRR |
| 200300 | Tx | | 1100 | ~ OY5ET SM7IUN 73 |
| 200315 | -6 | 0.0 | 1375 | ~ SM7IUN OY5ET 73 |
| 200330 | 2 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200345 | -7 | 0.0 | 1375 | ~ G5LP OY5ET -08 |
| 200400 | -1 | -0.5 | 1374 | ~ OY5ET G5LP IO92 |
| 200415 | -23 | 0.1 | 2401 | ~ CQ 5Z4/G3AB |
| 200436 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200500 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200530 | Tx | | 1100 | ~ <5Z4/G3AB> SM7IUN |
| 200700 | -4 | 0.2 | 2403 | ~ <5Z4/G3AB> IZ8JFA |
| 200730 | -9 | 0.1 | 2401 | ~ <5Z4/G3AB> SV1LIQ |

40m

Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx

40m 7,074 000 Tx even/1st Tx 2832 Hz Hold Tx Freq

DX Call DX Grid

5Z4/G3AB Rx 2901 Hz Report -19

Lookup Add

Auto Seq Call 1st

2020 jan 07 20:16:07

FT8 Last Tx: <5Z4/G3AB> SM7IUN JO65

Settings

General Radio Audio Tx Macros Reporting Frequencies Colors Advanced

Soundcard

Input: IC-7610 Rx (3- USB Audio CODEC) Left

Output: IC-7610 Tx (3- USB Audio CODEC) Both

Save Directory

Location: C:/Users/SM7IUN/AppData/Local/WSJT-X/save Select

AzEl Directory

Location: C:/Users/SM7IUN/AppData/Local/WSJT-X Select

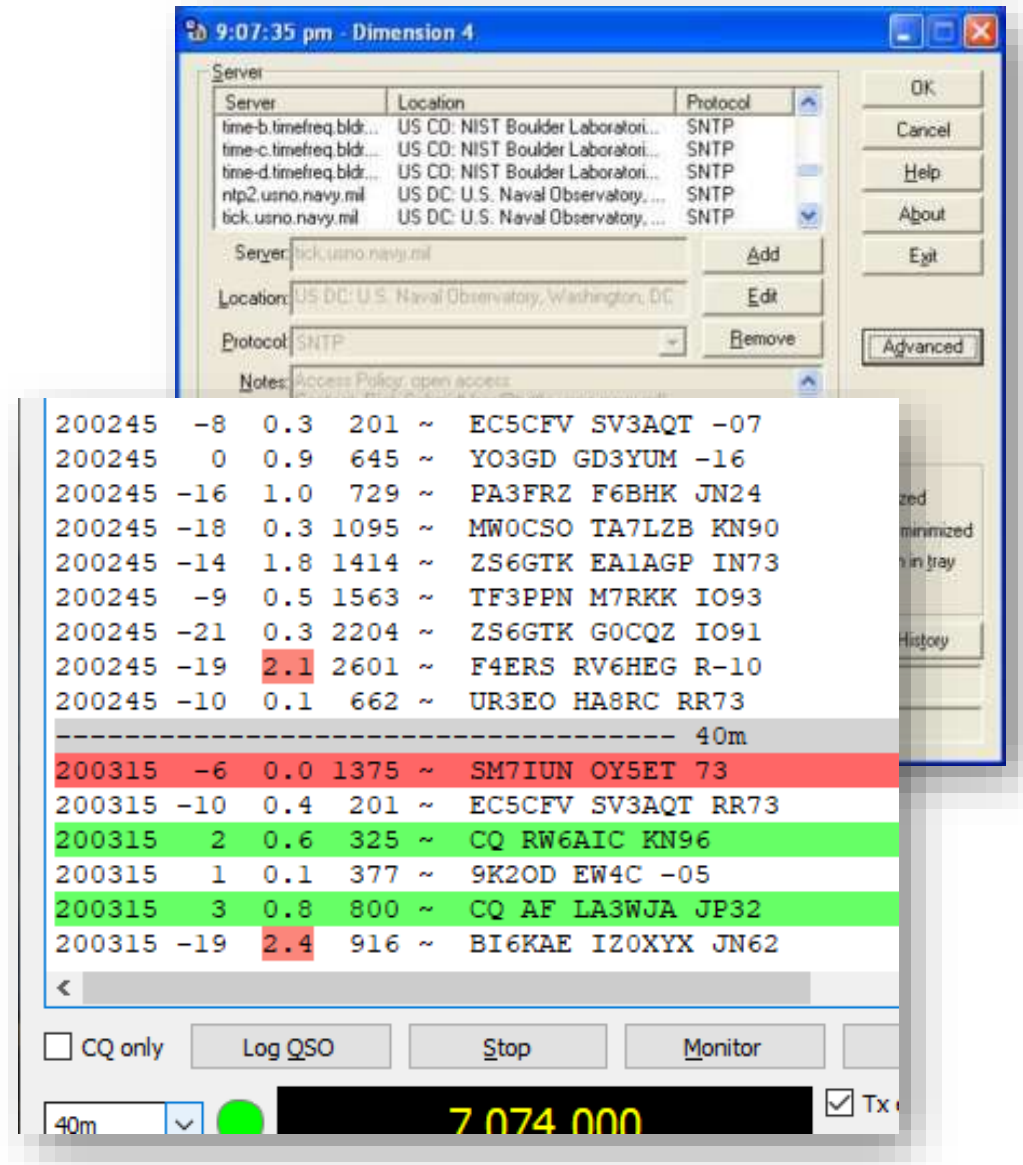
Remember power settings by band

☒ Transmit ☒ Tune

OK Cancel

Accurate time is essential

- Timing needs to be within 1 second.
- www.time.is – checks your clock.
- The built-in Windows facility for time synchronization is usually not adequate.
- *Meinberg NTP* and *Dimension 4* are popular time synchronization clients.



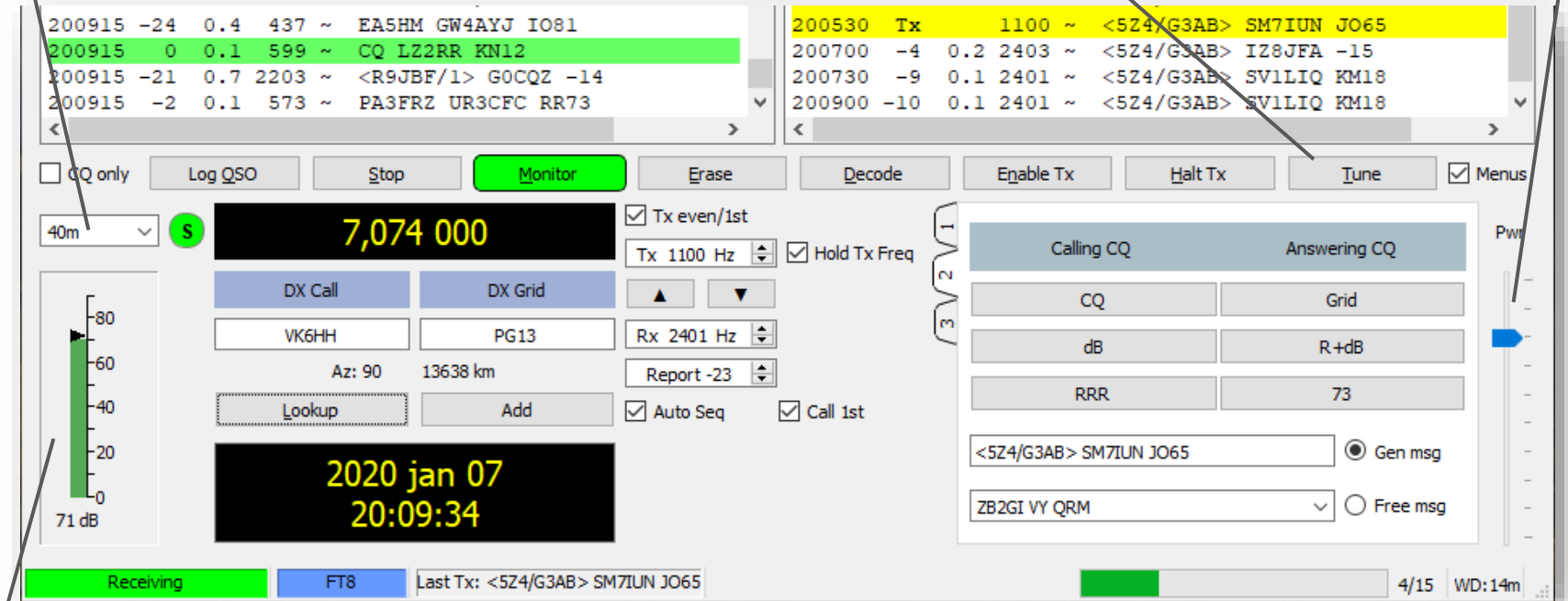
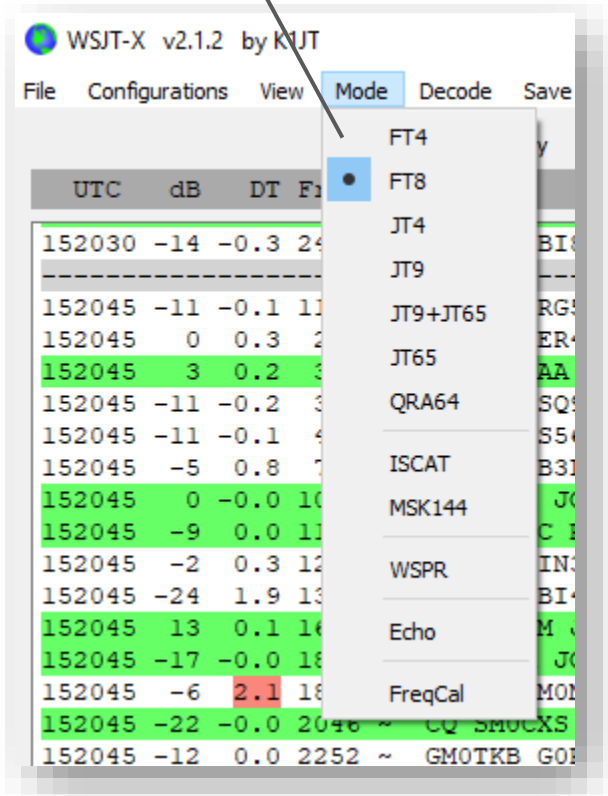
Getting Started

Select mode

Select band

Use Tune to check
power level

Adjust slider until
transmit power
drops



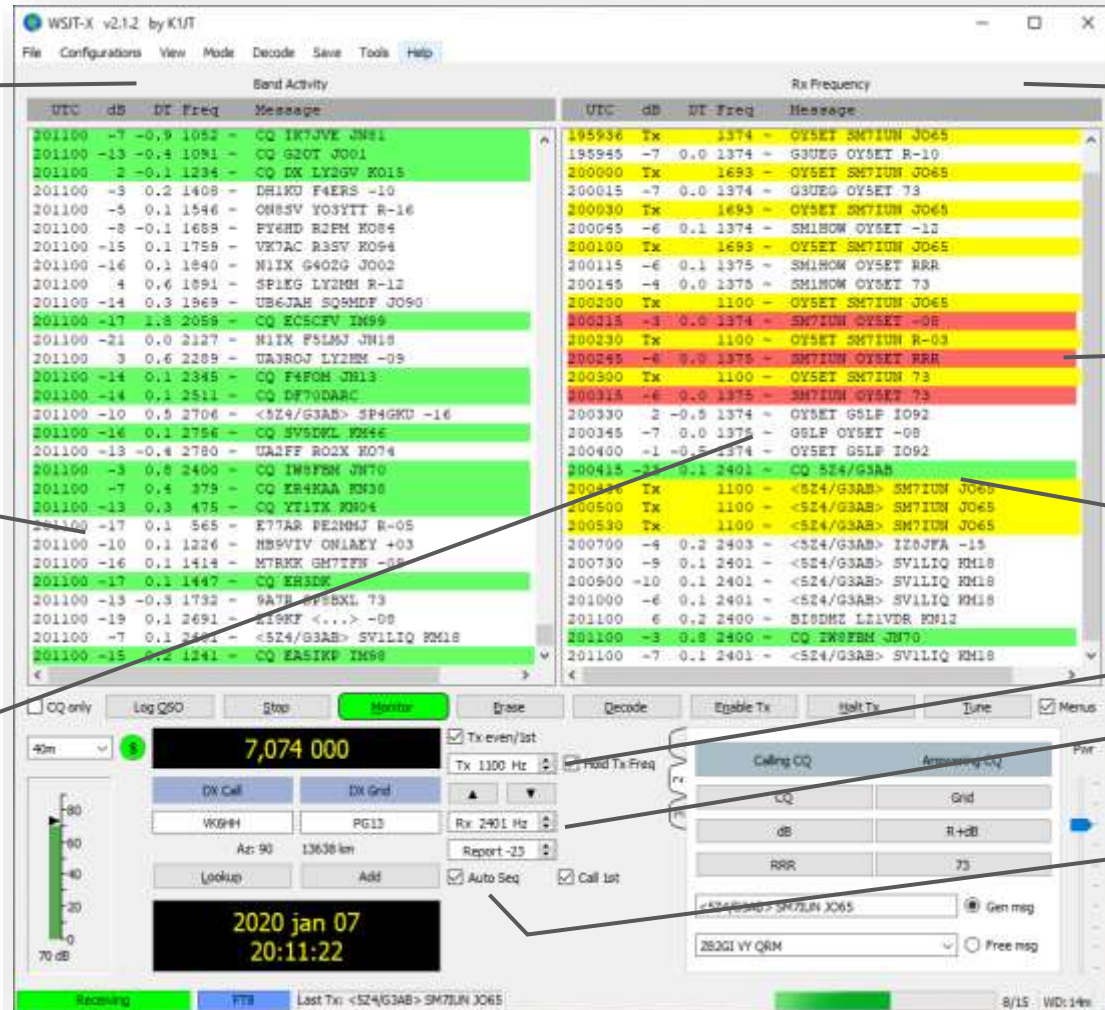
Adjust AF level as high as possible
without ever turning red.

WSJT-X Main Screen

All QSO activity
in the receive
spectrum

Stations calling
“CQ” are
highlighted in
green

Mentions of your
call are highlighted
in red



All activity shown
on the “Rx”
frequency

Your transmissions
are highlighted in
yellow

Your transmissions
are sent in a 50
Hz-wide slot at the
base frequency +
the audio offset

The message
transmissions are
generated
automatically and
sent in sequence

Where to send and receive

The screenshot shows the WSJT-X v2.1.2 interface. The Monitor window is open, displaying a list of stations with columns for UTC, dB, DT, and Frequency. The main control panel is also visible, showing settings for Tx and Rx frequencies, Hold Tx Freq, Auto Seq, and Call 1st. A call sign '00' is visible in the Monitor window.

Monitor Window:

| UTC | dB | DT | Freq | Message |
|--------|-----|------|------|------------------------|
| 201100 | -7 | -0.9 | 1052 | CQ 1W7JVE JN81 |
| 201100 | -13 | -0.4 | 1091 | CQ G2OT J001 |
| 201100 | -2 | -0.1 | 1234 | CQ DX LY2GV K015 |
| 201100 | -3 | 0.2 | 1409 | DH1KO F4ERS -10 |
| 201100 | -5 | 0.1 | 1546 | OH8SV Y03YIT R-16 |
| 201100 | -8 | -0.1 | 1688 | PT6HD R3PM K084 |
| 201100 | -15 | 0.1 | 1758 | VK7AC R3SV K084 |
| 201100 | -16 | 0.1 | 1840 | N1IX G40ZG J002 |
| 201100 | 4 | 0.6 | 1891 | SP1EG LY2MM R-12 |
| 201100 | -14 | 0.3 | 1969 | US6JAH SQMHDF J090 |
| 201100 | -17 | 1.8 | 2058 | CQ EC5CFV IM99 |
| 201100 | -21 | 0.0 | 2127 | N1IX F51MJ JN18 |
| 201100 | 3 | 0.6 | 2289 | UA3ROJ LY2MM -09 |
| 201100 | -14 | 0.1 | 2345 | CQ F4FOM JN13 |
| 201100 | -14 | 0.1 | 2511 | CQ DF70DARC |
| 201100 | -10 | 0.5 | 2706 | <S24/G3AB> SP4GKD -16 |
| 201100 | -16 | 0.1 | 2756 | CQ SV5DKL KX46 |
| 201100 | -13 | -0.4 | 2780 | UA2FF R02X K074 |
| 201100 | -3 | 0.8 | 2400 | CQ IW8FSN JN70 |
| 201100 | -7 | 0.4 | 379 | CQ IR4KAA KX30 |
| 201100 | -13 | 0.3 | 475 | CQ YT1TX KX04 |
| 201100 | -17 | 0.1 | 565 | E77AR PE2N04J R-05 |
| 201100 | -10 | 0.1 | 1226 | HB9VIV ON1AEY +03 |
| 201100 | -16 | 0.1 | 1414 | MT8KK GM7TFW -09 |
| 201100 | -17 | 0.1 | 1447 | CQ EH3DK |
| 201100 | -13 | -0.3 | 1732 | 9A7H SP8BX1 73 |
| 201100 | -19 | 0.1 | 2691 | K19KF <...> -08 |
| 201100 | -7 | 0.1 | 2401 | <S24/G3AB> SV11IQ KX18 |
| 201100 | -15 | 0.2 | 1241 | CQ EASIKP IM98 |

Main Control Panel:

- Monitor** (highlighted)
- Erase**
- Decode**
- 00** (Call sign)
- ☒ Tx even/1st
- Tx 1100 Hz**
- ☒ Hold Tx Freq
- DX Grid**
- PG13**
- 38 km**
- Add**
- 07** (Call sign)
- Rx 2401 Hz**
- Report -23**
- ☒ Auto Seq
- ☒ Call 1st

Bottom Panel:

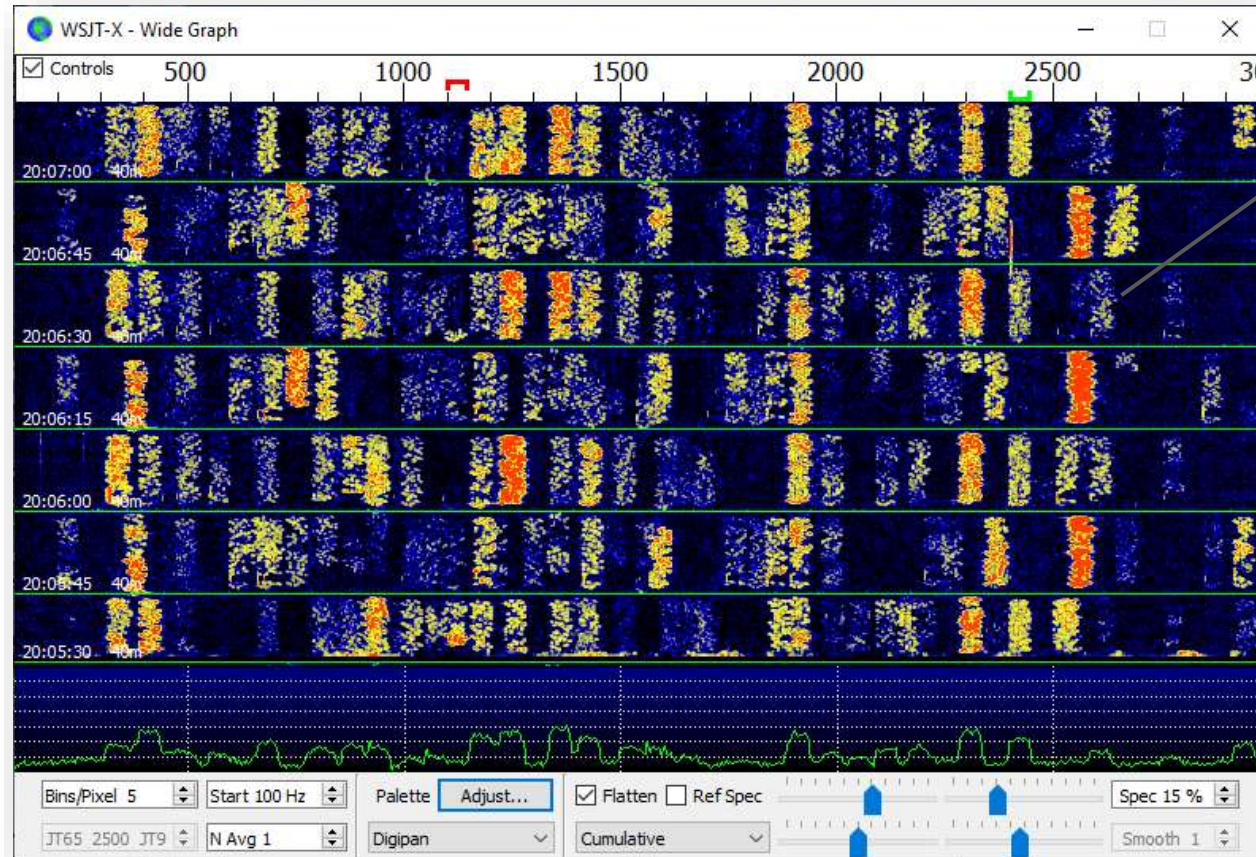
- 7,074 000** (Frequency)
- 40m** (Band)
- DX Call** (Call sign)
- DX Grid** (Grid)
- W8BH** (Call sign)
- PG13** (Grid)
- Az: 90** (Azimuth)
- 13636 km** (Distance)
- Report -23** (Report)
- 2020 jan 07** (Date)
- 20:11:22** (Time)
- Receiving** (Status)
- PT8** (Mode)
- Last Tx: <S24/G3AB> SM7JUN J065** (Last transmission)

- Frequencies are offset vs. base frequency.
- Check "Hold Tx Freq"
- Check "Auto Seq"
- Personal choice if you want to check "Call 1st"

The Looks and Sounds of FT8

Clickable
waterfall
display

- Click = Rx
- Shift-Click = Tx
- Ctrl-Click = Both



15 seconds,
50 Hz segments

Single FT8 signal

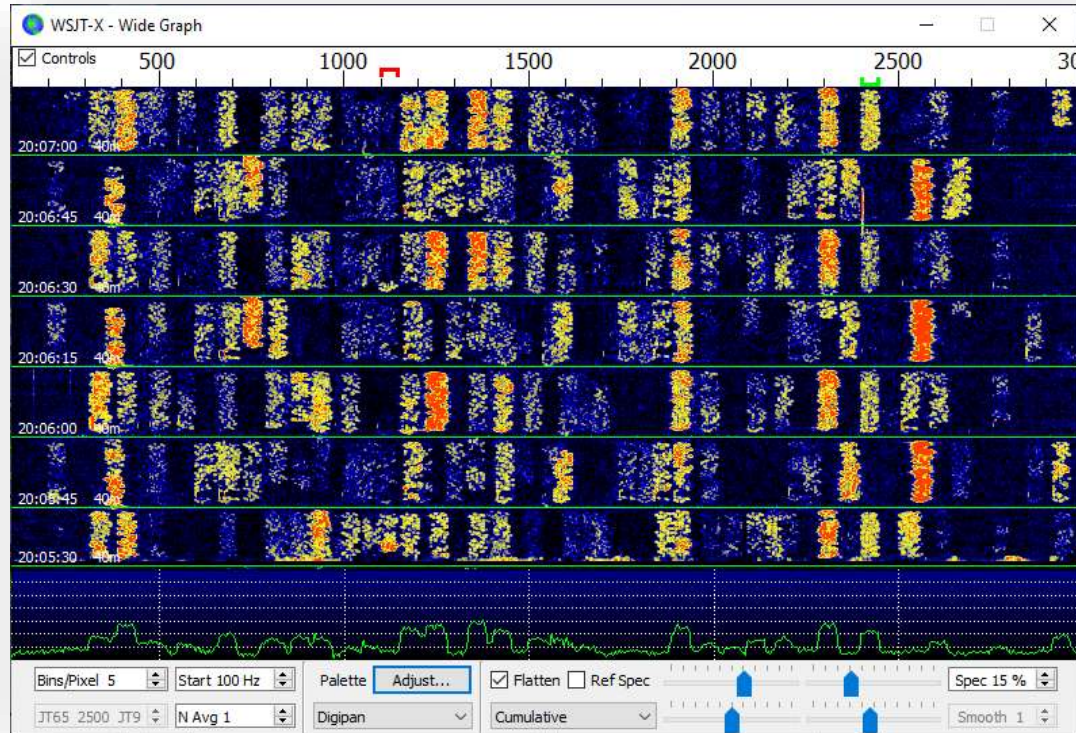


An entire FT8 sub-band

Audio courtesy of Dave le Vasseur, N0DL

Typical QSO sequence

- Select a clear transmit slot with Shift-Click.
- Avoid transmitting on the same offset as the station you call.
- Double-Click to call a station calling CQ.



| UTC | dB | DT | Freq | Message |
|--------|-----|-----|------|------------------------|
| 201100 | -7 | 0.9 | 1082 | CQ IK7JVE JN61 |
| 201100 | -13 | 0.4 | 1091 | CQ G2OT J001 |
| 201100 | -2 | 0.1 | 1234 | CQ EX LY2GV K015 |
| 201100 | -3 | 0.2 | 1408 | DR1KO F4ERS -10 |
| 201100 | -5 | 0.1 | 1546 | OM8SV Y03YTT R-16 |
| 201100 | -8 | 0.1 | 1689 | FY6HD R3FM K084 |
| 201100 | -15 | 0.1 | 1759 | VH7AC R3SV K094 |
| 201100 | -16 | 0.1 | 1840 | N1IX G40ZG J002 |
| 201100 | -4 | 0.6 | 1891 | SP1EG LY2MM R-12 |
| 201100 | -14 | 0.3 | 1969 | UB6JAH SQ5MDF J090 |
| 201100 | -17 | 1.8 | 2059 | CQ EC5CFV IN99 |
| 201100 | -21 | 0.0 | 2127 | N1IX F51MJ JN18 |
| 201100 | -3 | 0.6 | 2289 | UA3ROJ LY2MM -09 |
| 201100 | -14 | 0.1 | 2345 | CQ F4FOM JN13 |
| 201100 | -14 | 0.1 | 2511 | CQ DF70DARC |
| 201100 | -10 | 0.5 | 2706 | <524/G3AB> SP4GKD -16 |
| 201100 | -16 | 0.1 | 2756 | CQ SV5DKL FM46 |
| 201100 | -13 | 0.4 | 2780 | UA2FF RO2X K074 |
| 201100 | -3 | 0.8 | 2400 | CQ IW5FBN JN70 |
| 201100 | -7 | 0.4 | 379 | CQ ER4KAA K030 |
| 201100 | -13 | 0.3 | 475 | CQ YT1TX K004 |
| 201100 | -17 | 0.1 | 565 | E77AR PE2MMJ R-05 |
| 201100 | -10 | 0.1 | 1226 | HB9VIV ON1AKY +03 |
| 201100 | -16 | 0.1 | 1414 | MT8KK SM7TFW -09 |
| 201100 | -17 | 0.1 | 1447 | CQ ER3DK |
| 201100 | -13 | 0.3 | 1732 | 9A7R SP5BKX 73 |
| 201100 | -19 | 0.1 | 2691 | E19KF <...> -08 |
| 201100 | -7 | 0.1 | 2401 | <524/G3AB> SV1LIQ K018 |
| 201100 | -15 | 0.2 | 1241 | CQ EASIKP IN98 |

| UTC | dB | DT | Freq | Message |
|--------|-----|-----|------|------------------------|
| 195945 | -7 | 0.0 | 1374 | OY5ET SM7IUN J045 |
| 195945 | -7 | 0.0 | 1374 | G3UEG OY5ET R-10 |
| 200000 | Tx | | 1693 | OY5ET SM7IUN J045 |
| 200015 | -7 | 0.0 | 1374 | G3UEG OY5ET 73 |
| 200030 | Tx | | 1693 | OY5ET SM7IUN J045 |
| 200045 | -6 | 0.1 | 1374 | SM1HOW OY5ET -12 |
| 200100 | Tx | | 1693 | OY5ET SM7IUN J045 |
| 200115 | -6 | 0.1 | 1375 | SM1HOW OY5ET RRR |
| 200145 | -4 | 0.0 | 1375 | SM1HOW OY5ET 73 |
| 200200 | Tx | | 1100 | OY5ET SM7IUN J045 |
| 200215 | -4 | 0.0 | 1374 | SM7IUN OY5ET -08 |
| 200230 | Tx | | 1100 | OY5ET SM7IUN R-03 |
| 200245 | -8 | 0.0 | 1375 | SM7IUN OY5ET RRR |
| 200300 | Tx | | 1100 | OY5ET SM7IUN 73 |
| 200315 | -6 | 0.0 | 1375 | SM7IUN OY5ET 73 |
| 200330 | -2 | 0.0 | 1374 | OY5ET G5LF IO92 |
| 200345 | -7 | 0.0 | 1375 | G5LF OY5ET -08 |
| 200400 | -1 | 0.0 | 1374 | OY5ET G5LF IO92 |
| 200415 | -25 | 0.1 | 2401 | CQ 524/G3AB |
| 200436 | Tx | | 1100 | <524/G3AB> SM7IUN J045 |
| 200500 | Tx | | 1100 | <524/G3AB> SM7IUN J045 |
| 200530 | Tx | | 1100 | <524/G3AB> SM7IUN J045 |
| 200700 | -4 | 0.2 | 2403 | <524/G3AB> IZ0JFA -15 |
| 200730 | -9 | 0.1 | 2401 | <524/G3AB> SV1LIQ K018 |
| 200900 | -10 | 0.1 | 2401 | <524/G3AB> SV1LIQ K018 |
| 201000 | -6 | 0.1 | 2401 | <524/G3AB> SV1LIQ K018 |
| 201100 | 6 | 0.2 | 2400 | B18DMZ LL2VDR K012 |
| 201100 | -3 | 0.8 | 2400 | CQ IW5FBN JN70 |
| 201100 | -7 | 0.1 | 2401 | <524/G3AB> SV1LIQ K018 |

Log QSO Stop Monitor Erase Decode Enable Tx Split Tx Tune Menu

40m 7,074 000 Tx even/list Tx 1100 Hz Hold Tx Freq

DX Call DX Grid W09EH PG13 Rx 2401 Hz Report -25 Auto Seq Call list

2020 jan 07 20:11:22

Receiving FTS Last Tx: <524/G3AB> SM7IUN J045 8/15 WD: 14m

Typical contact – message exchange

| Party station | You |
|-------------------|-------------------|
| CQ ZL2LW RF80 | |
| | ZL2LW SM7IUN JO65 |
| SM7IUN ZL2LW -18 | |
| | ZL2LW SM7IUN R-16 |
| SM7IUN ZL2LW RR73 | |
| | ZL2LW SM7IUN 73 |

Sometimes magic happens

| | | | | | | |
|--------|-----|-----|------|---|--------------------|----|
| 061000 | Tx | | 1357 | ~ | CQ SM7IUN JO65 | |
| 061015 | -3 | 0.1 | 1358 | ~ | SM7IUN IU8CEE JN71 | |
| 061015 | -6 | 0.3 | 1357 | ~ | SM7IUN RW6AB KN95 | a2 |
| 061015 | -13 | 0.7 | 1357 | ~ | SM7IUN VK2EHQ QF56 | |

Spotting: PSK Reporter

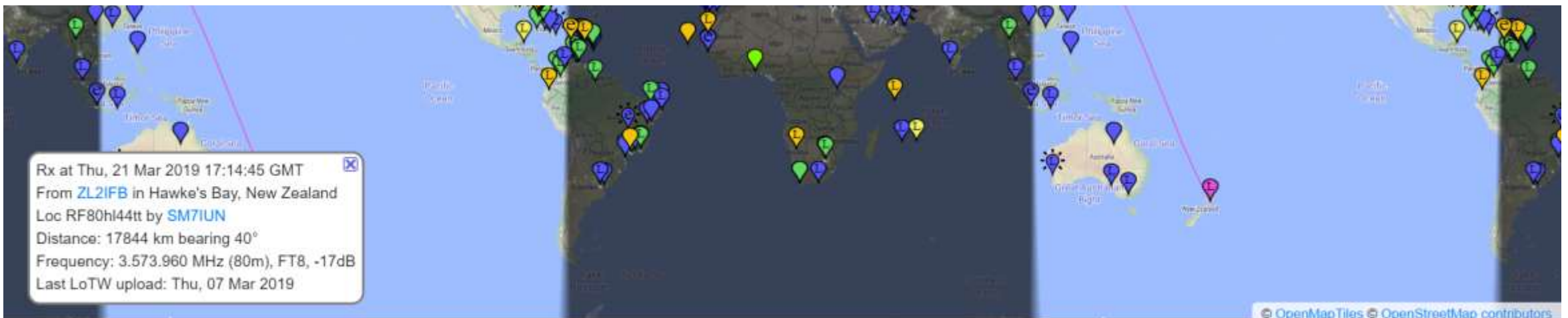
On , show , rcvd by using over the last [Display options](#) [Permalink](#)

Automatic refresh in 3 minutes. Small markers are the 1621 transmitters ([show logbook](#)) heard ([distance chart](#)) at SM7IUN (22426 reports, 135 countries last 24 hours; 158269 reports, 150 countries last week).

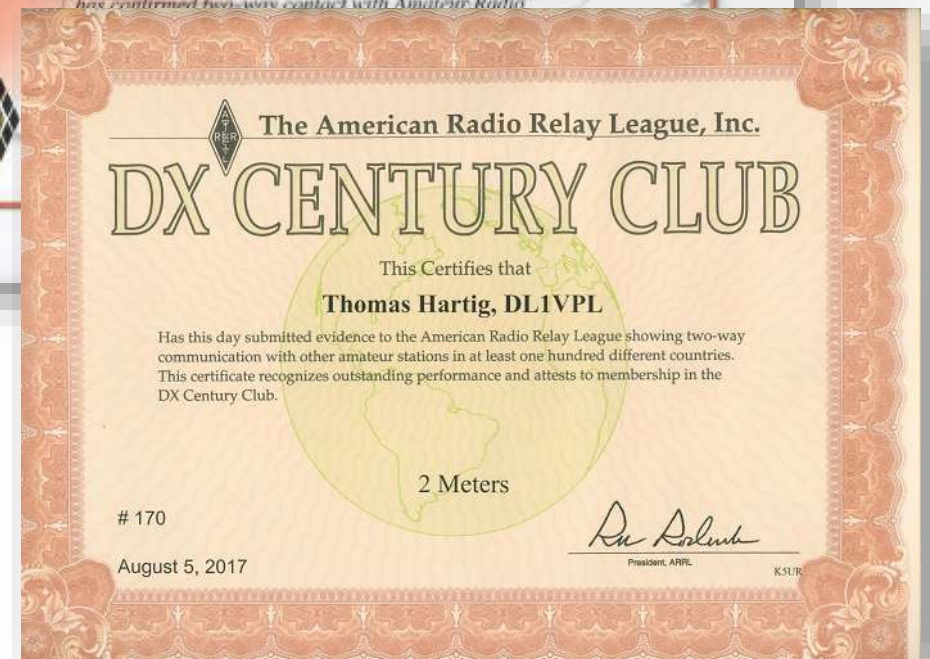
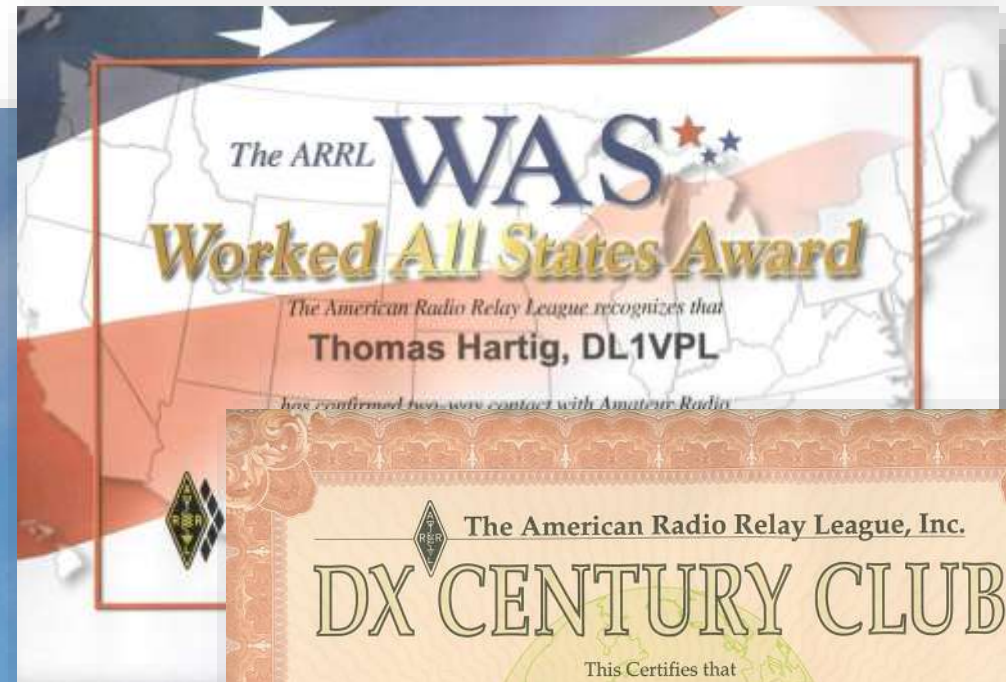
There are 3357 active monitors: 1031 on 40m, 918 on 20m, 474 on 30m, 284 on 80m, 131 on 17m, 128 on 160m, 109 on 60m, 87 on 15m, 60 on 2m, 56 on 6m, 33 on unknown, 4 on 10m, 4 on 600m, 3 on 23cm, 3 on 4m, 2 on 2200m, 1 on uhf. [Legend](#)



([distance chart](#)) at SM7IUN (24775 reports, 143 countries last 24 hours; 160391 reports, 149 countries last week).



There is also **real** space communication



Resources

- Lecture on weak signal communications by Joe Taylor
https://youtu.be/233HQs_8JGQ
- Lecture on the evolution of FT8 and FT4 by Joe Taylor
<https://youtu.be/2Pd7zB40xdY>
- Joe Taylor's web page at Princeton University
<https://physics.princeton.edu/pulsar/k1jt>
- Ham radio science organization
<http://www.hamsci.org/>

Table 1: Parameters of the Slow WSJT-X Protocols

Bandwidths (BW) are for the narrowest submodes. S/N threshold is referenced to a 2,500 Hz bandwidth at a 50% probability for decoding of an unfading signal.

| Mode | FEC type (n,k) | q m | Modulation | Keying rate, baud | BW, Hz | Sync energy | TX duration, s | S/N threshold, dB |
|-------|----------------|------|------------|-------------------|--------|-------------|----------------|-------------------|
| FT8 | LDPC(174,87) | 1 3 | 8-FSK | 6.250 | 50.0 | 0.27 | 12.6 | −20 |
| JT4 | C(206,72) | 1 2 | 4-FSK | 4.375 | 17.5 | 0.50 | 47.1 | −23 |
| JT9 | C(206,72) | 1 3# | 9-FSK | 1.736 | 15.6 | 0.19 | 49.0 | −27 |
| JT65 | RS(63,12) | 6 6# | 65-FSK | 2.692 | 177.6 | 0.50 | 46.8 | −25 |
| QRA64 | QRA(63,12) | 6 6 | 64-FSK | 1.736 | 111.1 | 0.25 | 48.4 | −26 |
| WSPR | C(162,50) | 1 2 | 4-FSK | 1.465 | 5.9 | 0.50 | 110.6 | −28 |

#Modulation includes one additional tone used for synchronization.

Table 2: Parameters of the Fast WSJT-X Protocols

MSK144-Sh is the optional short-message format in the MSK144 protocol.

| Mode | FEC type (n,k) | q m | Mod | Keying rate, baud | BW, Hz | Sync energy | Message duration, s |
|-----------|----------------|------|--------|-------------------|--------|-------------|---------------------|
| ISCAT-A | — | — | 42-FSK | 21.5 | 905 | 0.17 | 1.176 |
| ISCAT-B | — | — | 42-FSK | 43.1 | 1809 | 0.17 | 0.588 |
| JT9E | C(206,72) | 1 3# | 9-FSK | 25 | 225 | 0.19 | 3.400 |
| JT9F | C(206,72) | 1 3# | 9-FSK | 50 | 450 | 0.19 | 1.700 |
| JT9G | C(206,72) | 1 3# | 9-FSK | 100 | 900 | 0.19 | 0.850 |
| JT9H | C(206,72) | 1 3# | 9-FSK | 200 | 1800 | 0.19 | 0.425 |
| MSK144 | LDPC(128,80) | 1 1 | OQPSK | 2,000 | 2400 | 0.11 | 0.072 |
| MSK144-Sh | LDPC(32,16) | 1 1 | OQPSK | 2,000 | 2400 | 0.20 | 0.020 |

#Modulation includes one additional tone used for synchronization.