

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

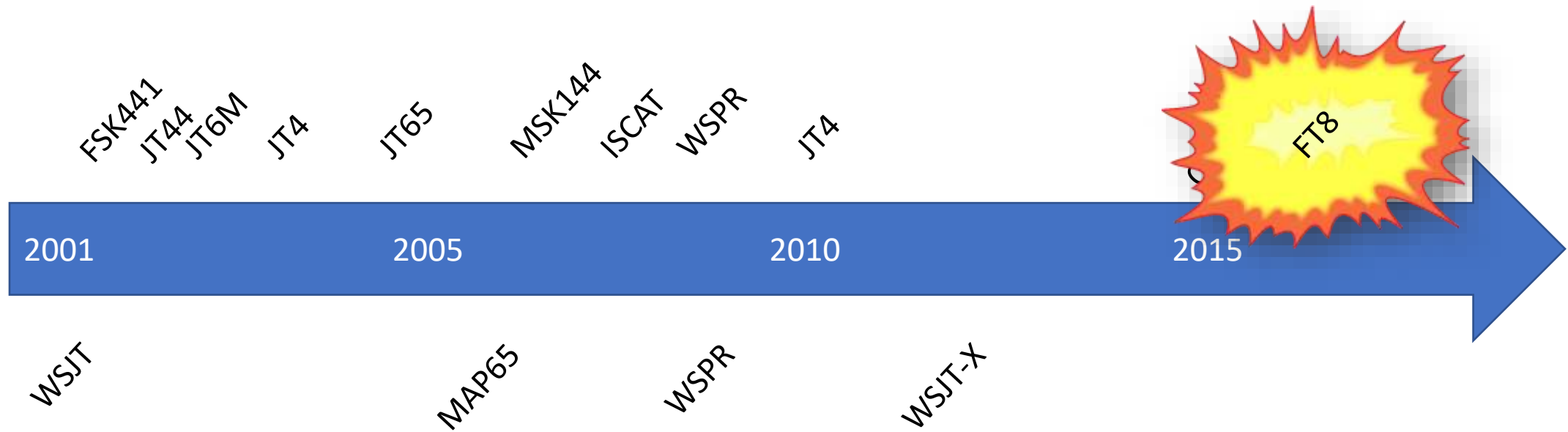


Prof. Steven J. Franke, K3AN
Electrical and Computer
Engineering
University of Illinois at
Urbana

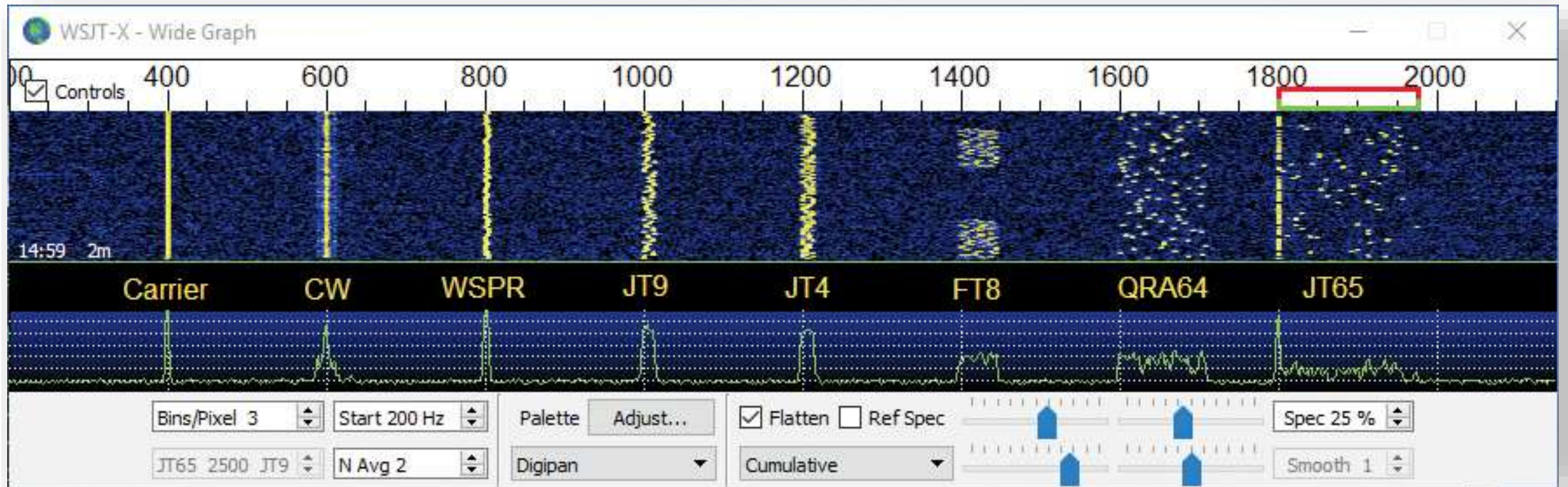


Bill Somerville, G4WJS
Freelance software engineer
Stokenchurch, UK

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...



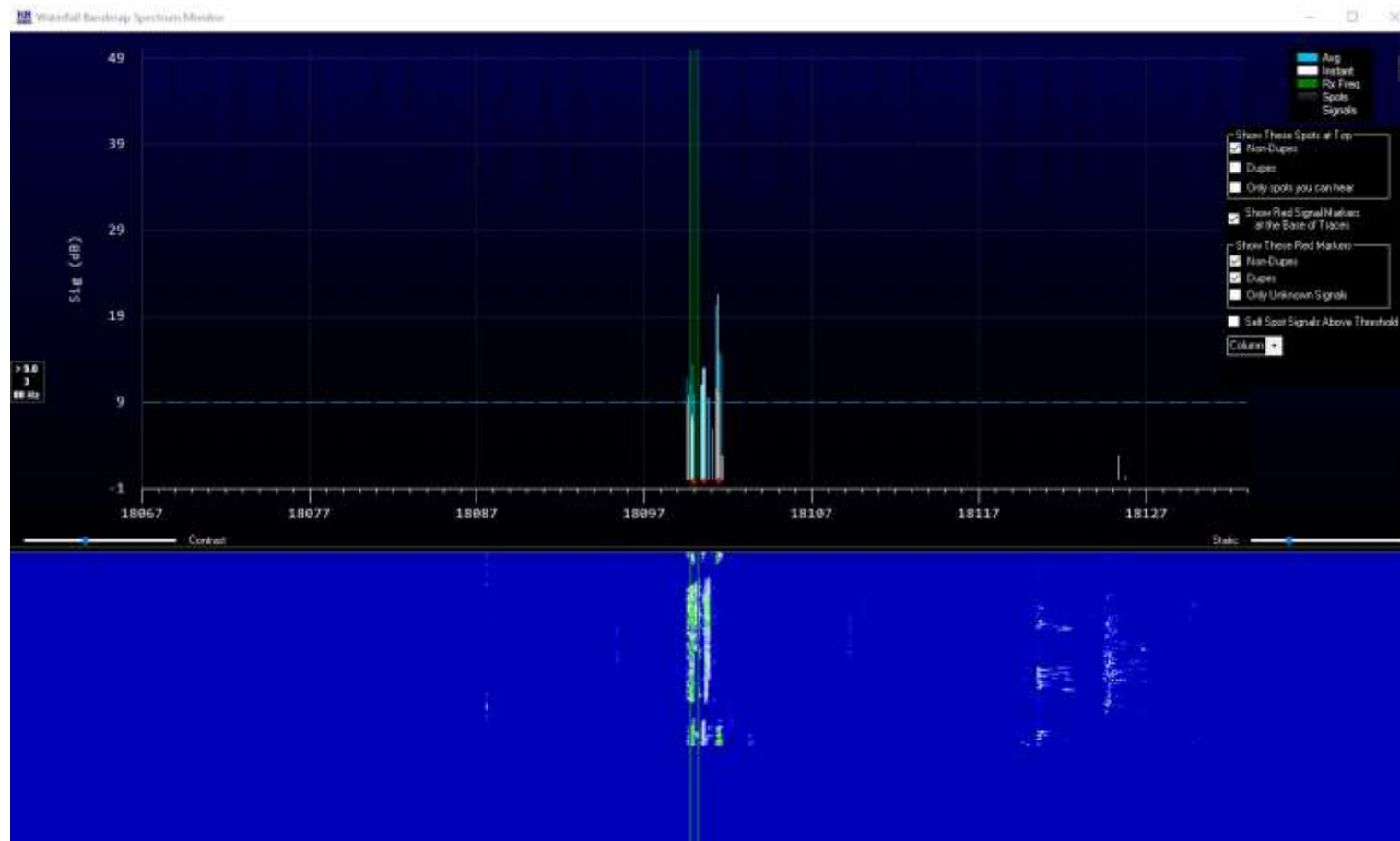
FT8: DXing on Dead Bands

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



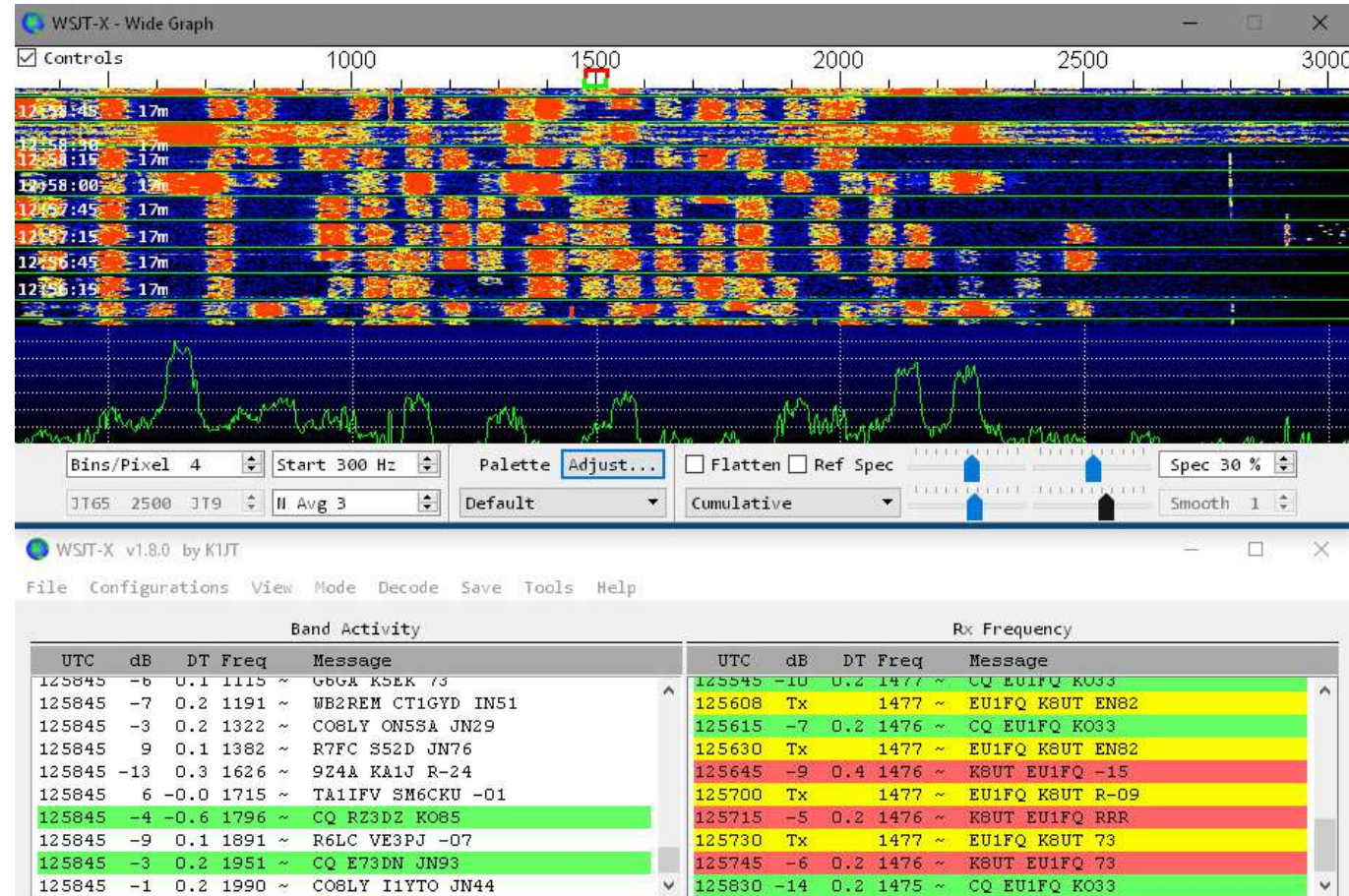
Slide courtesy of Larry Gauthier, K8UT

FT8: 17 Meters, Monday 8am



Slide courtesy of Larry Gauthier, K8UT

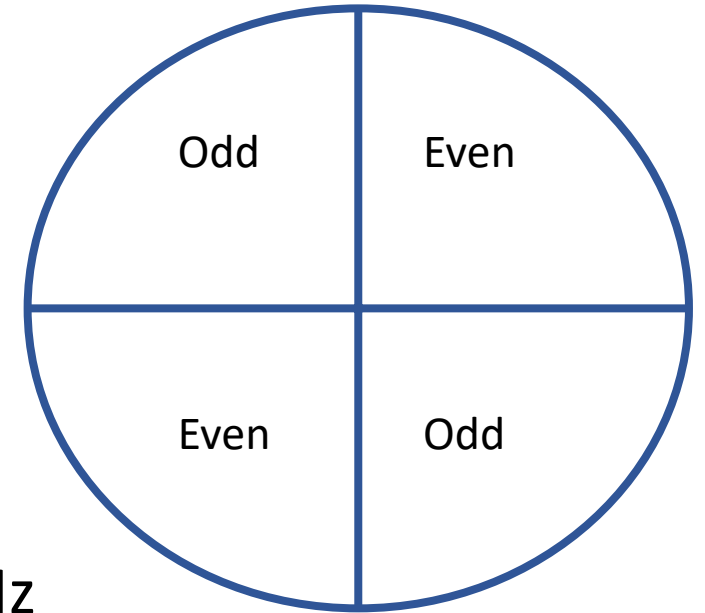
FT8: 17 Meters, Monday 8am



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



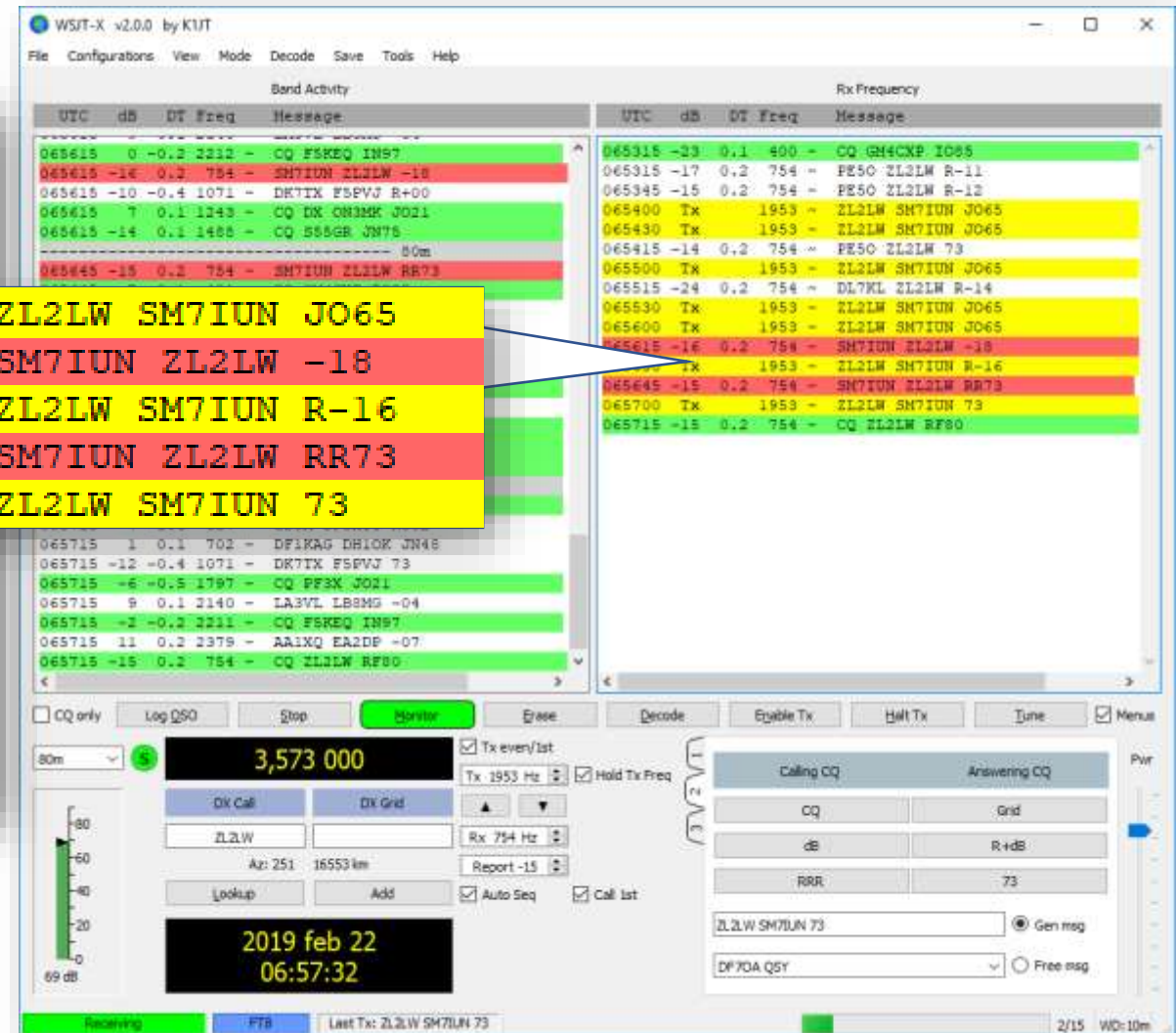
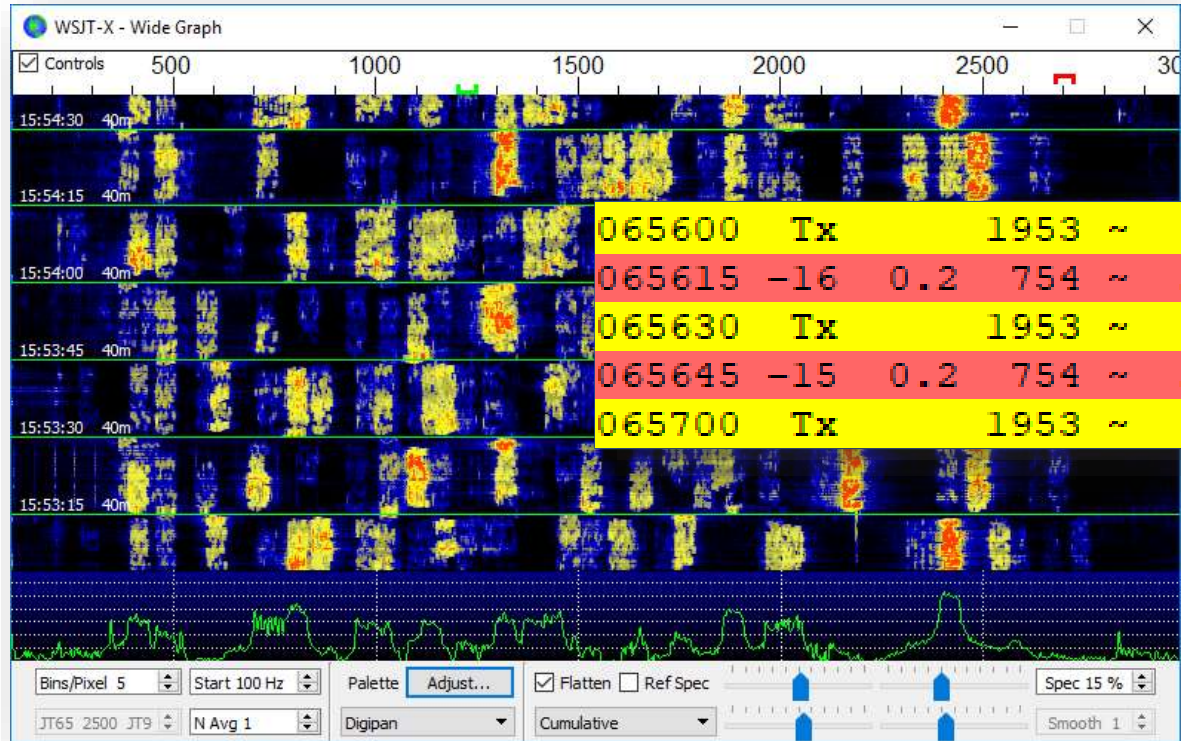
Audio



CAT



Using the software



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

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40m 7,074 000

DX Call DX Grid

5Z4/G3AB

Lookup Add

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

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.

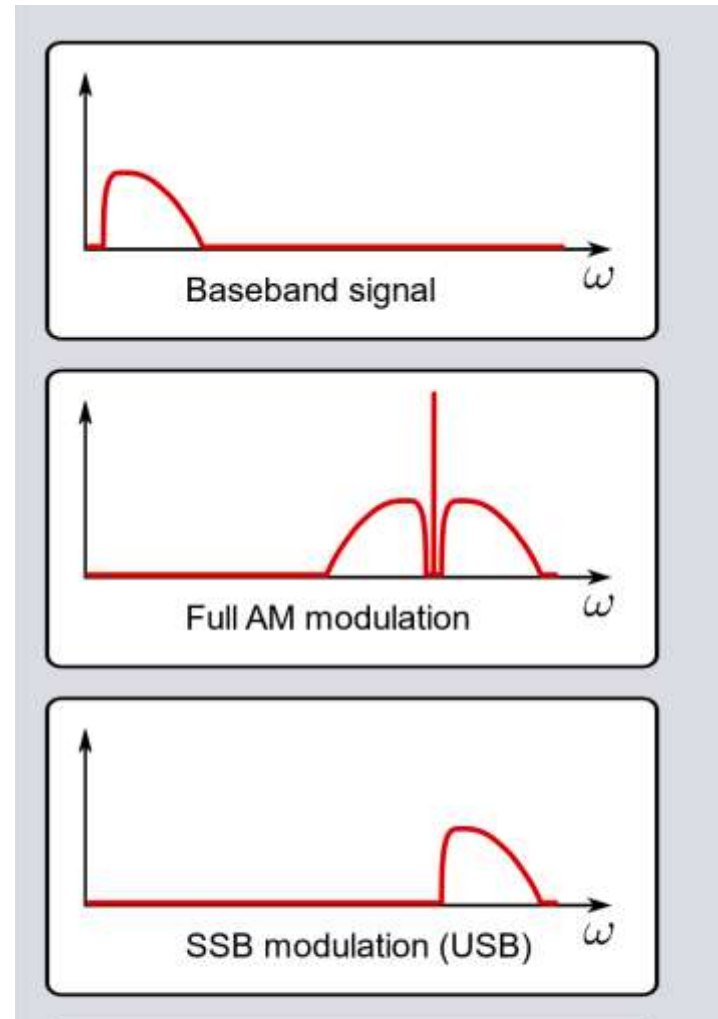
Example: You want to transmit on 3573.5kHz.

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

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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

DX Call DX Grid

5Z4/G3AB

Lookup Add

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

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

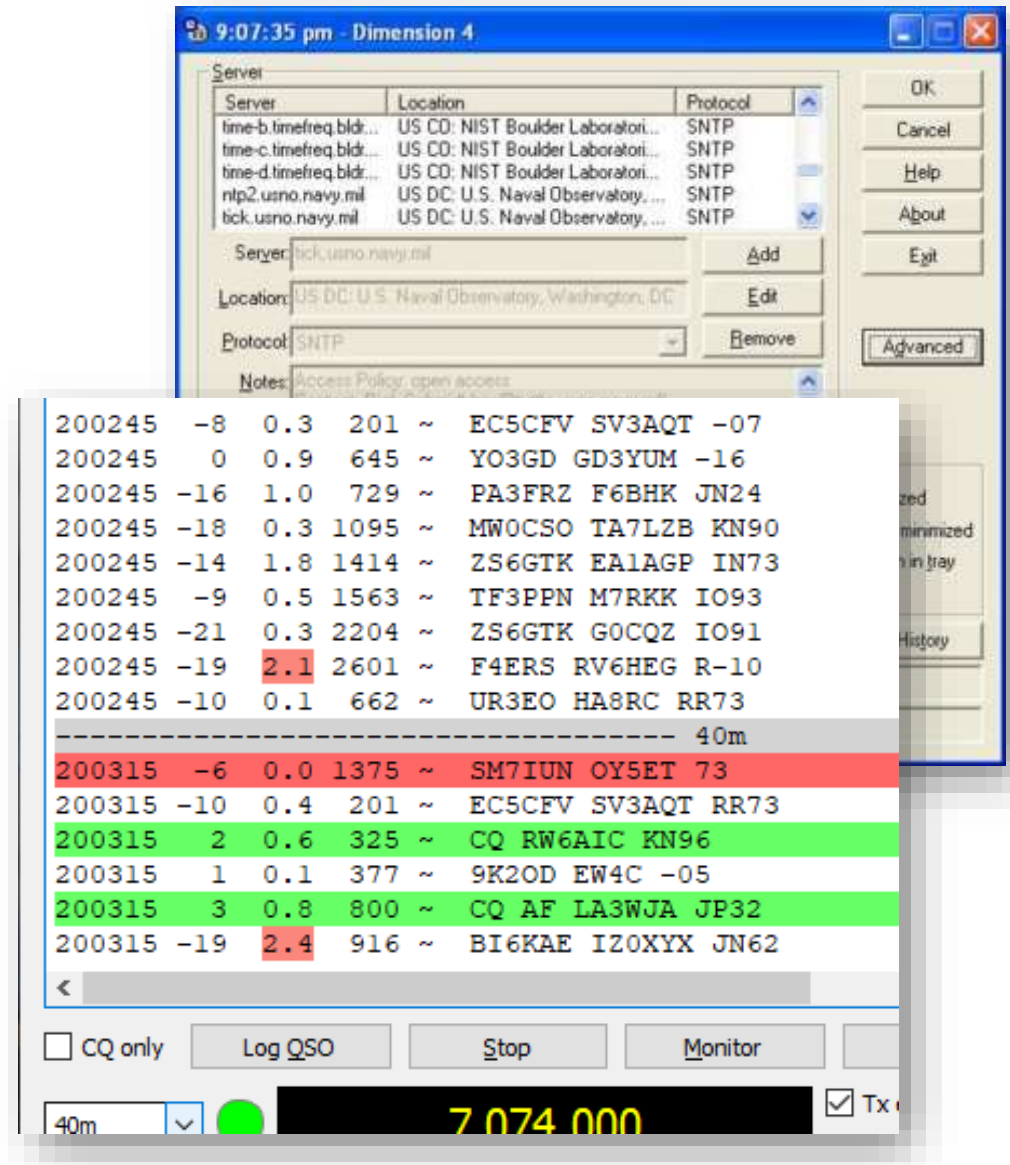
Remember power settings by band

☒ 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.



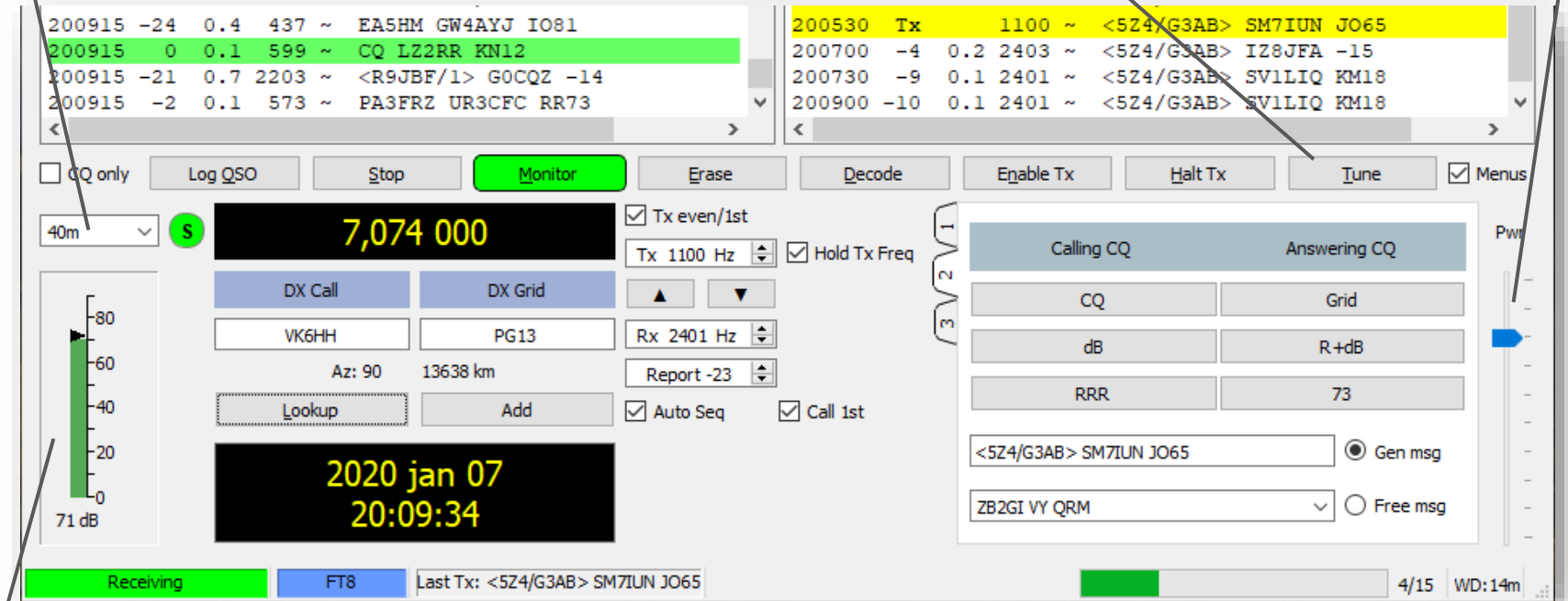
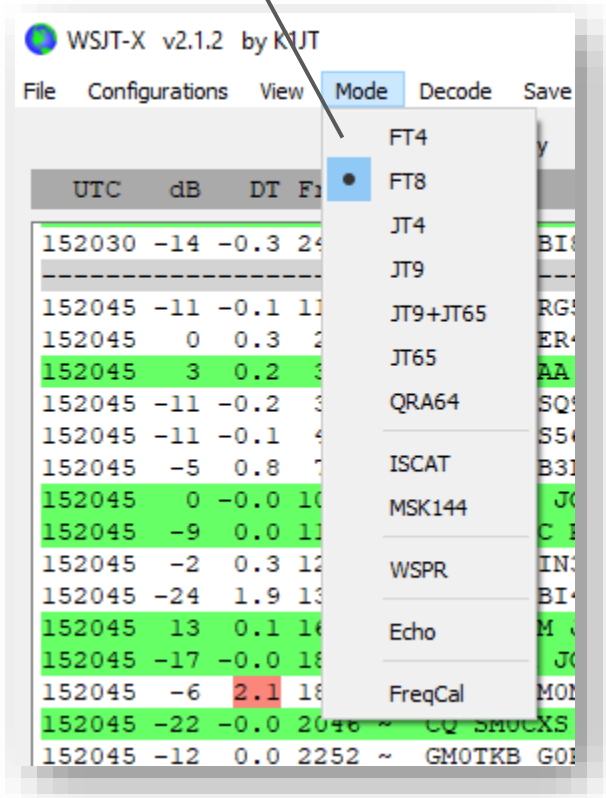
Getting Started

Select mode

Select band

Use Tune to check
power level

Adjust slider until
transmit power
drops



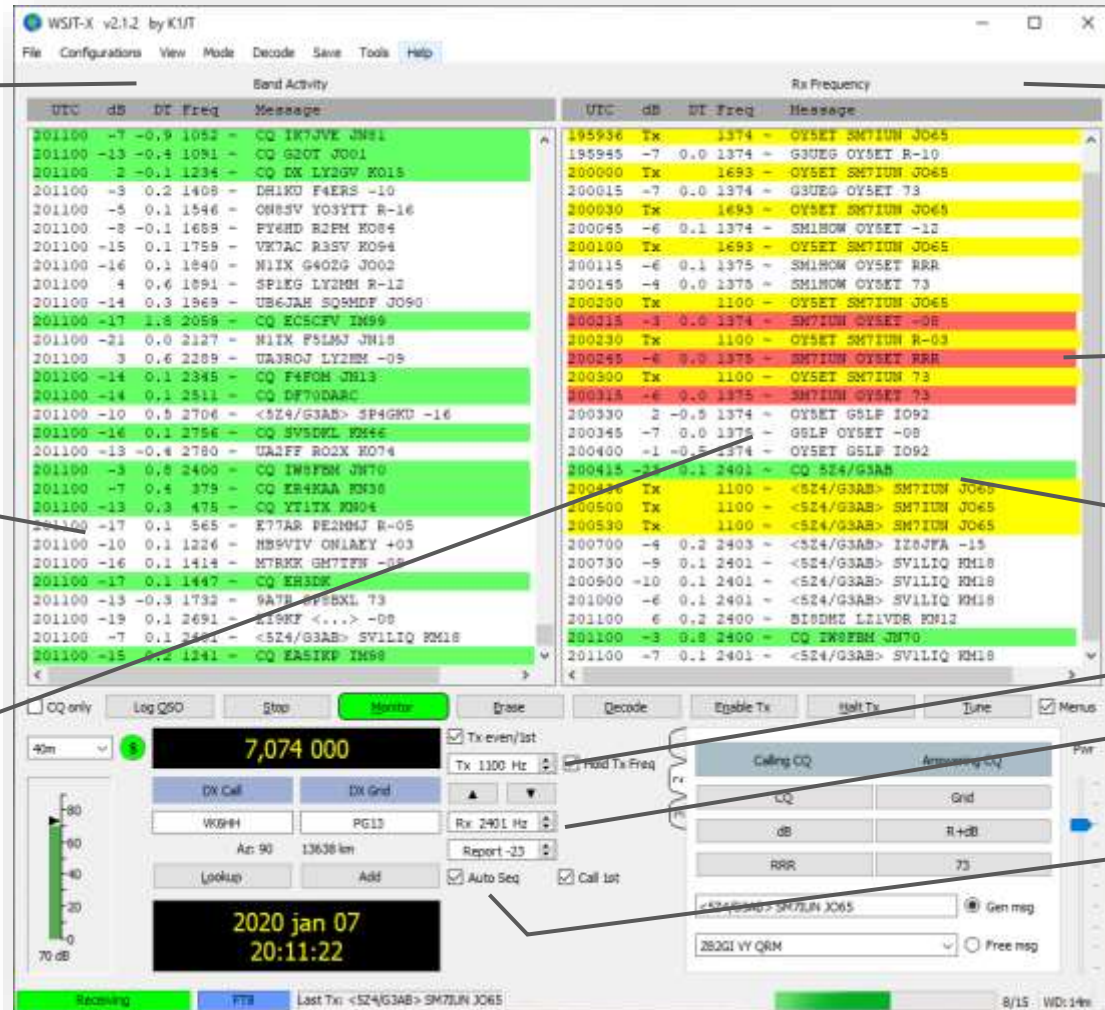
Adjust AF level as high as possible
without ever turning red.

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 the DX Grid, PG13, 38 km, and various settings like Tx 1100 Hz, Rx 2401 Hz, Report -23, Auto Seq, and Call 1st. A call sign '00' is displayed in the top left of the Monitor window, and '07' is displayed in the bottom right. The main control panel also shows a frequency display of 7,074,000 Hz and a date/time display of 2020 jan 07 20:11:22.

Monitor

Erase

Decode

00

☒ Tx even/1st

Tx 1100 Hz

☒ Hold Tx Freq

DX Grid

PG13

38 km

Add

☒ Auto Seq

☒ Call 1st

07

7,074 000

2020 jan 07 20:11:22

Receiving

PTB

Last Tx: <SZ4G3AB> SM7JUN JO65

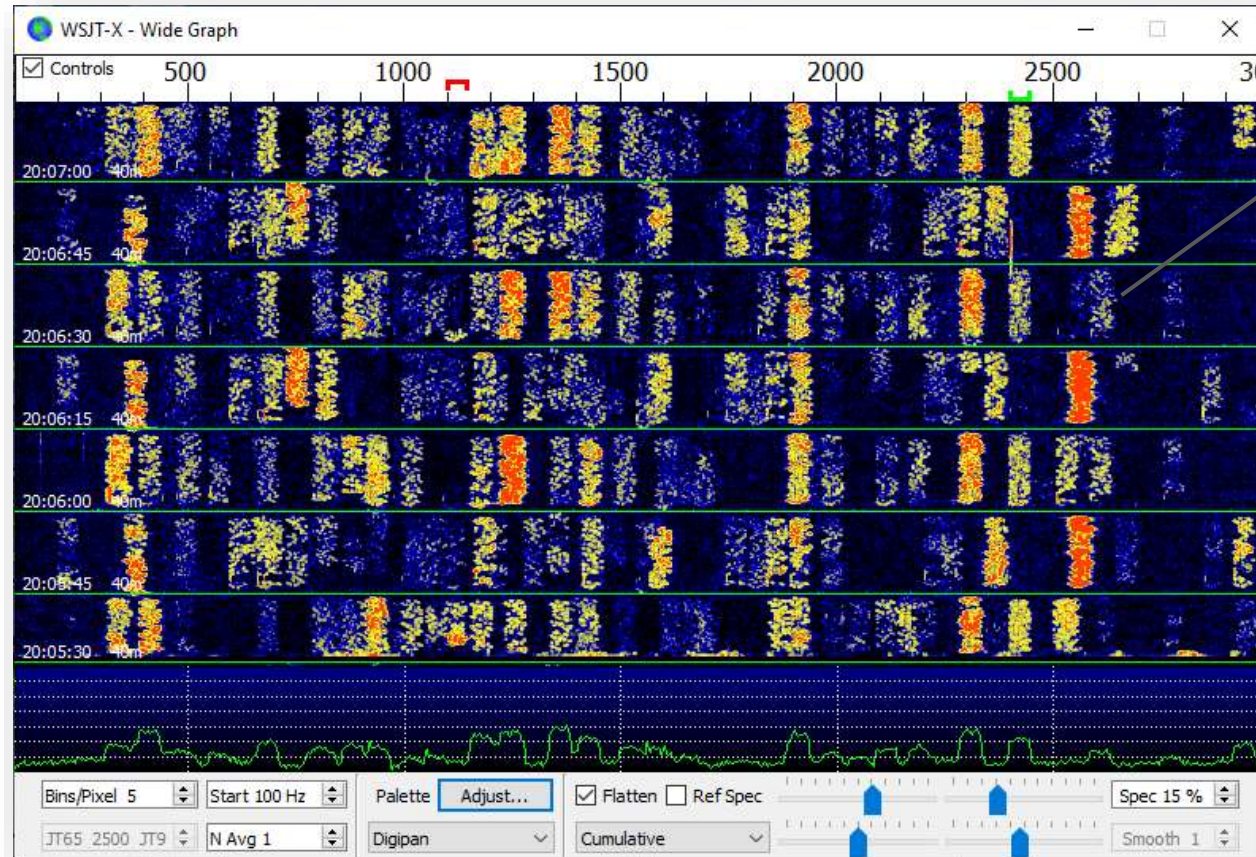
8/15 WID:14m

- 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

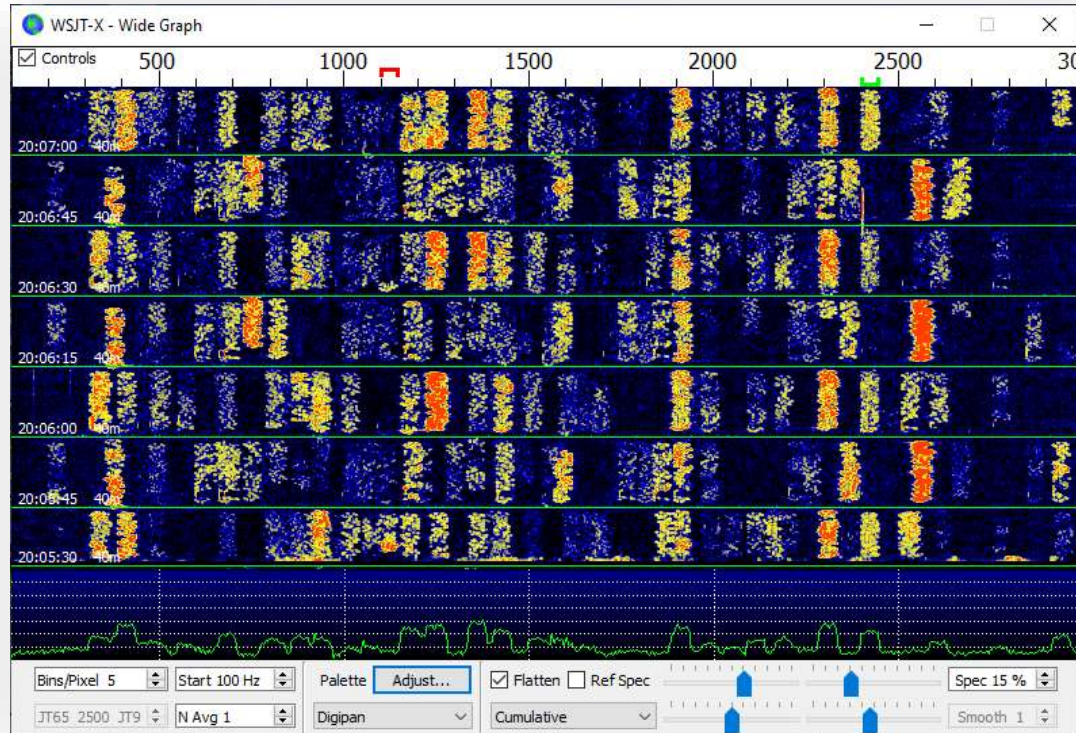


An entire FT8 sub-band

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	1092	CQ 1K7JVE JN61
201100	-13	0.4	1091	CQ G2OT J001
201100	-2	0.1	1234	CQ DX LY2GV K015
201100	-3	0.2	1408	DR1KO F4ERS -10
201100	-5	0.1	1546	OM8SV Y03YIT R-16
201100	-8	0.1	1689	FY6HD R3FM K084
201100	-15	0.1	1759	VH7AC R3SV K094
201100	-16	0.1	1840	N1IX G4OZG J002
201100	-4	0.6	1891	SP1EG LY2HM R-12
201100	-14	0.3	1969	UB6JAH SQMDF J090
201100	-17	1.8	2059	CQ ECSCFV IM99
201100	-21	0.0	2127	N1IX F51MJ JN18
201100	-3	0.6	2289	UA3ROJ LY2HM -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 SV3DKL PM46
201100	-13	0.4	2780	UA2FF R02X K074
201100	-3	0.8	2400	CQ IW5FBN JN70
201100	-7	0.4	379	CQ ER4KAA KM38
201100	-13	0.3	475	CQ YT1TX KM04
201100	-17	0.1	565	E77AR PE2MMJ R-05
201100	-10	0.1	1226	HB9VIV ONIAKY +03
201100	-16	0.1	1414	MT8KK SM7TFW -09
201100	-17	0.1	1447	CQ ER3DK
201100	-13	0.3	1732	9A7R SP8BKJ 73
201100	-19	0.1	2691	E19KF <...> -08
201100	-7	0.1	2401	<524/G3AB> SV1LIQ KM18
201100	-15	0.2	1241	CQ EASIKP IM98

UTC	dB	DT	Freq	Message
195936	Tx		1374	OY5ET SM7IUN J065
195945	-7	0.0	1374	G3UEG OY5ET R-10
200000	Tx		1693	OY5ET SM7IUN J065
200015	-7	0.0	1374	G3UEG OY5ET 73
200030	Tx		1693	OY5ET SM7IUN J065
200045	-6	0.1	1374	SM1HOW OY5ET -12
200100	Tx		1693	OY5ET SM7IUN J065
200115	-6	0.1	1375	SM1HOW OY5ET RRR
200145	-4	0.0	1375	SM1HOW OY5ET 73
200200	Tx		1100	OY5ET SM7IUN J065
200215	-4	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 G5LF IO92
200345	-7	0.0	1375	G5LF OY5ET -08
200400	-1	0.5	1374	OY5ET G5LF IO92
200415	-23	0.1	2401	CQ 524/G3AB
200436	Tx		1100	<524/G3AB> SM7IUN J065
200500	Tx		1100	<524/G3AB> SM7IUN J065
200530	Tx		1100	<524/G3AB> SM7IUN J065
200700	-4	0.2	2403	<524/G3AB> IZ0JFA -15
200730	-9	0.1	2401	<524/G3AB> SV1LIQ KM18
200900	-10	0.1	2401	<524/G3AB> SV1LIQ KM18
201000	-6	0.1	2401	<524/G3AB> SV1LIQ KM18
201100	6	0.2	2400	B18DMZ L2LVDR PM12
201100	-3	0.8	2400	CQ IW5FBN JN70
201100	-7	0.1	2401	<524/G3AB> SV1LIQ KM18

Log QSO: 7,074 000

TX Call: W09EH, PG13, Az: 90, 13638 km, Report: -23, Auto Seq, Call list

2020 jan 07 20:11:22

Receiving: FTS, Last Tx: <524/G3AB> SM7IUN J065

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).

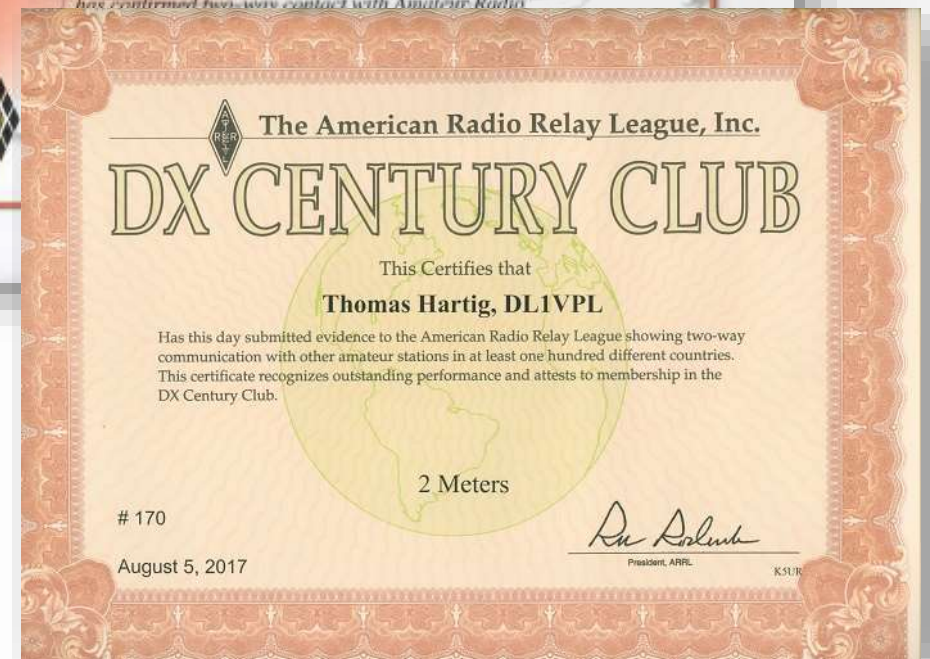
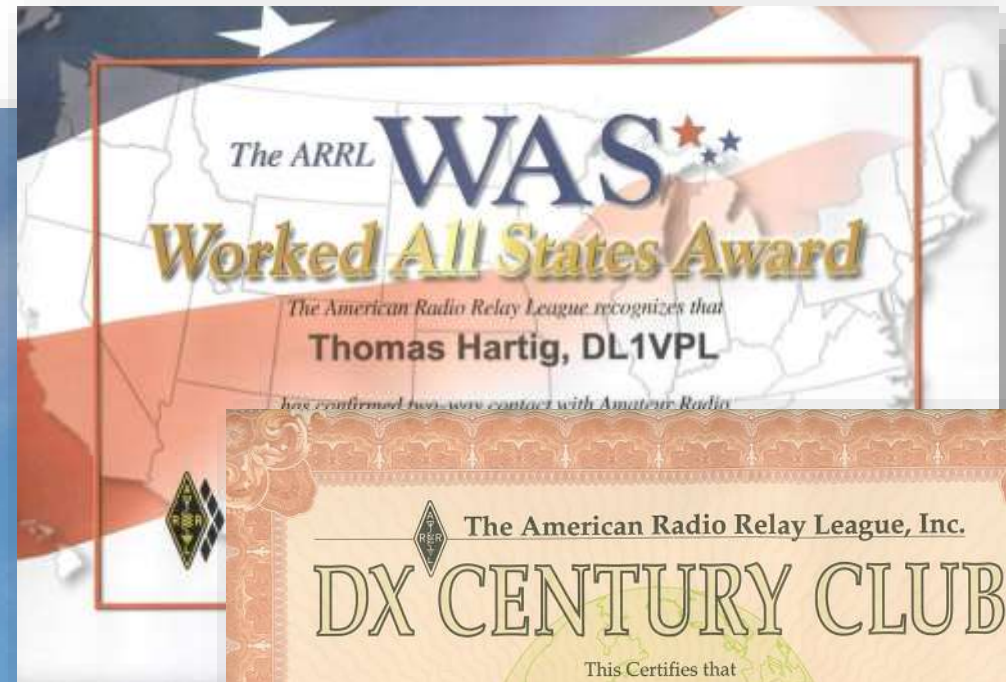
There are 3357 active monitors: 1031 on 40m, 918 on 20m, 474 on 30m, 284 on 80m, 131 on 17m, 128 on 160m, 109 on 60m, 87 on 15m, 60 on 2m, 56 on 6m, 33 on unknown, 4 on 10m, 4 on 600m, 3 on 23cm, 3 on 4m, 2 on 2200m, 1 on uhf. [Legend](#)



([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.