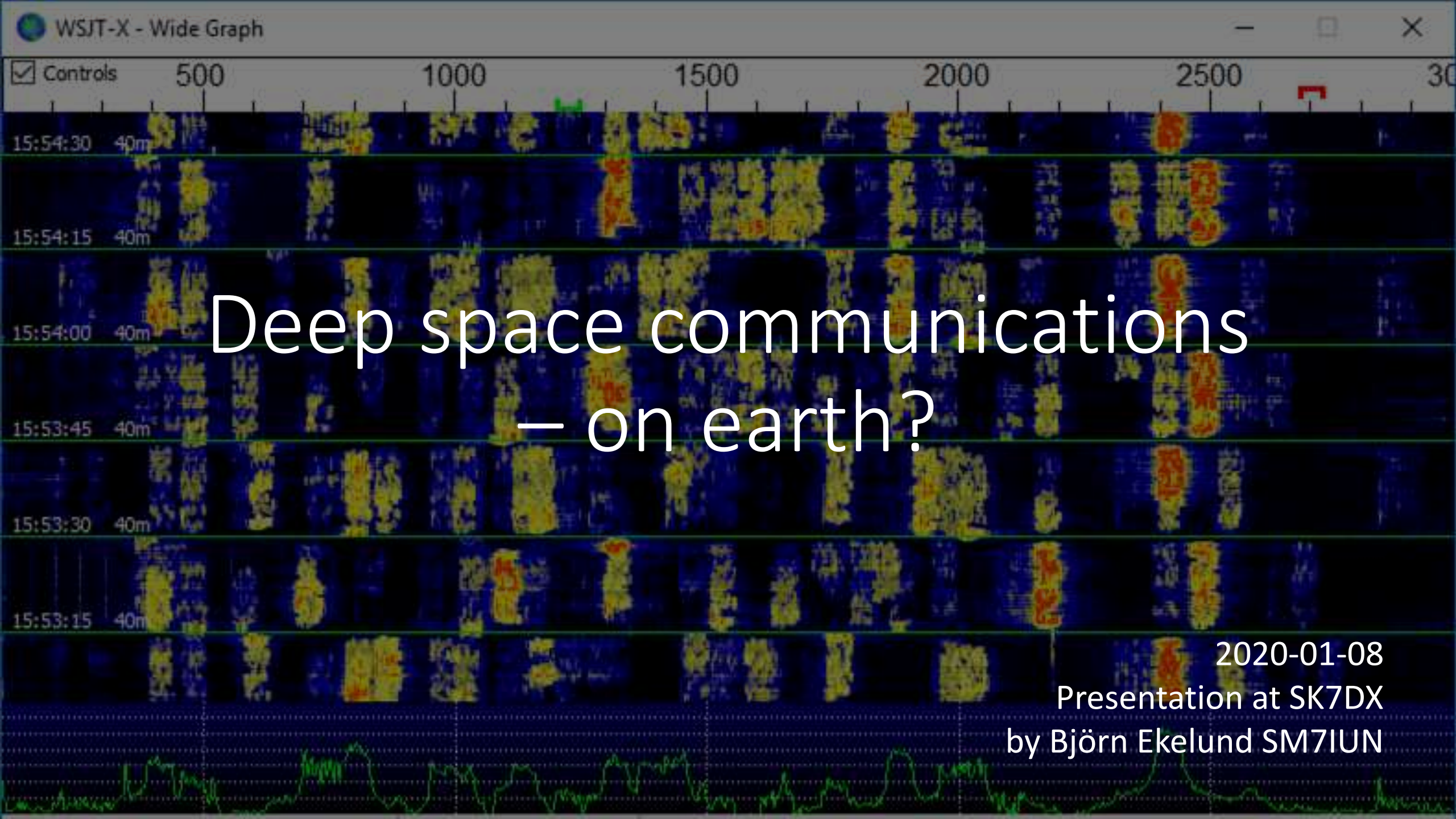


Deep space communications – on earth?

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.

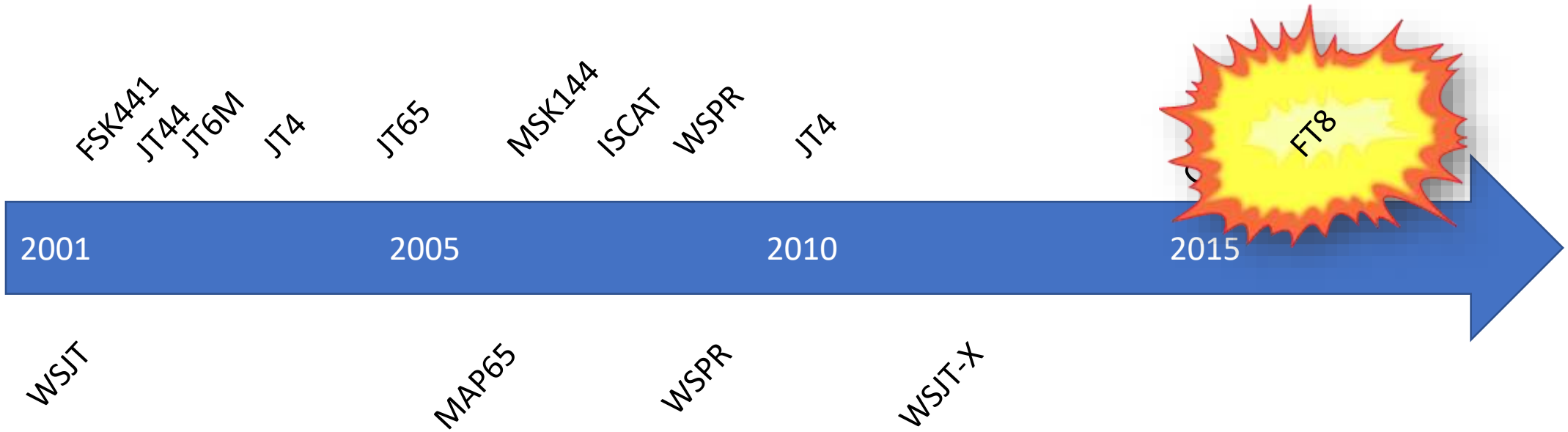
Two professors and a software guru

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

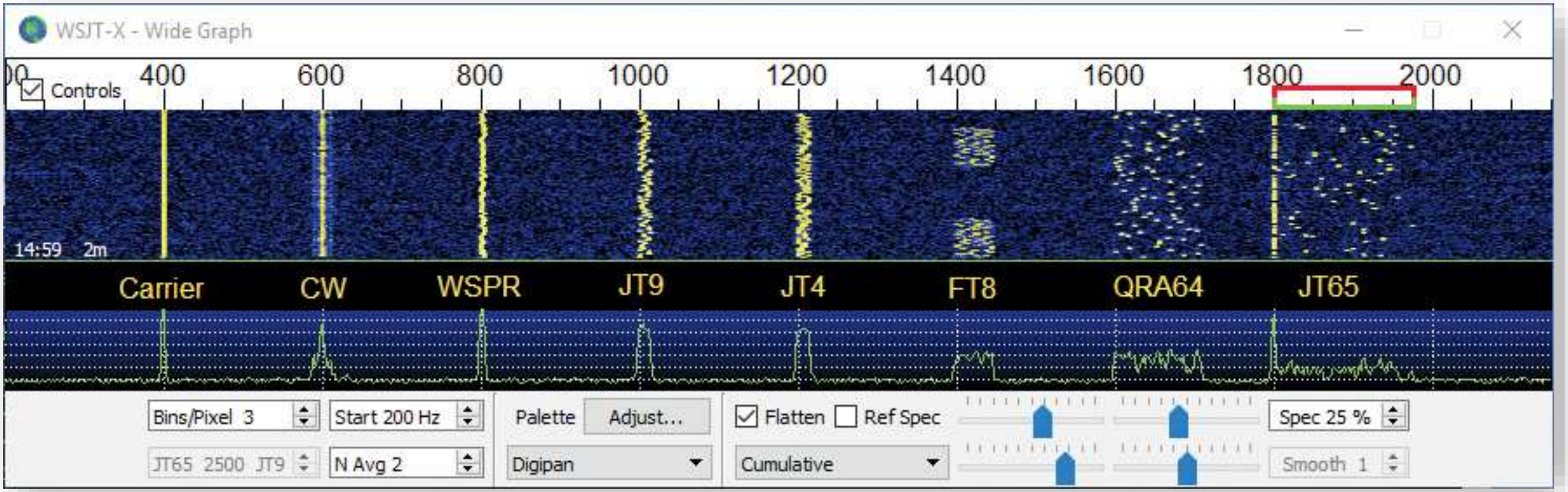
Prof. Steven J. Franke, K3AN
Electrical and Computer Engineering
University of Illinois at Urbana

Bill Somerville, G4WJS
Freelance software engineer
Stokenchurch, UK

Evolution


FSK441
JT44
JT6M
JT4
JT65
MSK144
ISCAT
WSPR
JT4
FT8
2001
2005
2010
2015
WSJT
MAP65
WSPR
WSJT-X

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…

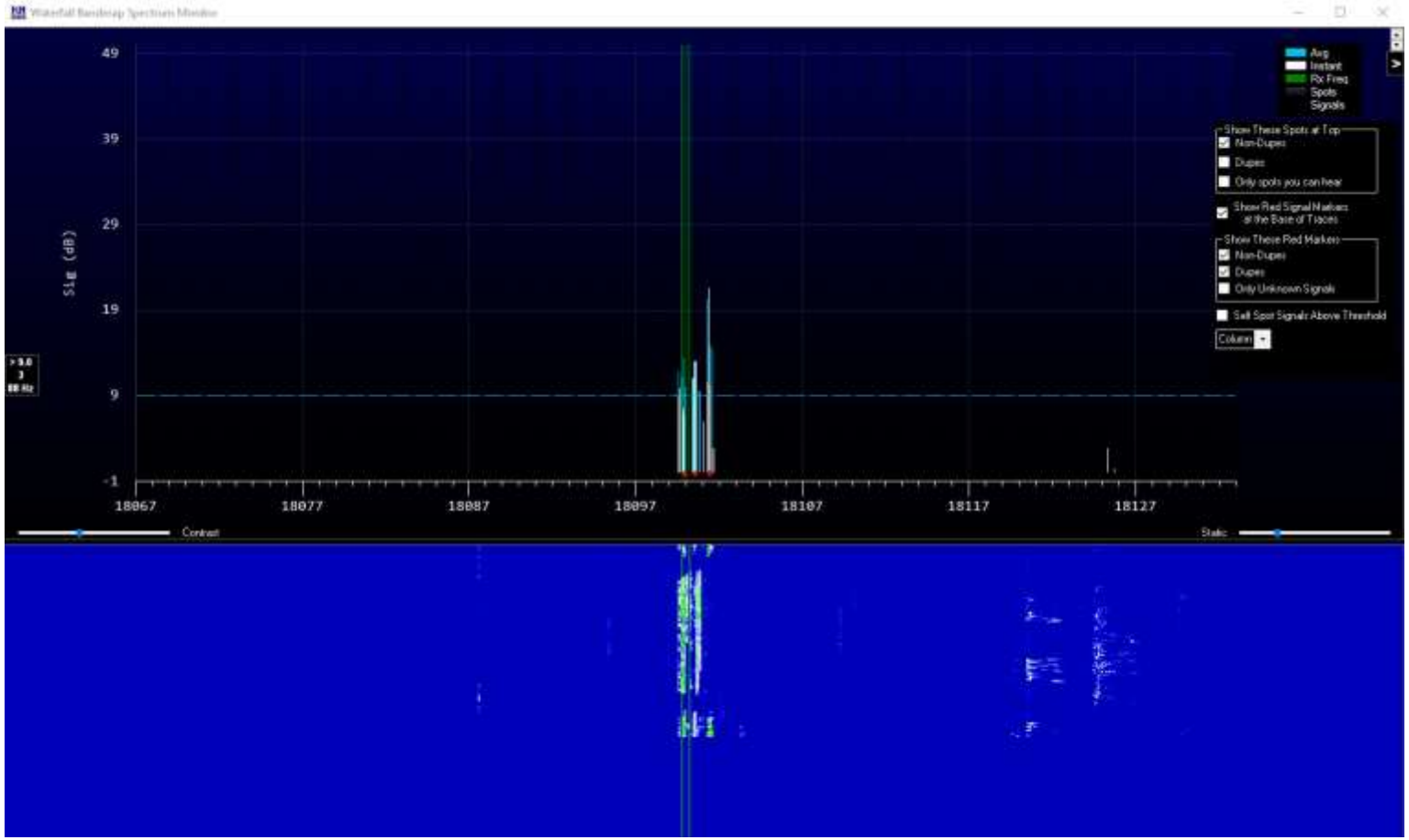
Slide courtesy of Larry Gauthier, K8UT

FT8: DXing on Dead Bands

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

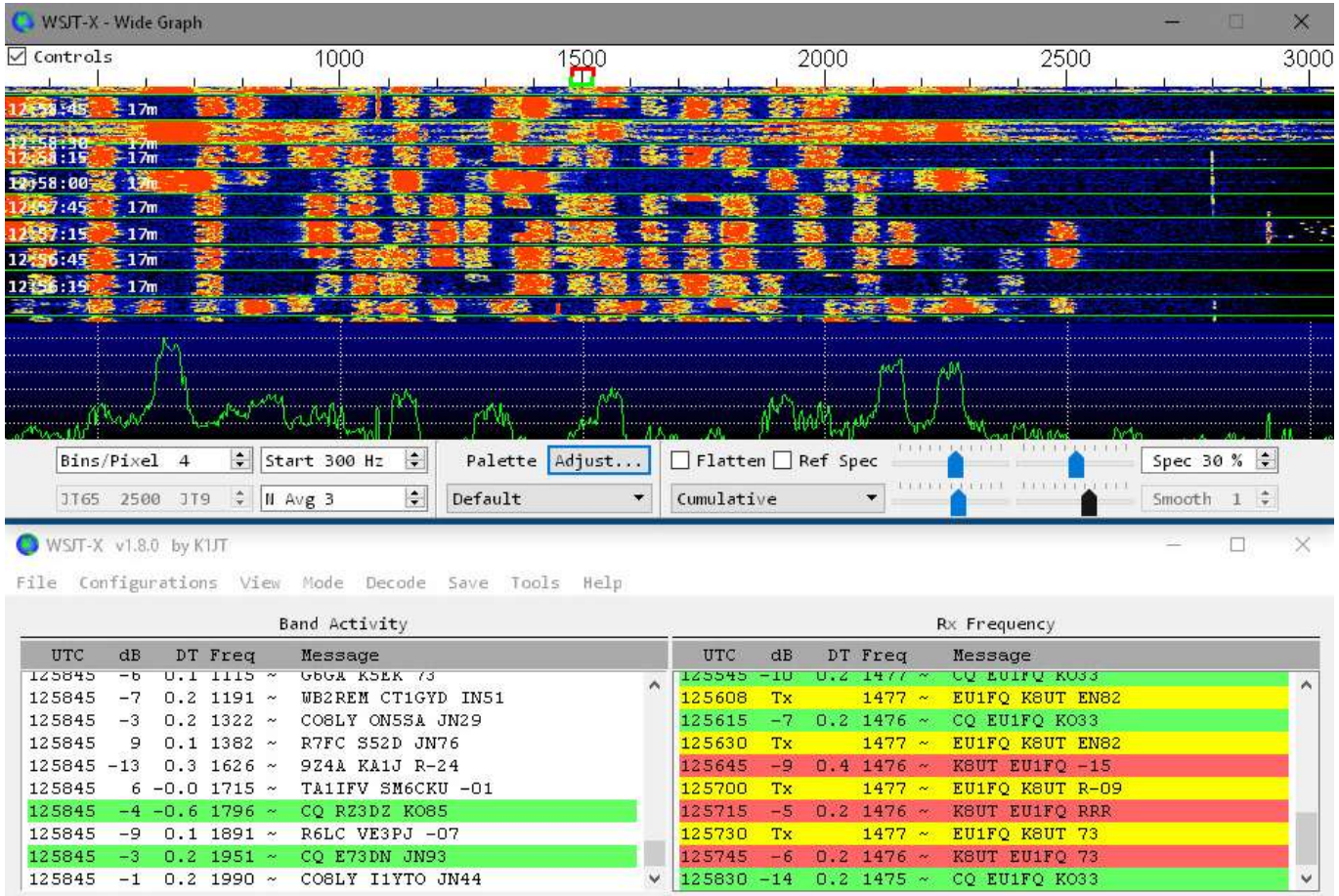
Slide courtesy of Larry Gauthier, K8UT

FT8: 17 Meters, Monday 8am



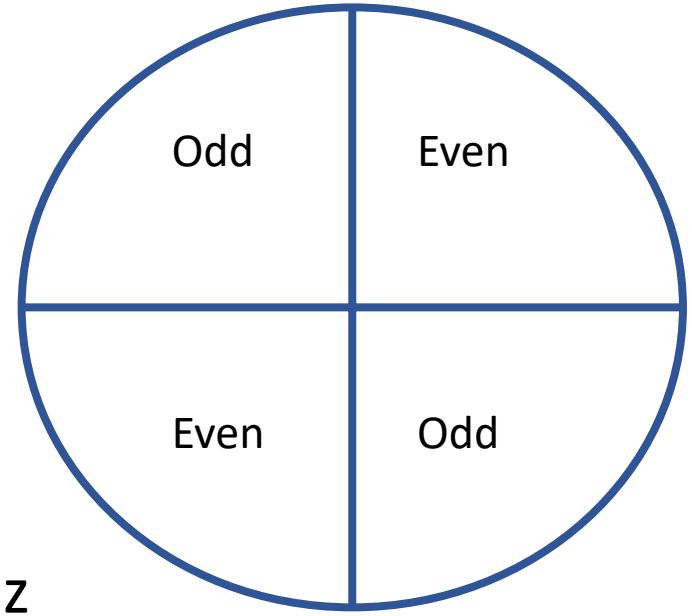
Slide courtesy of Larry Gauthier, K8UT

FT8: 17 Meters, Monday 8am



Slide courtesy of Larry Gauthier, K8UT

FT8 – Franke-Taylor-8FSK



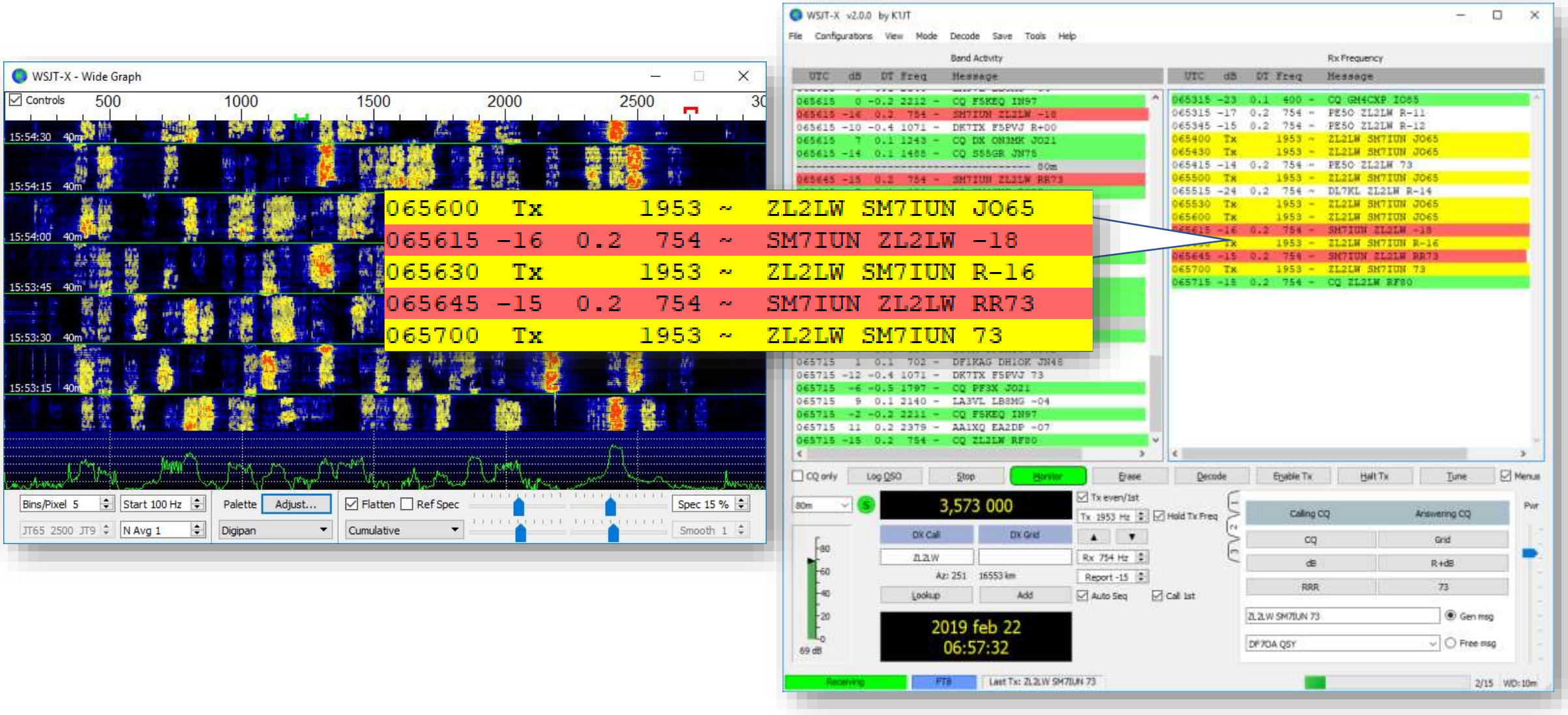
- T/R sequence period: 15s
- Message length: 75 bits + 12-bit CRC
- FEC code: (174,87) LDPC
- Modulation: 8-FSK, keying rate = tone spacing = 6.25Hz
- Waveform: Continuous phase, constant envelope
- Occupied bandwidth: 50Hz
- Synchronization: Three 7 x 7 Costas arrays (start, middle, end of transmission)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

Equipment

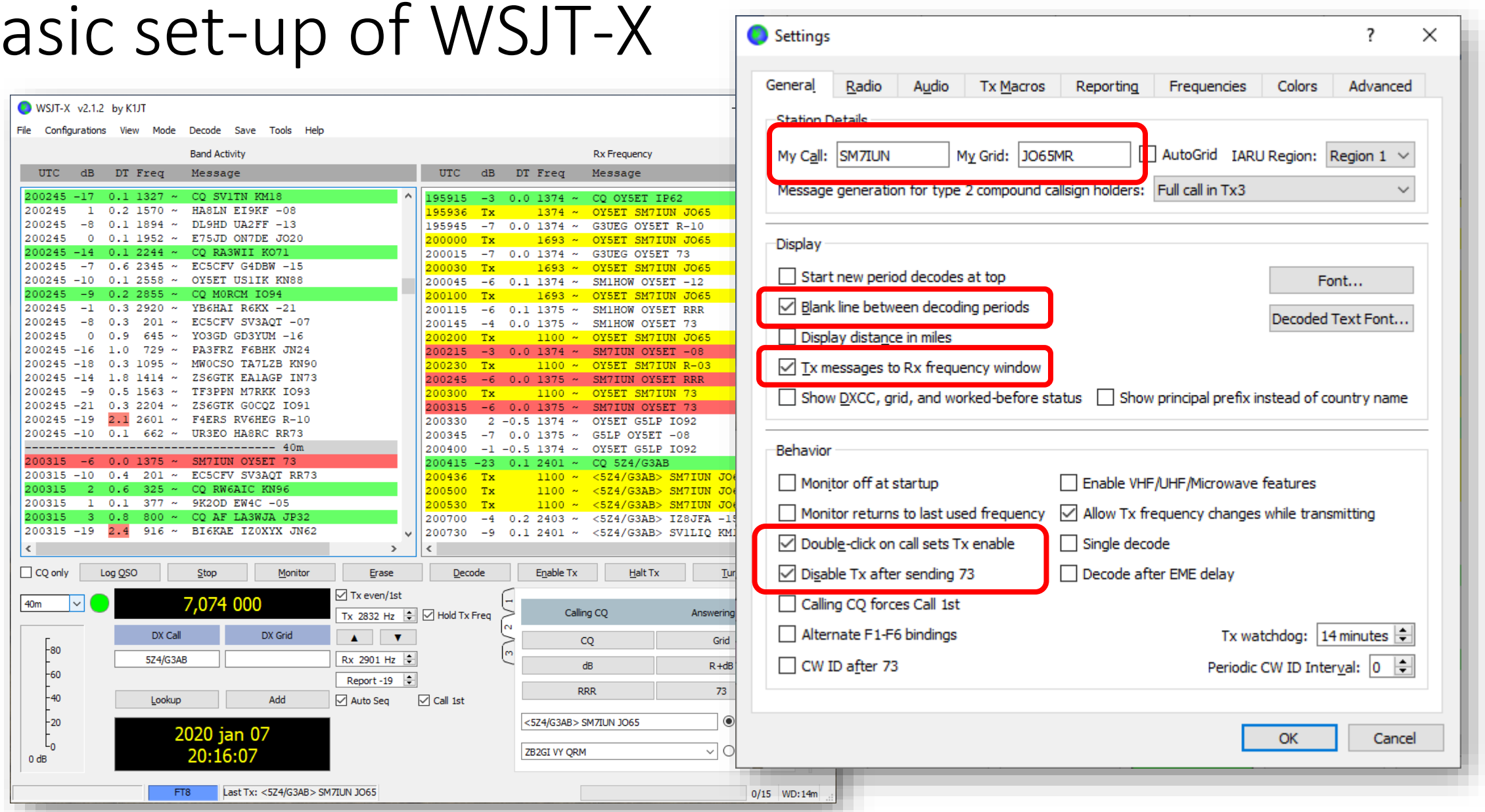
Audio

CAT

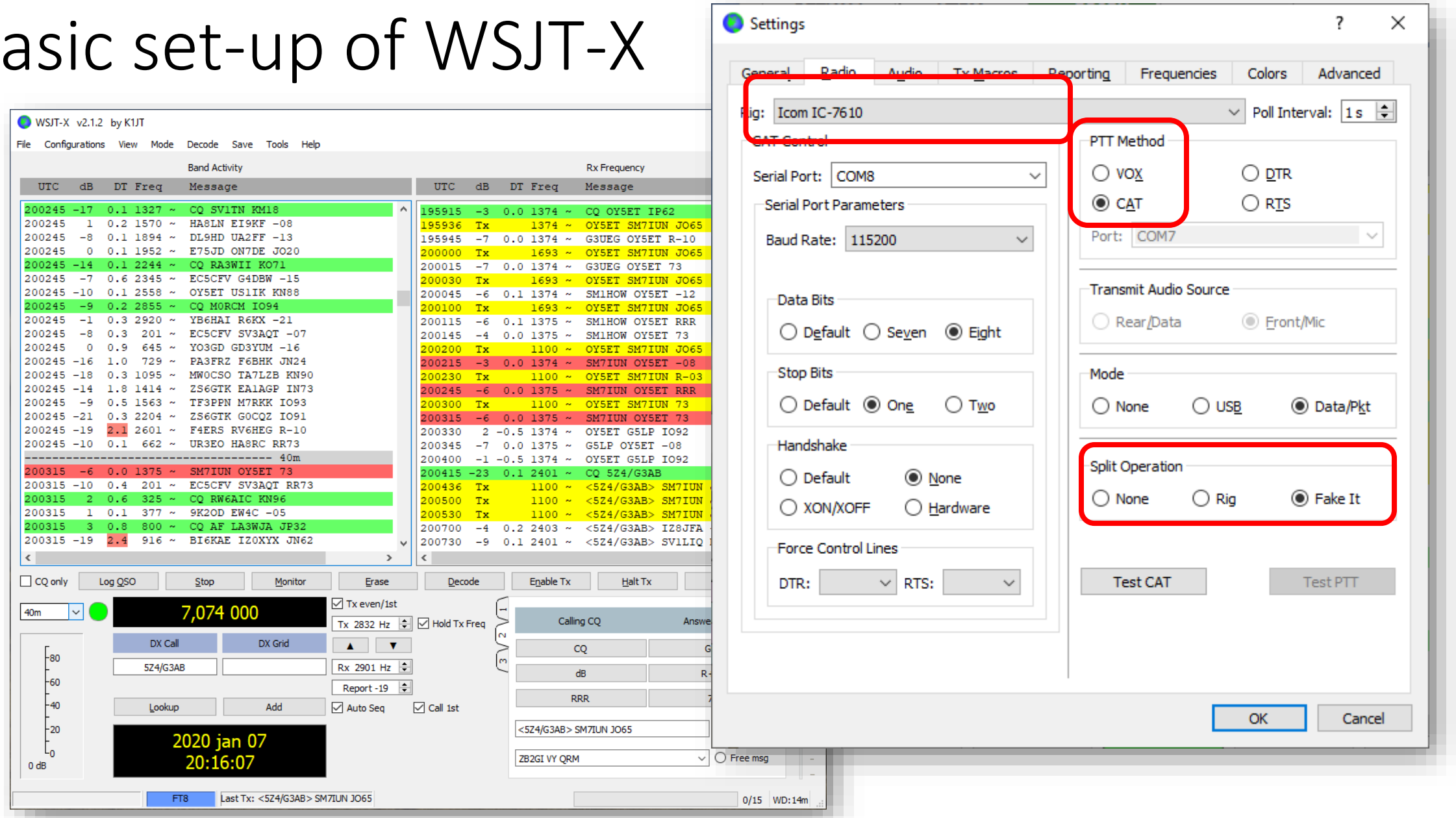
Using the software



Basic set-up of WSJT-X



Basic set-up of WSJT-X



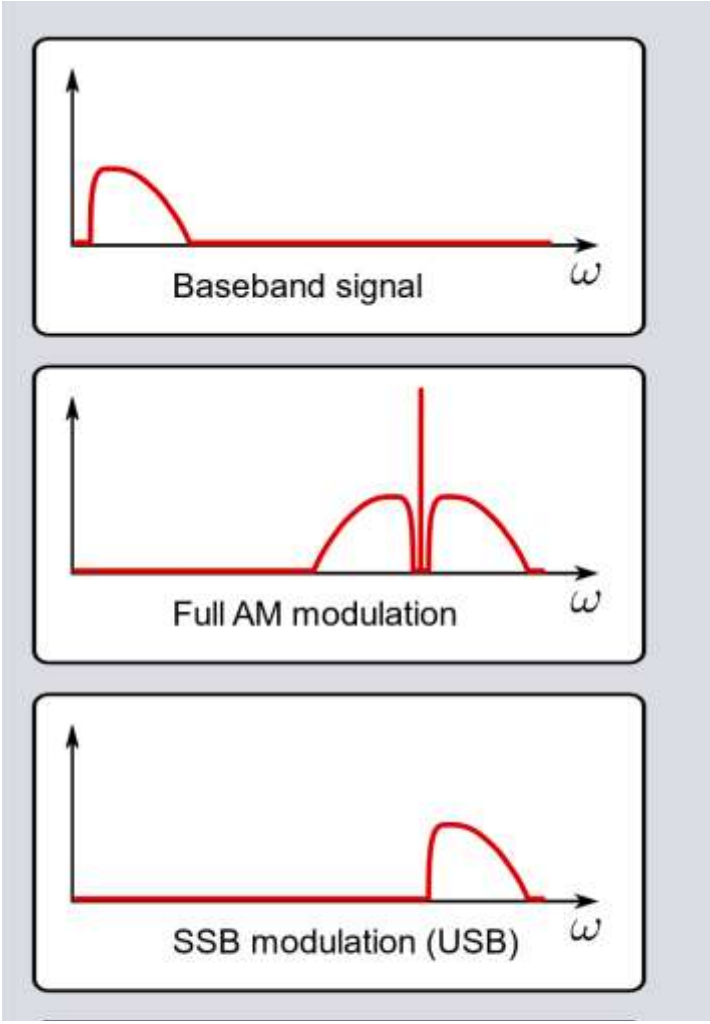
“Split operation”

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

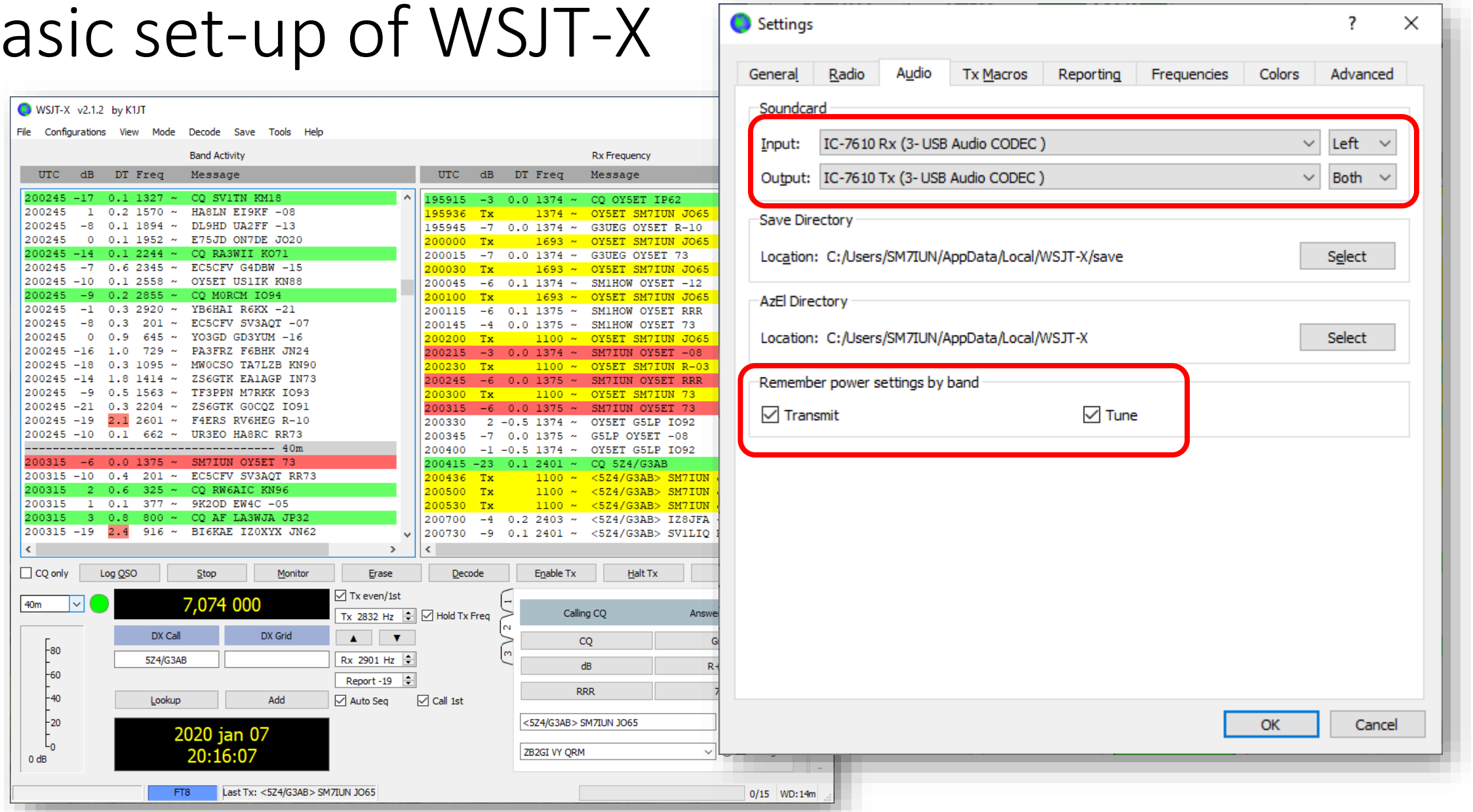
To secure a clean transmission WSJT-X only generates transmit audio signals between 1500kHz and 2000kHz and then modifies the base frequency down or up to achieve the wanted radio frequency.

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!

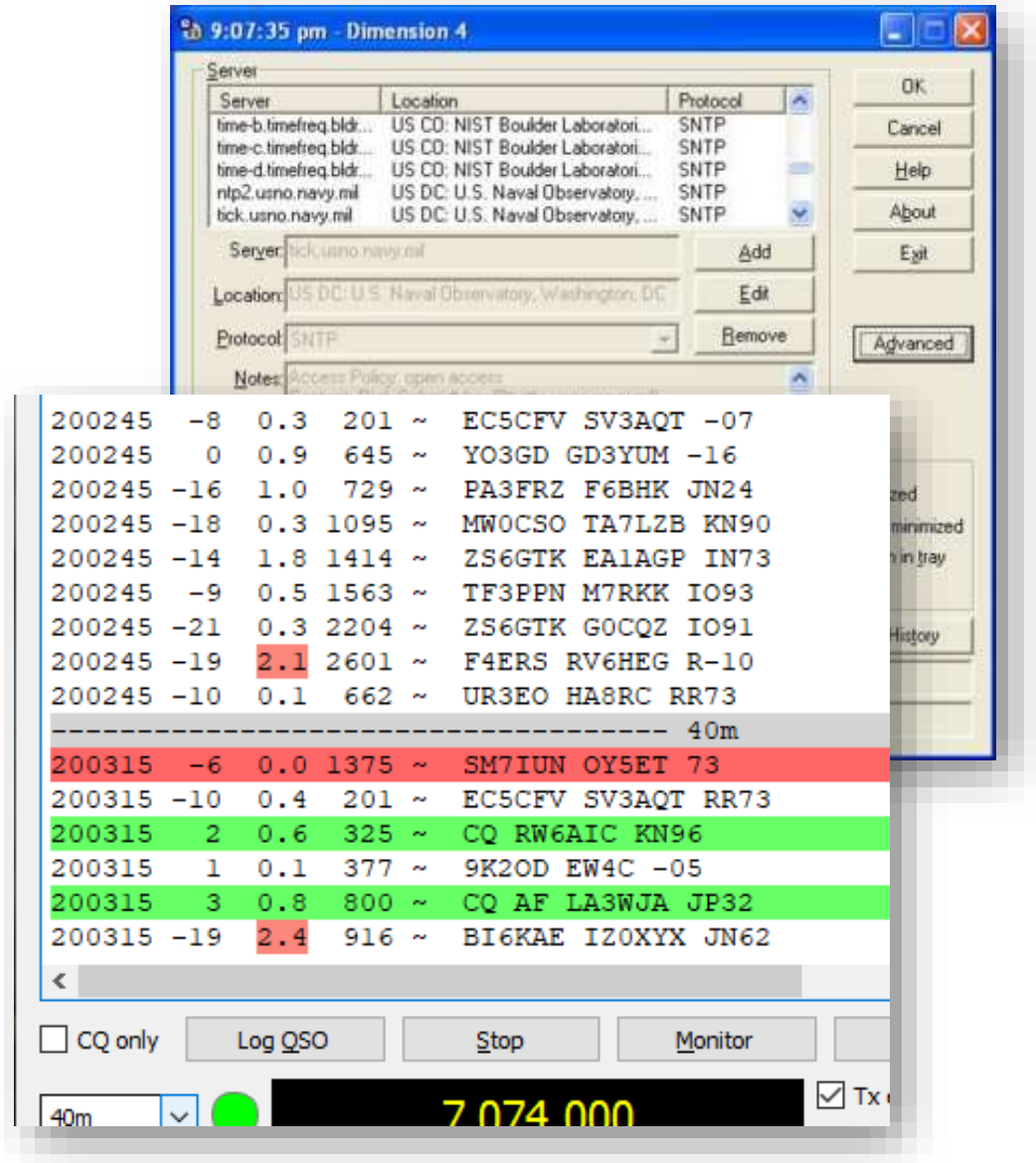


Basic set-up of WSJT-X



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.



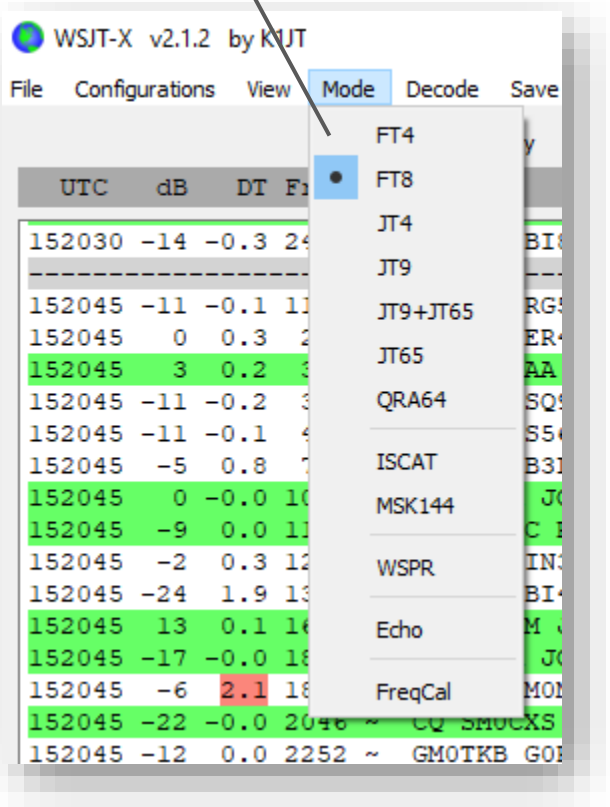
Getting Started

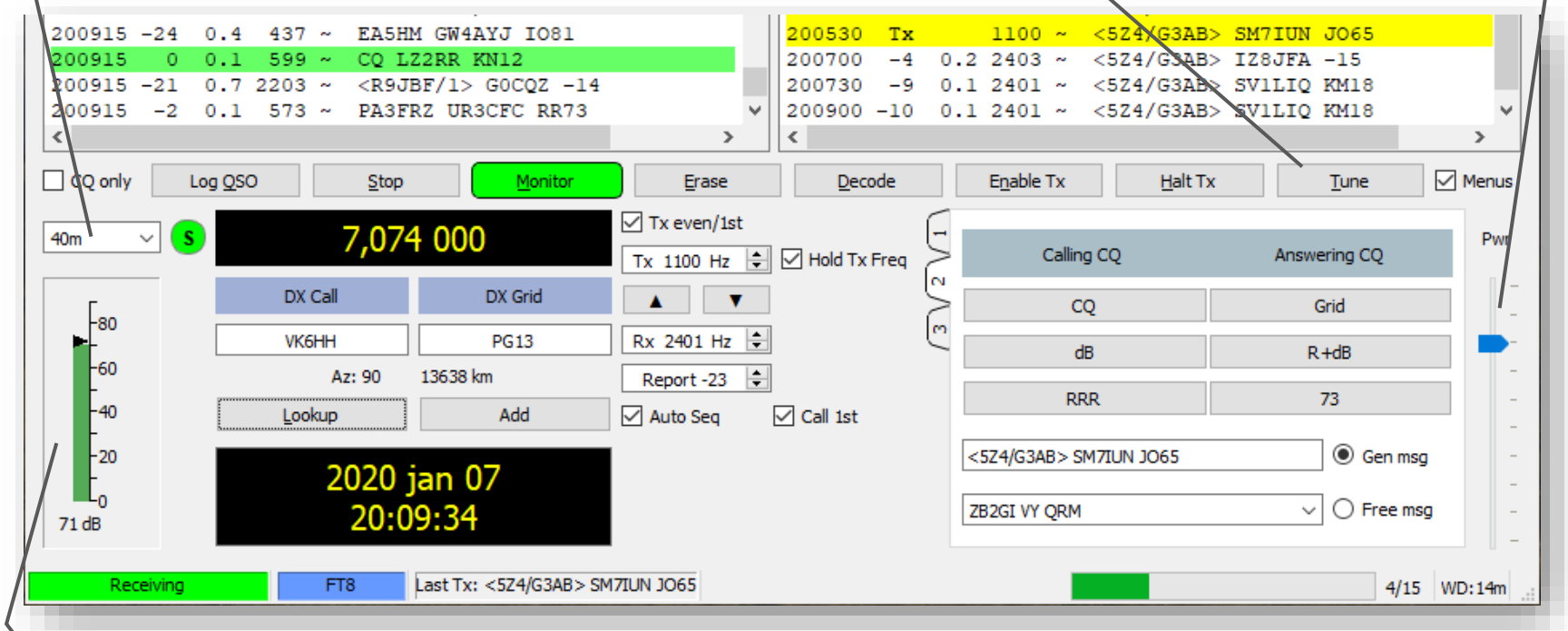
Select mode

Select band

Use Tune to check power level

Adjust slider until transmit power drops





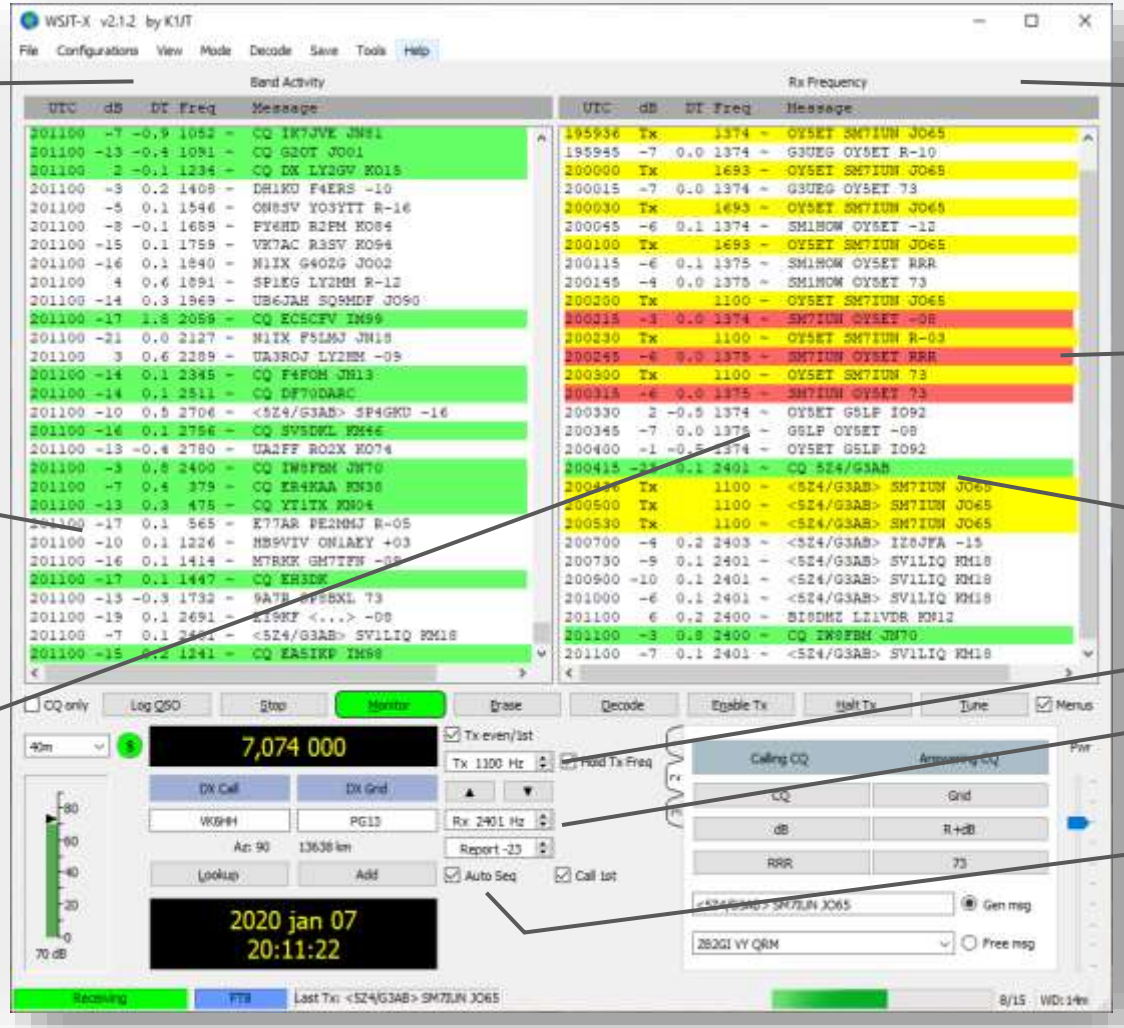
Adjust AF level as high as possible without ever turning red.

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



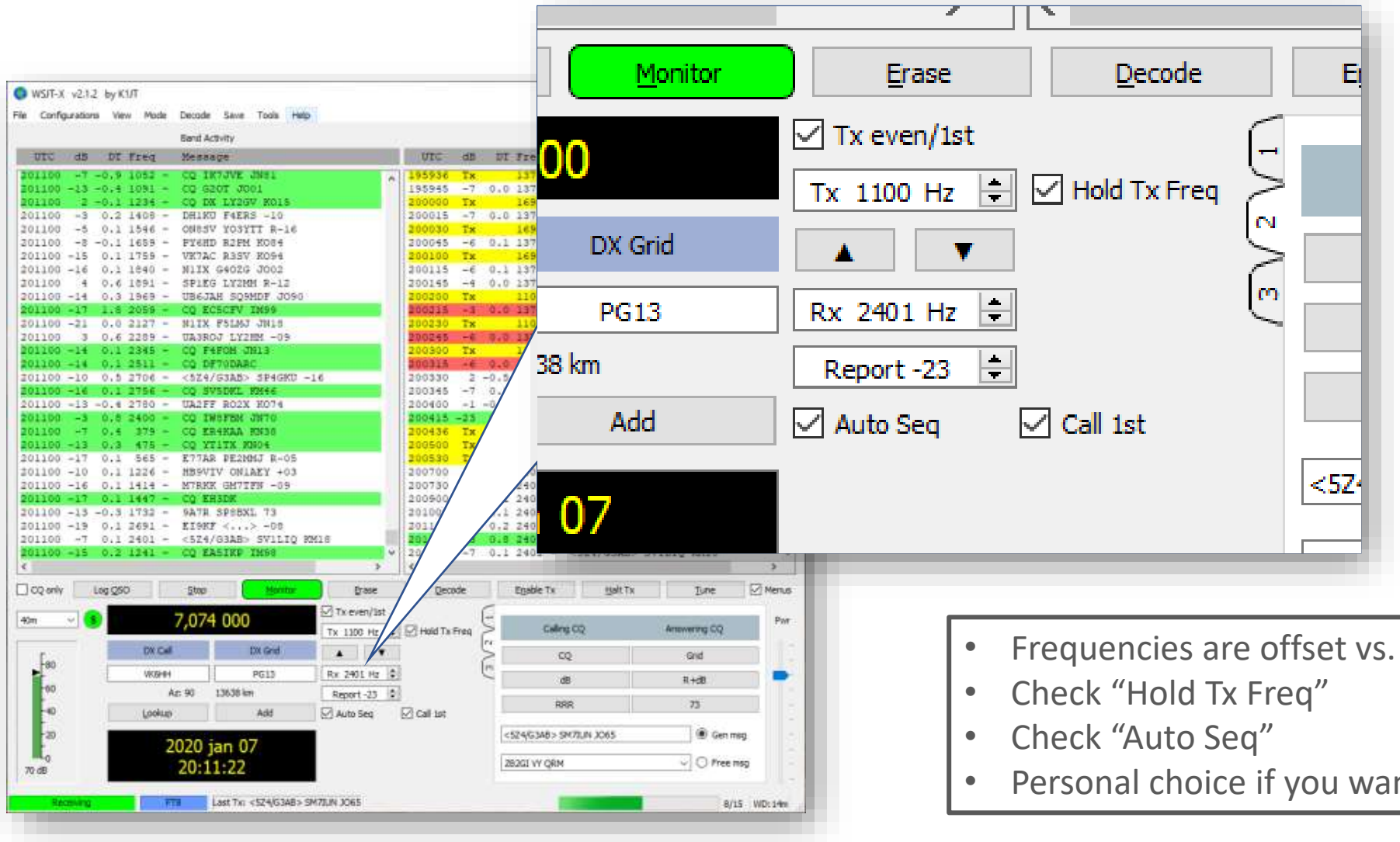
All activity shown on the “Rx” frequency

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

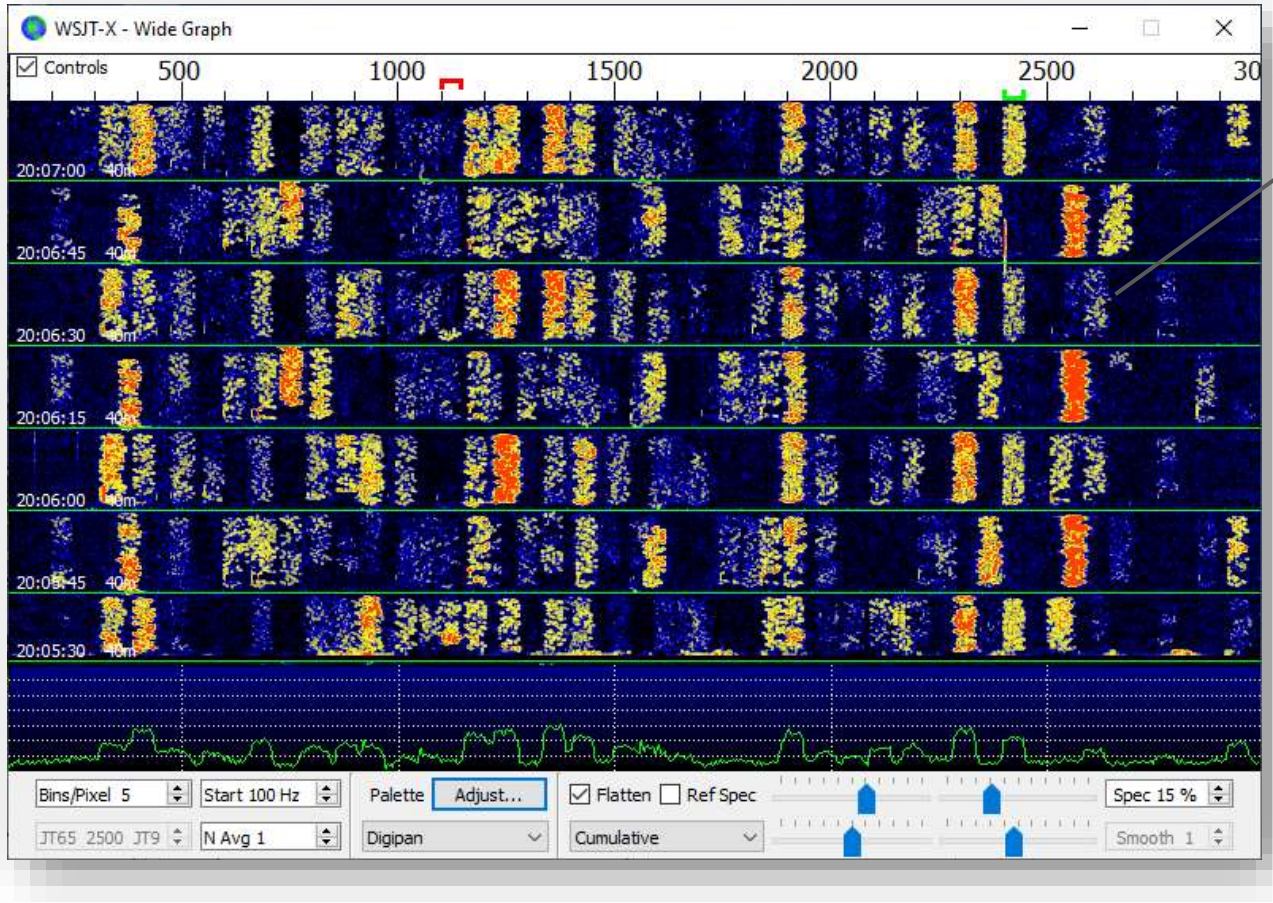


- Frequencies are offset vs. base frequency.
- Check “Hold Tx Freq”
- Check “Auto Seq”
- Personal choice if you want to check “Call 1st“

The Looks and Sounds of FT8

Clickable waterfall display

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



15 seconds, 50 Hz segments

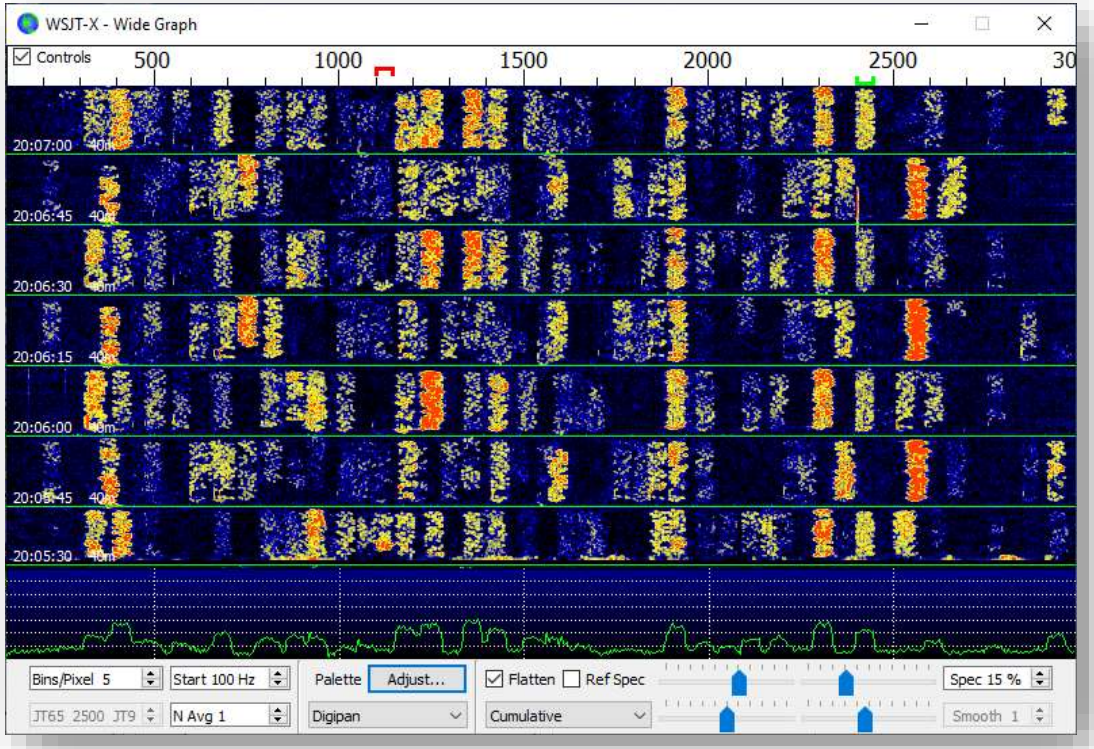
Single FT8 signal

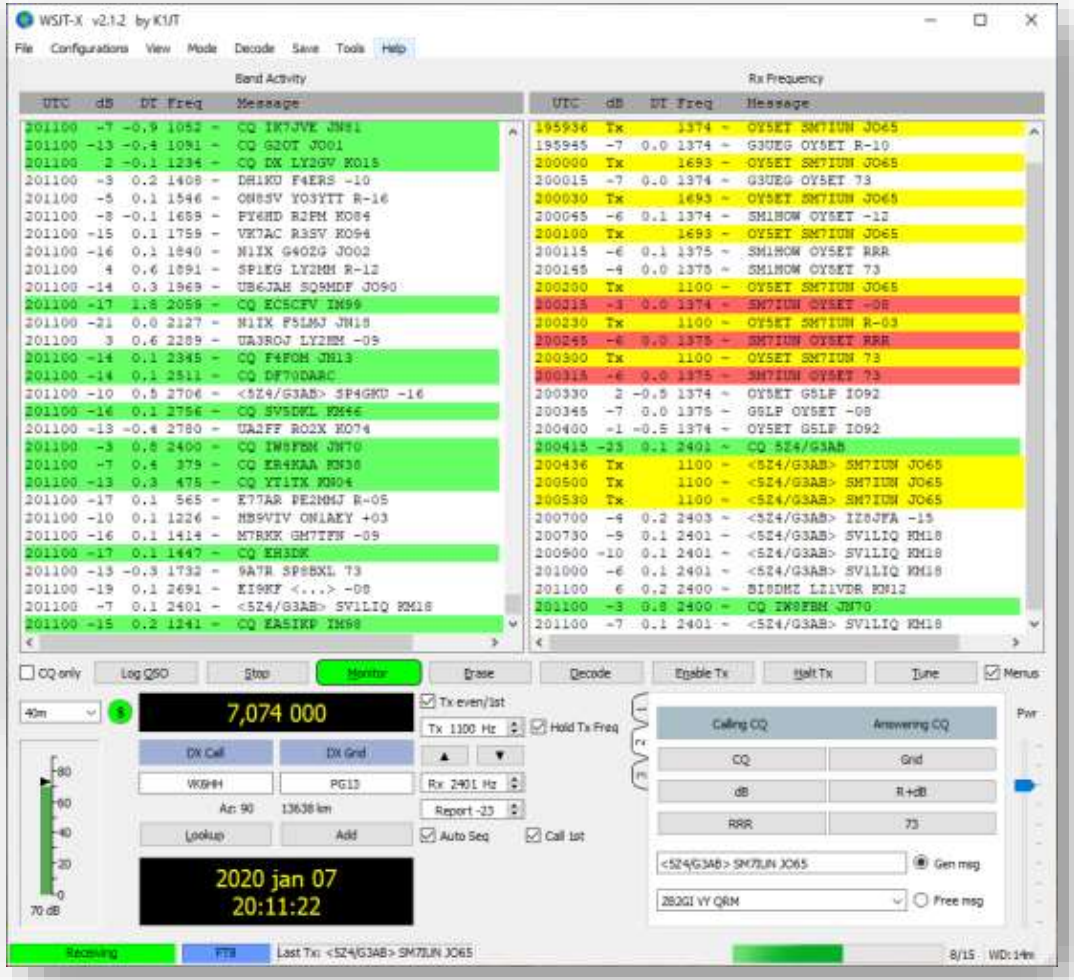
An entire FT8 sub-band

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.





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 all bands ▾, show signals ▾ rcvd by ▾ the callsign ▾ sm7iun using all modes ▾ over the last 24 hours ▾ Go! 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).

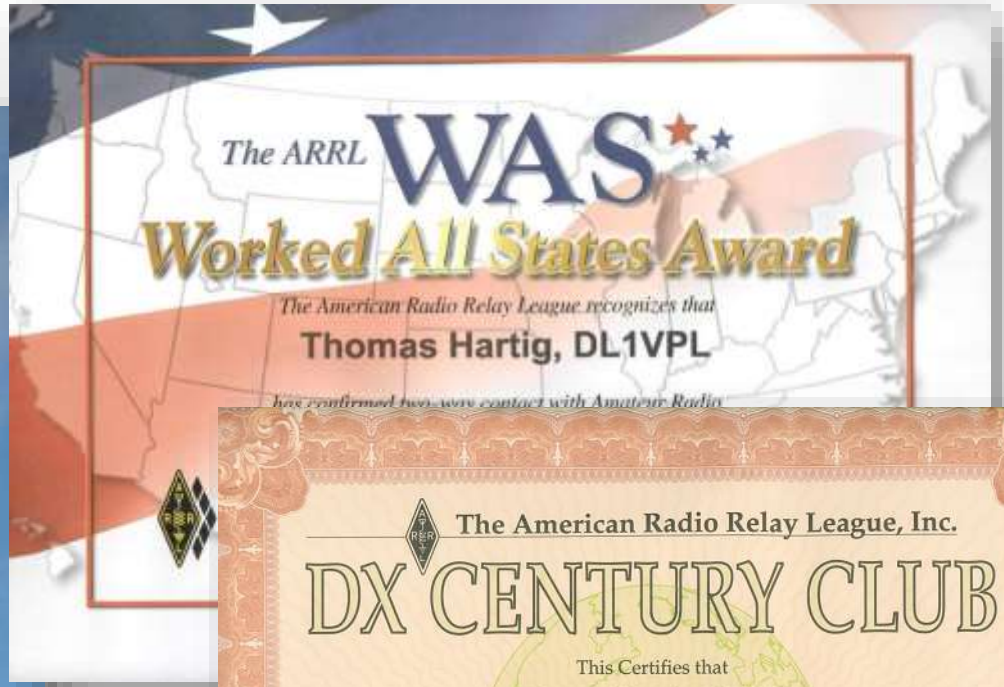
There are 3357 active monitors: 1031 on 40m, 918 on 20m, 474 on 30m, 284 on 80m, 131 on 17m, 128 on 160m, 109 on 60m, 87 on 15m, 60 on 2m, 56 on 6m, 33 on unknown, 4 on 10m, 4 on 600m, 3 on 23cm, 3 on 4m, 2 on 2200m, 1 on uhf. Legend

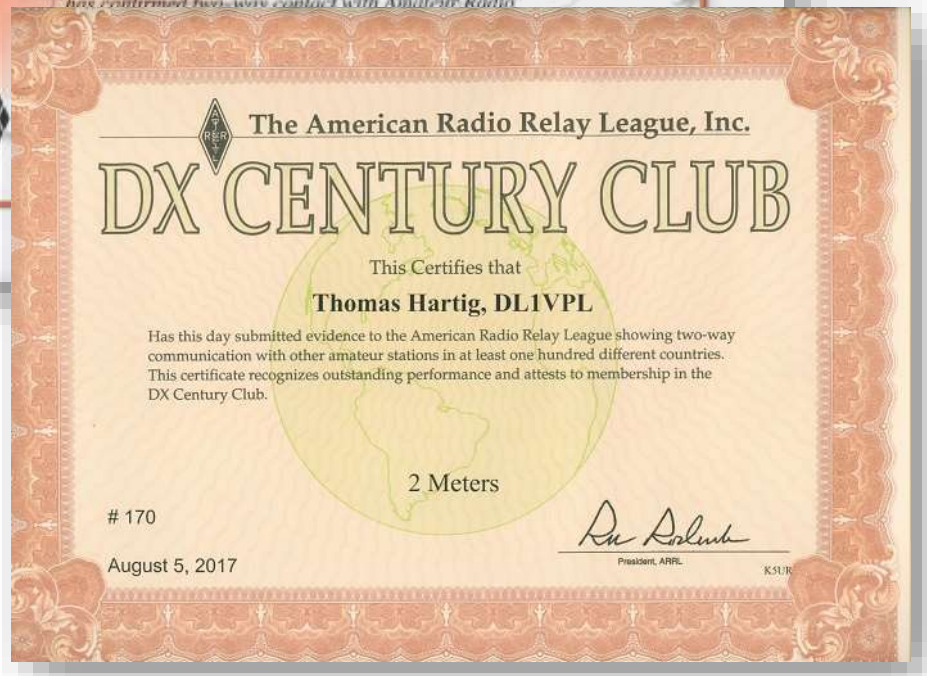
(distance chart) at SM7IUN (24775 reports, 143 countries last 24 hours; 160391 reports, 149 countries last week).

Statistics — Comments to Philip Gladstone — Online discussions — Reception records: 6,529,442,773 (150/sec) — Hosting by Fast Serv Networks, LLC

PSKREPORTER.INFO

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.