FT8
(Franke-Taylor design, 8-FSK Modulation)

A new, robust and highly versatile digital mode for HF

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What you will need to get on the air with FT8

- You should use a modern HF radio which likely has a built-in sound card. Examples of some common HF rigs (IC-7300, IC-7610, TS-590, FTDX-1200 and many more). If your rig has no sound card, the program (*WSJT-X*) will use your computer's sound card OR you may use an interface between the radio and computer such as the USB SignaLink (~ $100 + Tax at GigaParts in Las Vegas).
- You need a computer (desktop or laptop) with a 1.5 GHz or higher Pentium processor and at least 2GB of RAM installed and 200 MB of available memory.
- A monitor with at least 1024 X 780 resolution.
- It is **strongly advised** that you read, **in its entirety**, the new *WSJT-X* v.2.0.0 user guide available at: http://physics.princeton.edu/pulsar/k1jt/wsjtx-doc/wsjtx-main-2.0.0.html
- You will need to download and install the latest version of *WSJT-X* (v.2.0.0) at the link provided within the user guide documentation above or you can download it at SourceForge.net.
- **Important Note**: Earlier versions of *WSJT-X* will **NOT** decode currently generated 77-bit FT-8 messages. The latest version of *WSJT-X* was released on Dec. 10, 2018. Earlier versions would be sufficient for some of the other digital modes contained within the *WSJT-X* program but not FT8.

FT8 Basics

- FT8 is a **synchronous** digital mode for HF similar in character to its cousins JT65 and JT9 and its successful operation depends on accurate timing.
- FT8 requires a computer with a program designed to provide **accurate timing** through the internet.
- FT8 requires a program called WSJT-X or JTDX for the encoding and decoding of FT8 signals.
- FT8 uses 15 second TX/RX intervals.
- FT8 requires a connection between the radio and the computer (usually a USB connection) in order for the program to control the radio.
- **Always use low power** (20-40W) to avoid unnecessary interference to other hams.
- FT8 is a weak signal mode and **NOT** a high power mode.
- When setting up your transceiver for FT8 (or other similar digital modes), ensure that there is zero or very little ALC activity on transmit. This ensures a cleaner, less over driven signal in most all cases.

FT8 Basics Cont'd.

- **You must read the WSJT-X user guide in its entirety!**
- **http://physics.princeton.edu/pulsar/K1JT/wsjtx-doc/wsjtx-main-1.9.1.html#INTRO**
- Timing programs: Meinberg NTP, Dimension4, NetTime (easy, highly reliable, accurate, trouble free, etc.)
- NetTime is what I've been using for all digital modes for years and is infallible. Other programs are complicated, problematic and require much more computer memory and expertise.
- FT8 was designed for multi-hop E-skip where signals will be weak and fading, openings may be short, and for fast completion of reliable and confirmable QSO's.
- **Using low power cannot be emphasized enough**. Examples of the deleterious effects of using high power and/or improper ALC settings will be shown later in this presentation.

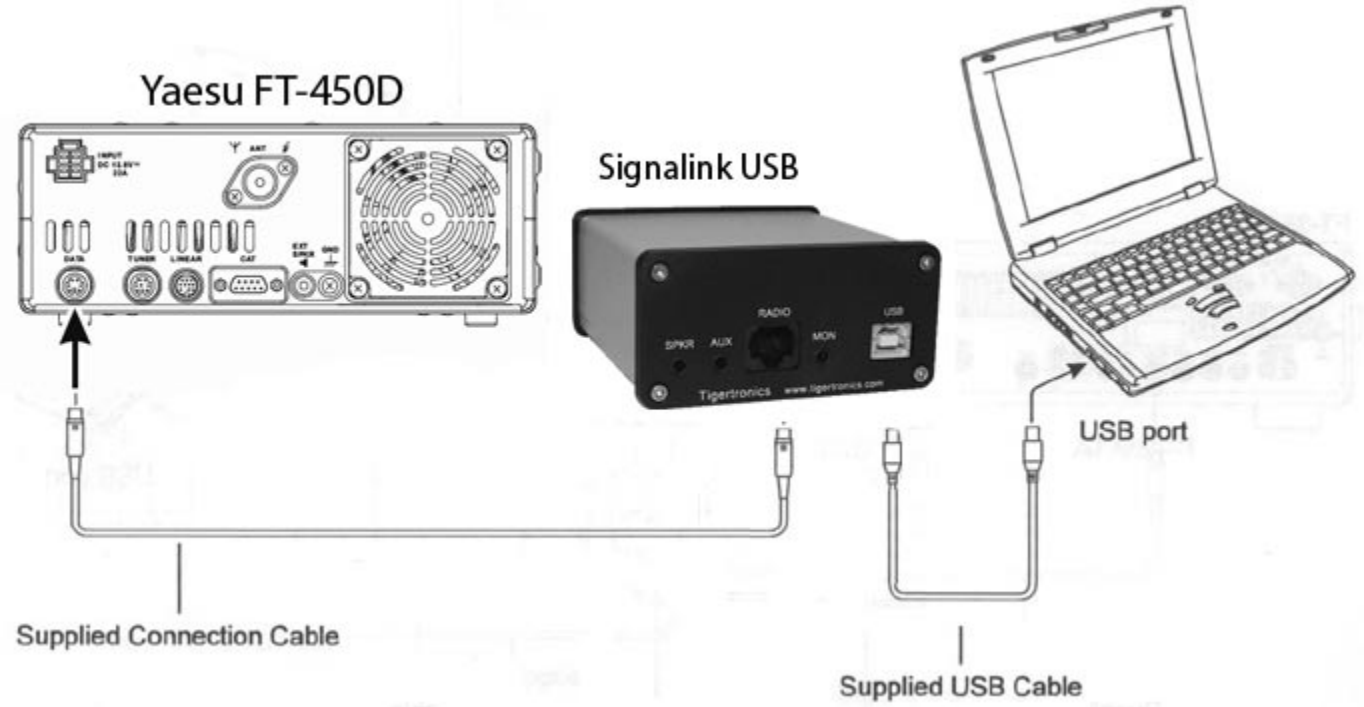
Software and Hardware Requirements

- Download the latest version of *WSJT-X* (v 2.0.0)
- Starting Jan 1, 2019 version 2.0 will not be backwards compatible with earlier versions and will not decode FT8 sigs generated by the older versions.
- JTDX is another program you can use. It's very similar to *WSJT-X* but has more functionalities and a different user interface.
- Minimum Pentium based PC (or equiv.) at 1.5 GHz or higher with at least 2 GB of RAM.
- You will also need an accurate clock timing program such as Meinberg NTP, Dimension 4 or NetTime.
- Your clock needs to be accurate to within ± 0.5 sec or so.
- The sound system in your computer needs to be set to sample at 48,000 Hz and 16-bits.

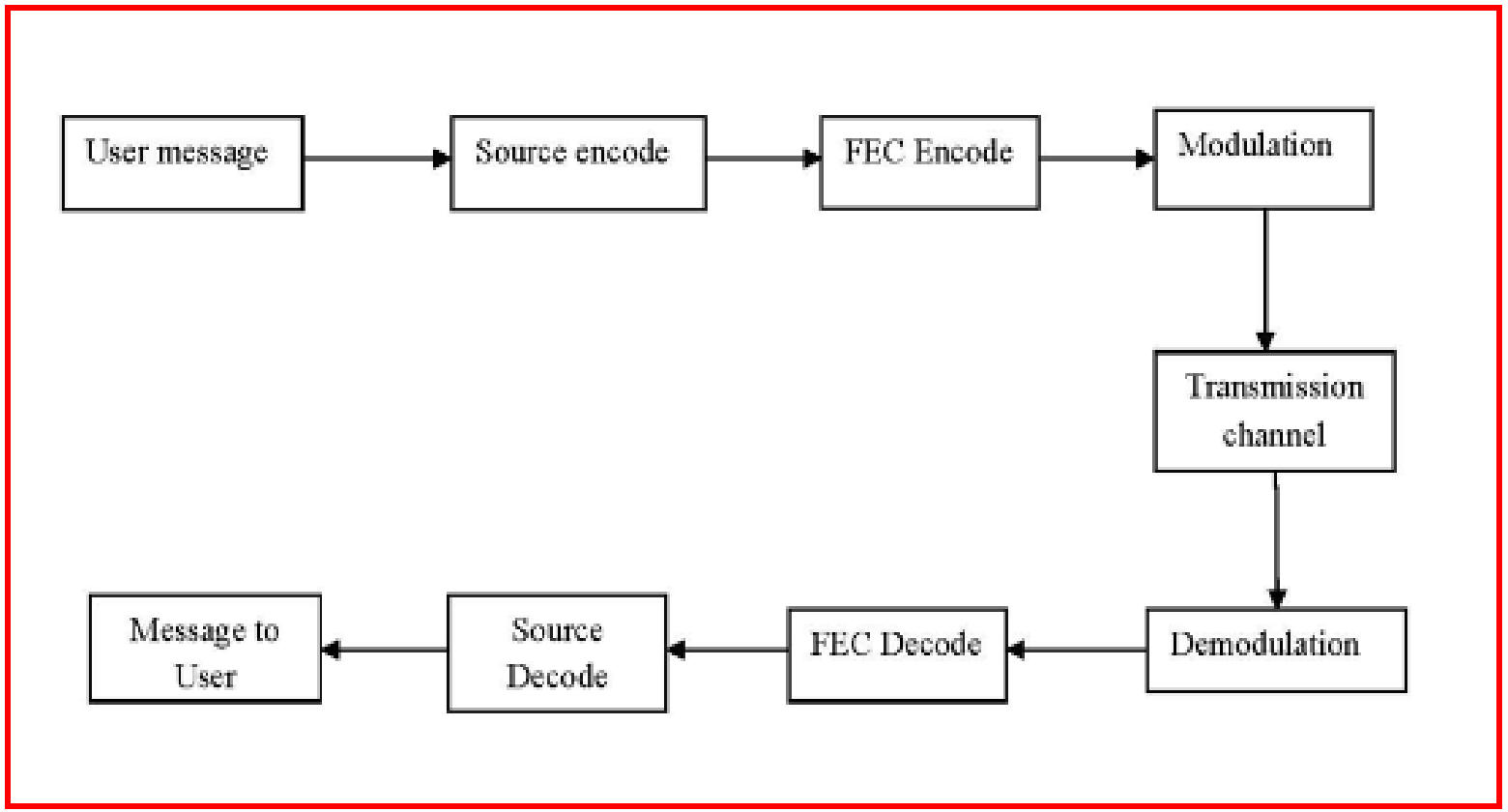
WSJT-X

- Open source software developed by the K1JT team
- Can operate the following digital modes: FT8, JT65, JT9, JT4, QRA64, MSK144, ISCAT, WSPR and Echo.
- The most common software used by amateurs for these modes
- Simple to use and highly versatile
- Newest version has the so-called “DXpedition mode”
- In DXpedition mode, you are the “Hound” and the DX station is the “Fox”
- You will likely never use the Fox functionality, only the hound
- The Fox can use up to five streams on a single transmission
- *WSJT-X* v.2.0.0 now supports various contest modes including ARRL Field Day, ARRL RTTY Roundup, NA and EU VHF contests.

Typical Station Setup for Digital HF using a Signalink USB



Block diagram showing steps in a typical digital communication System[5]



How do FT8 and Similar Synchronous Digital Modes Work?

- Digital information is modulated onto a carrier and transferred over a radio channel.
- The basic unit of transmitted data is a ***"channel symbol".***
- These ***channel symbols*** are each represented by numbers comprised of bits.
- The modulator will transmit *m* information bits in each symbol using 2^m different waveforms representing symbol values from 0 to $2^m - 1$
- The different waveforms may have distinct amplitudes, phases, frequencies or shapes. The *WSJT-X* waveforms are made of sinusoids with constant amplitude.
- Modes employing ***frequency shift keying*** **(FSK)** use a different tone frequency representing each allowed symbol value.
- Binary modulation ($m = 1$) implies transmitting only one bit at a time.
- Modulation schemes with larger *m* are used to an advantage in all but one of the *WSJT-X* modes.
- Controlled redundancy to a digital message to correct for errors can be obtained trivially via simple repetition of each symbol. However, much more powerful redundancy is achieved by mapping each sequence of *k* message symbols, in a controlled way, into a unique and longer sequence of *n* symbols called a ***codeword***.
- This technique is known as ***Forward Error Correction (FEC)***.[1]

How do FT8 and similar synchronous digital modes work? Cont'd

- *WSJT-X* protocols use ***block codes*** where the values of *n* and *k* are fixed and labeled as (*n*,*k*) codes. An integer parameter *q* is used to define a range of available symbol values for a code (similar to the *m* values used in the modulation scheme).
- Parameter $Q = 2^q$ is then created and defined as the ***alphabet size*** of the code.
- The code symbol values range from 0 to *Q* -1 and each codeword conveys *kq* message bits.
- The amount of redundancy is characterized as by the ratio *n/k*, and its reciprocal *k/n* is known as the *code rate*. The mathematics underlying the design of such *k*-to-*n* mapping schemes and their corresponding *n*-to-*k* reverse transformations, forms a major branch of modern communication theory.
- Reception of transmitted symbols requires accurate synchronization of time and frequency between transmitting and receiving stations. To make this possible with typical amateur radio equipment, each *WSJT-X* protocol includes a unique synchronizing pattern: a sequence of known symbols interspersed with those carrying message information.[2]

Table obtained from November, 2017 QST article by Joe Taylor, K1JT, Steve Franke, K9AN and Bill Somerville, G4WJS

Parameters of the slow WSJT-X Protocols
Bandwidths (BW) are for the narrowest submodes. S/N threshold is referenced to a 2.5kHz 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

#Modulation includes one additional tone used for synchronization[3]

Conventional Dial Frequencies for FT8, JT65, JT9 and WSPR

Band (m)	Frequencies (MHz)			
	FT8	**JT65**	**JT9**	**WSPR**
160	1.840	1.838	1.839	1.8366
80	3.573	3.570	3.572	3.5686*
40	7.074	7.076	7.078	7.0386
30	10.136	10.138	10.140	10.1387
20	14.074	14.076	14.078	14.0956
17	18.100	18.102	18.104	18.1046
15	21.074	21.076	21.078	21.0946
12	24.915	24.917	24.919	24.9246
10	28.074	28.076	28.078	28.1246
6	50.313	50.310†	50.312	50.293

How does FT8 compare to its cousins JT65 & JT9?

- FT8 is narrower (50 Hz) than JT65 (178 Hz) but wider than JT9 (15.6 Hz).
- FT8 is not as sensitive as JT65 & JT9 (-24 dB vs. -29 dB).
- FT8 uses shorter XMIT and Receive intervals (15s vs. 60s).
- FT8 QSO's are completed in 1.5 min vs. 6.0 min for JT65/JT9.
- FT8 uses FEC just like JT65 & JT9.
- FT8 uses 8-FSK modulation with a keying rate/tone spacing of 6.25 Hz (there is no synch tone, unlike JT65).
- FT8 uses Low-Density-Parity-Check Code LDPC (174,87). It is a linear error correcting type code.
- Occupied bandwidth is 50 Hz.

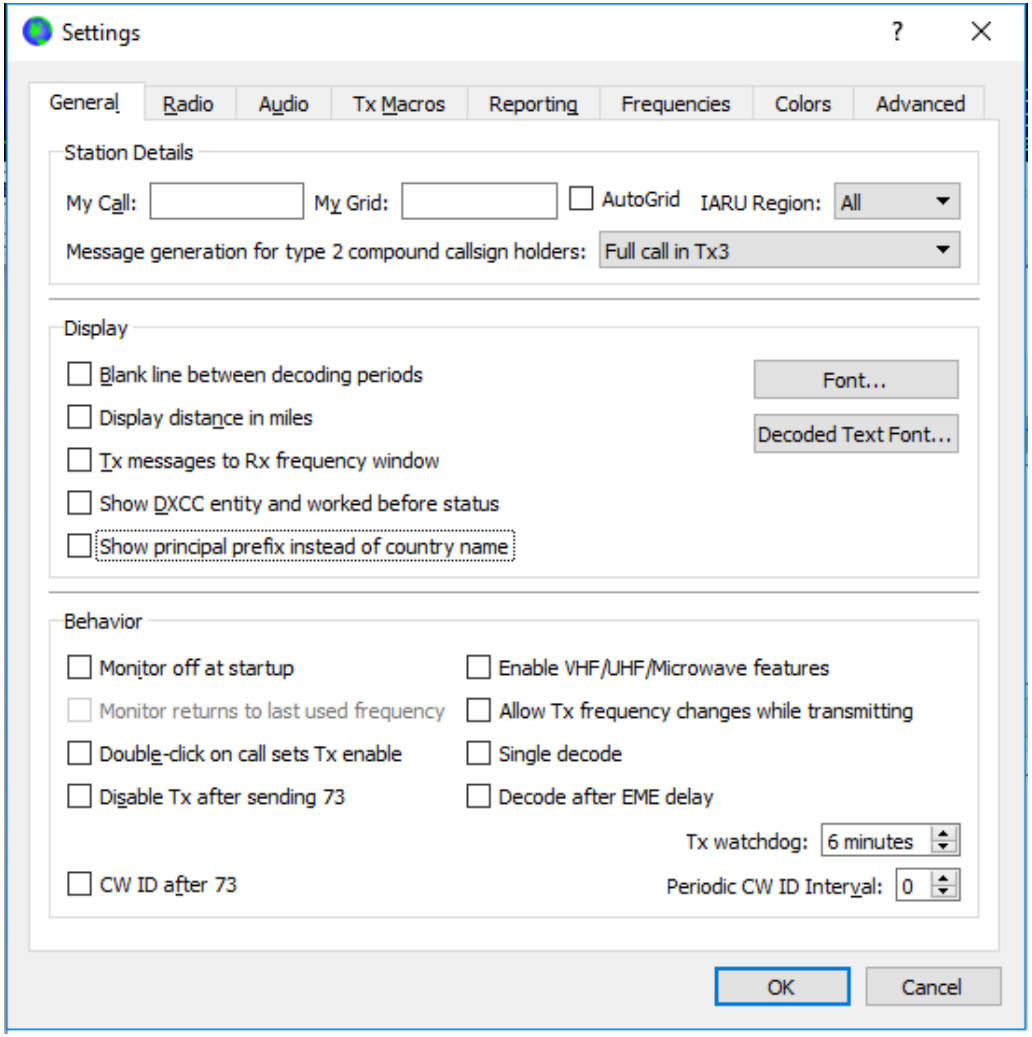
Important characteristics of FT8:

- T/R sequence length: 15 s
- Message length: 77 bits + 14-bit CRC (Cyclic Redundancy Code)
- FEC code: LDPC(174,87)
- Modulation: 8-FSK, keying rate = tone spacing = 6.25 Hz
- Waveform: Continuous phase, constant envelope
- Occupied bandwidth: 50 Hz
- Synchronization: three 7x7 Costas arrays (start, middle, end of Tx)
- Transmission duration: 79*1920/12000 = 12.64 s
- Decoding threshold: -20 dB (perhaps -24 dB with AP decoding)
- Operational behavior: similar to HF usage of JT9, JT65
- Multi-decoder: finds and decodes all FT8 signals in passband
- Auto-sequencing after manual start of QSO

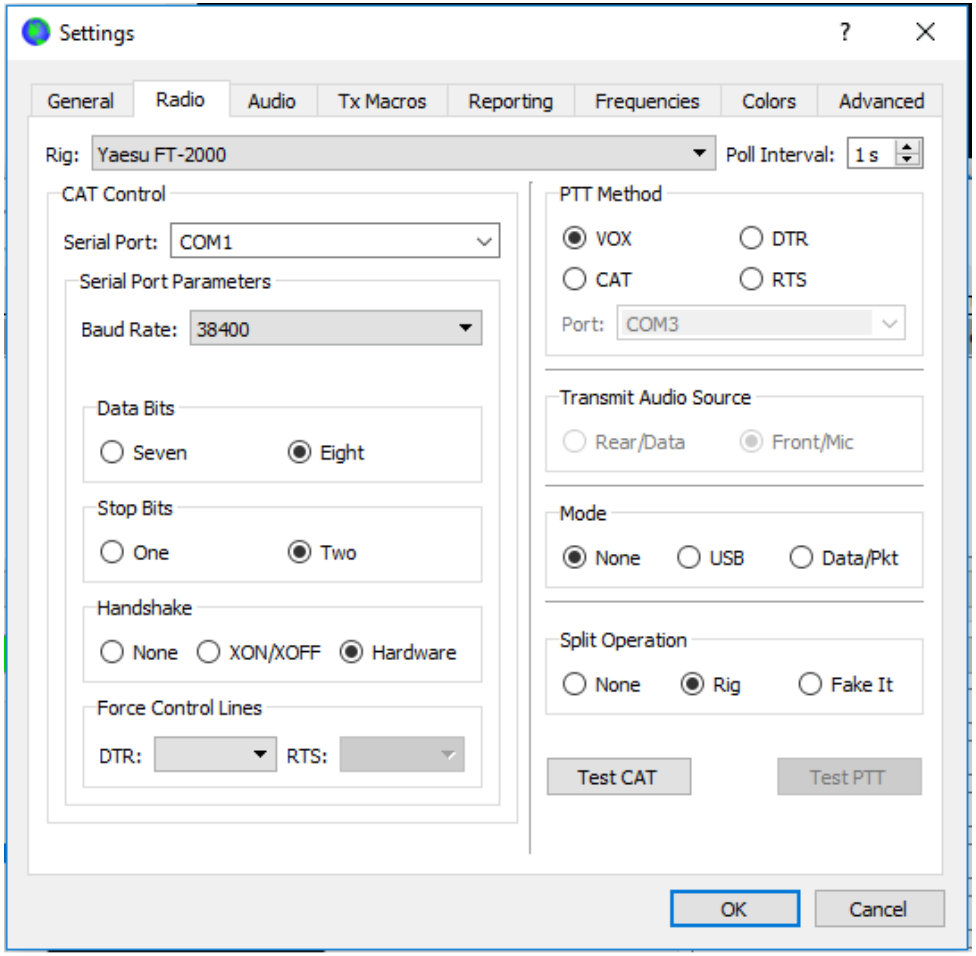
Color coding in WSJT-X

- CQ's appear in band activity screen and are colored blue
- When you choose and double click a CQ, the CQ is copied onto the RX frequency section and is colored green.
- All text that you transmit appear in RX freq. section and are colored yellow.
- All text that contains your call sign is colored red
- Default colors may be changed in settings menu
- You may control everything on the radio through the software (i.e., band, mode, power, etc.)
- The date and time appear and the time is in UTC
- The exact dial frequency is also shown

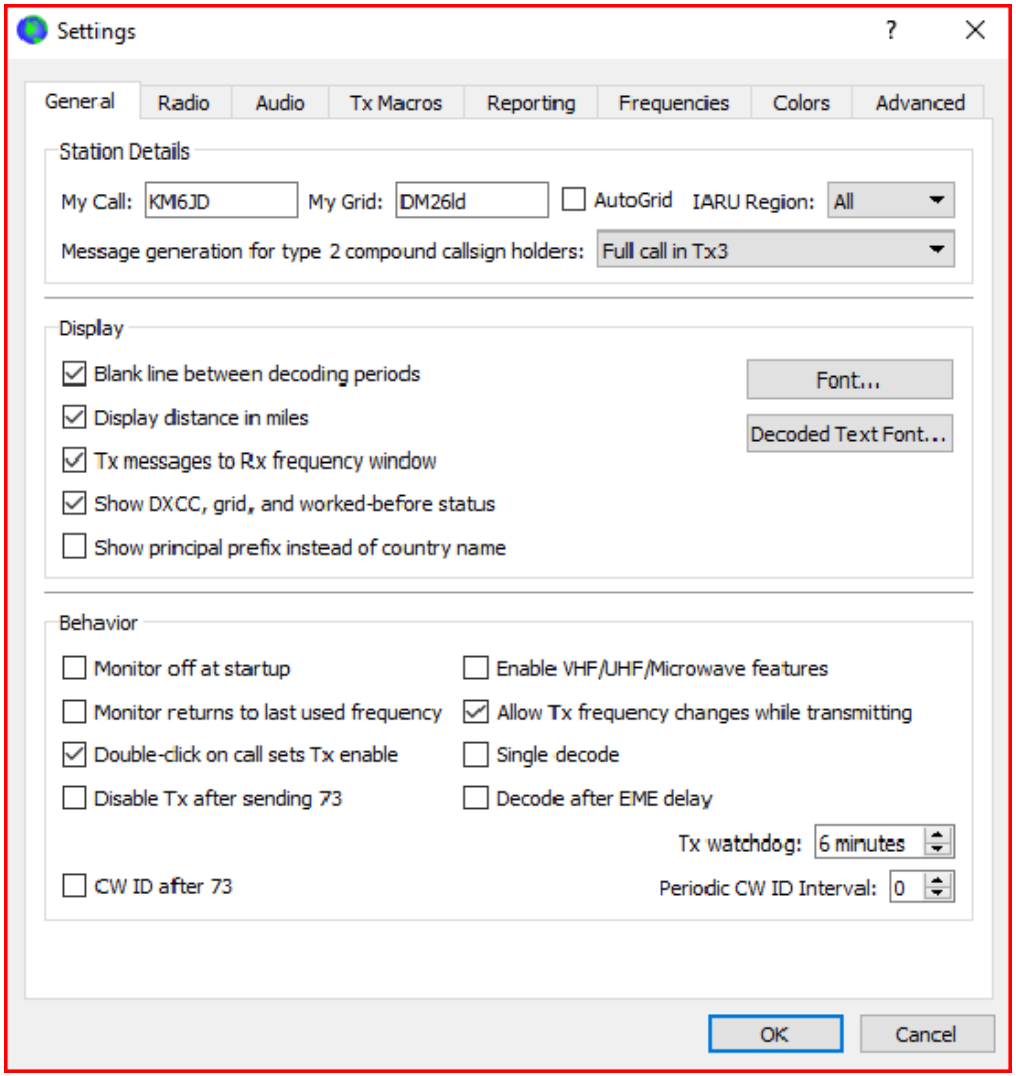
Settings Menu Items in WSJT-X



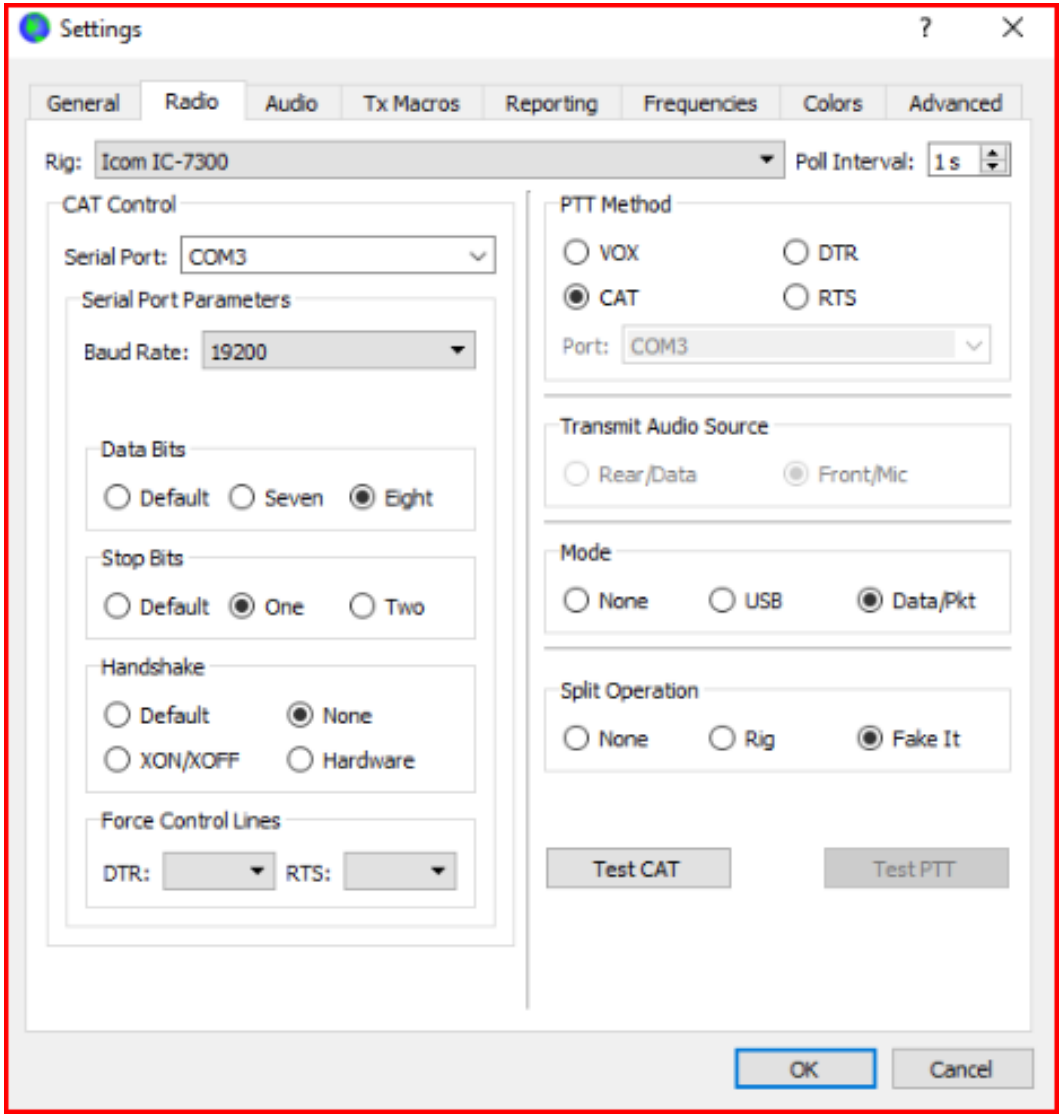
Radio settings in WSJT-X



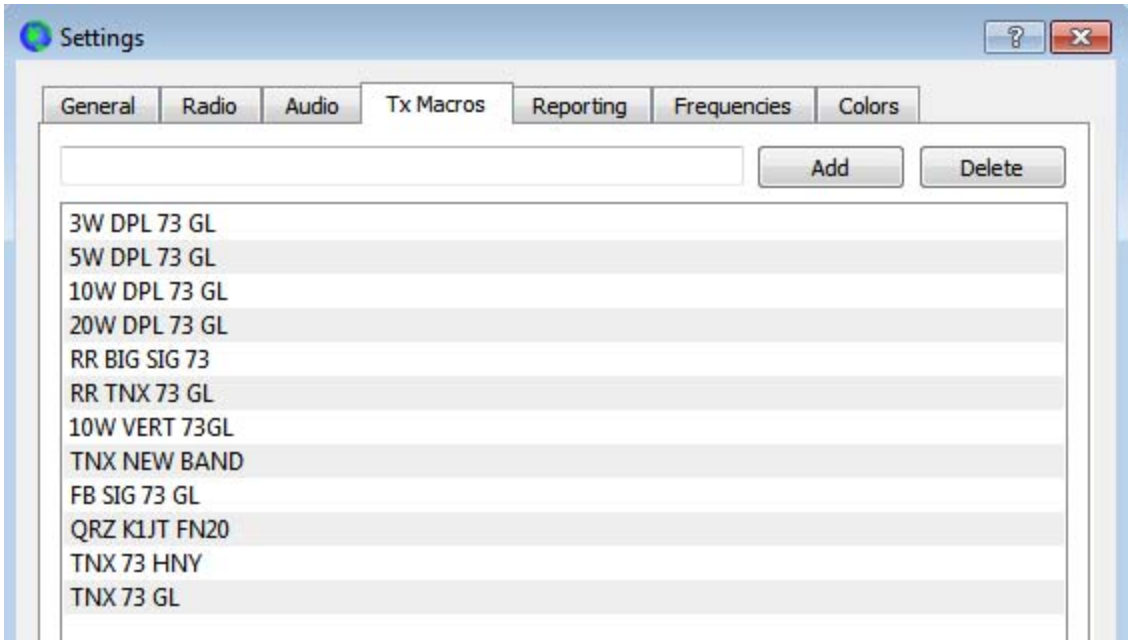
General Settings tab in WSJT-X for IC-7300



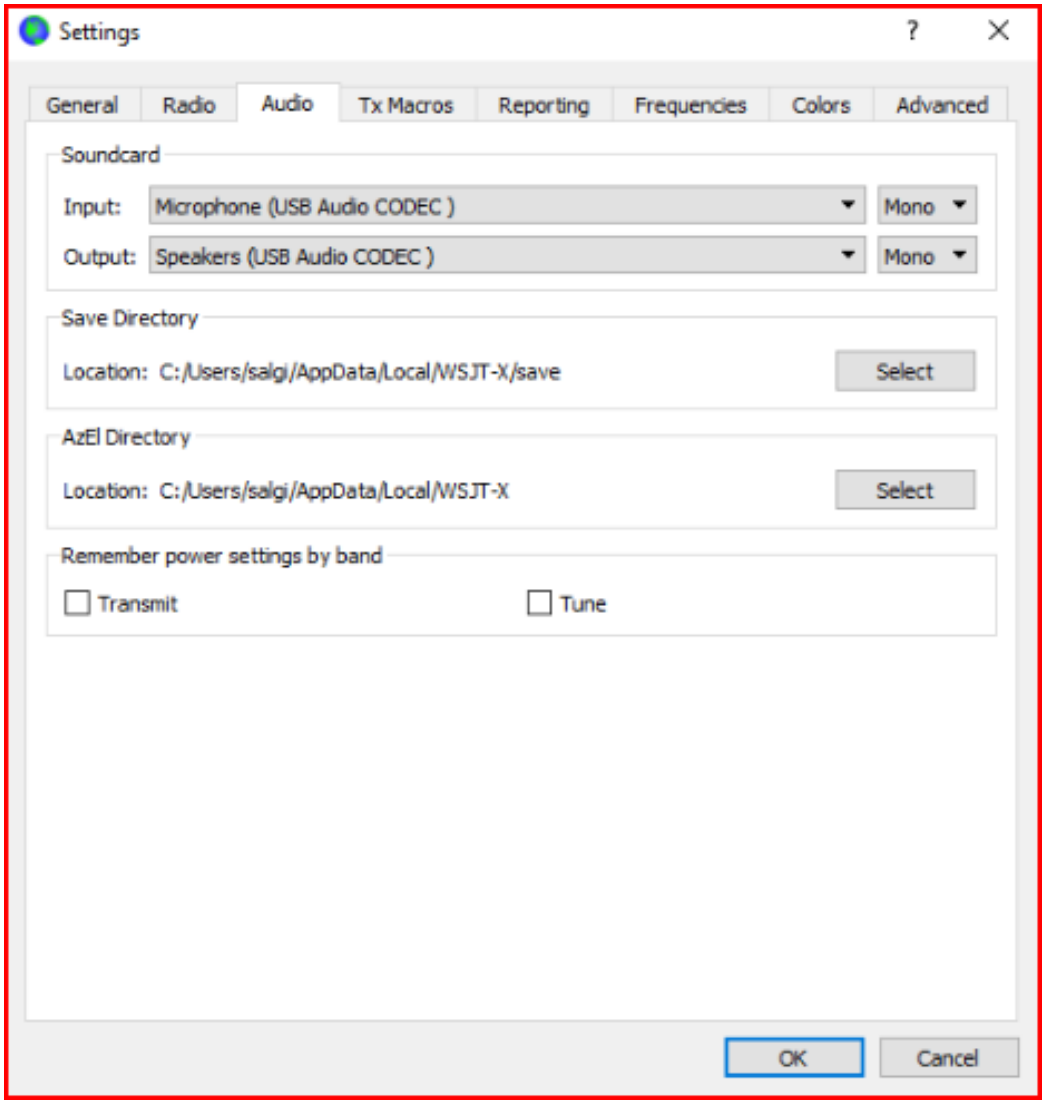
Radio Settings tab in WSJT-X for IC-7300



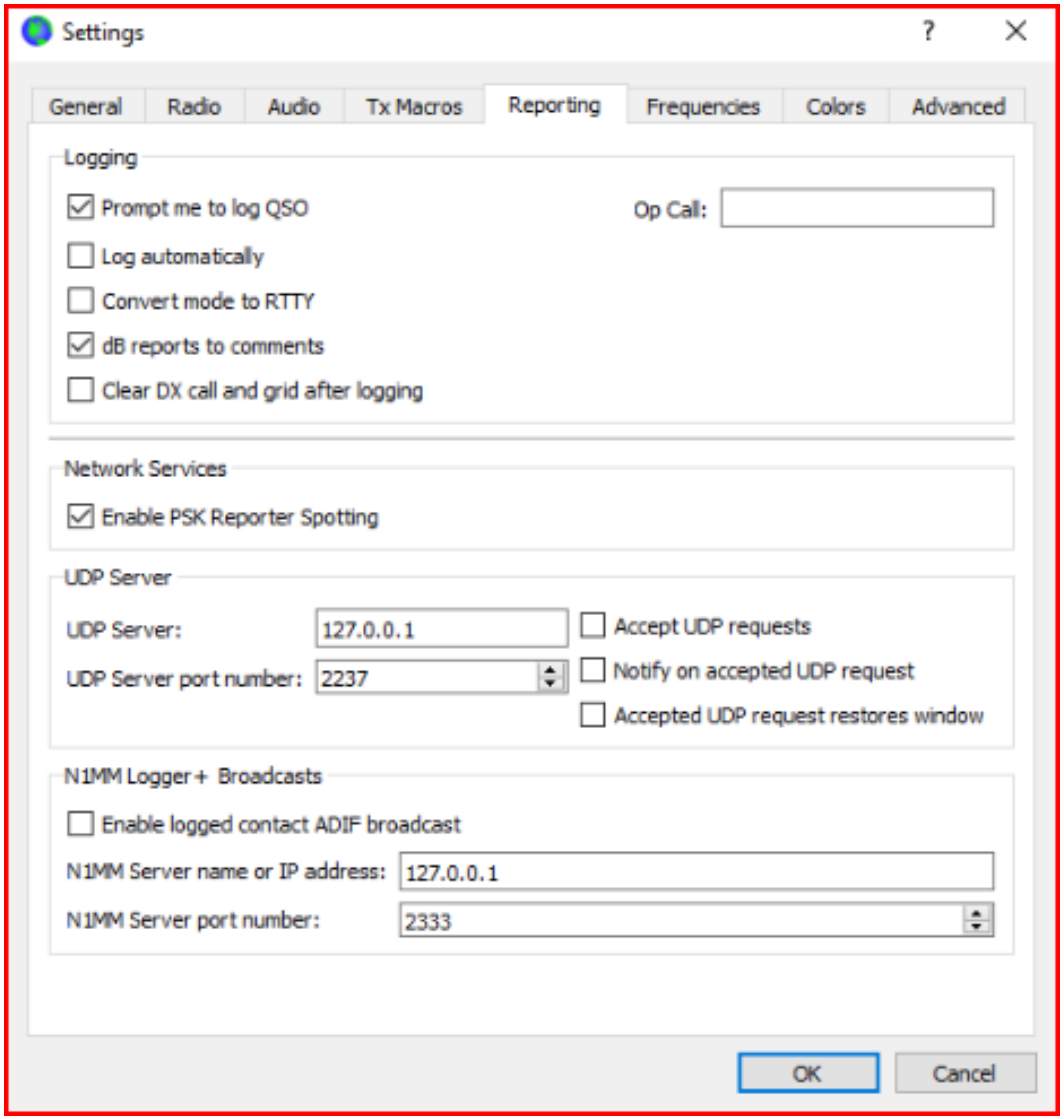
TX Macros (Optional messages): Limited to 13 characters (spaces count as one character)



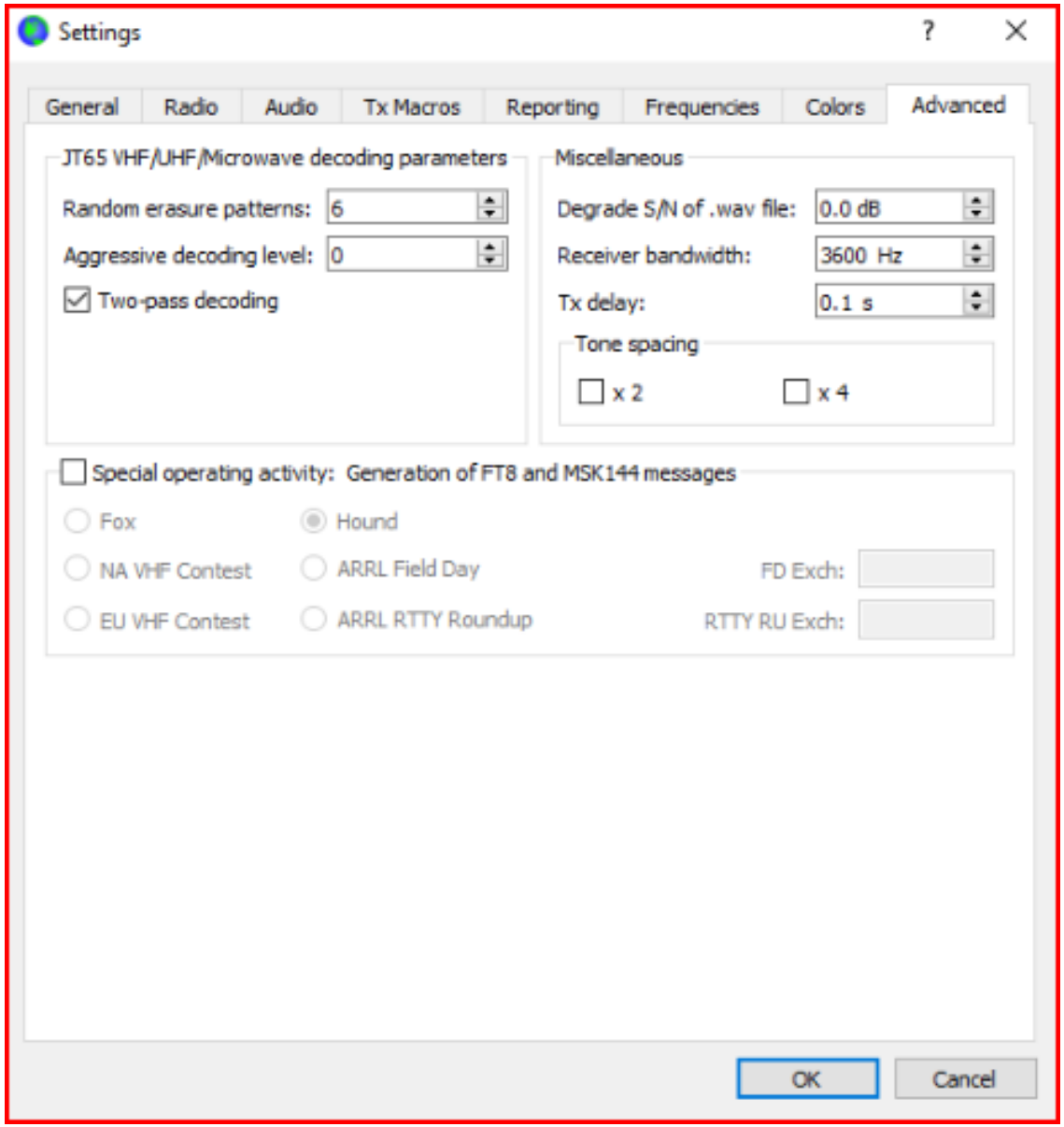
Audio Settings tab in WSJT-X for the IC-7300



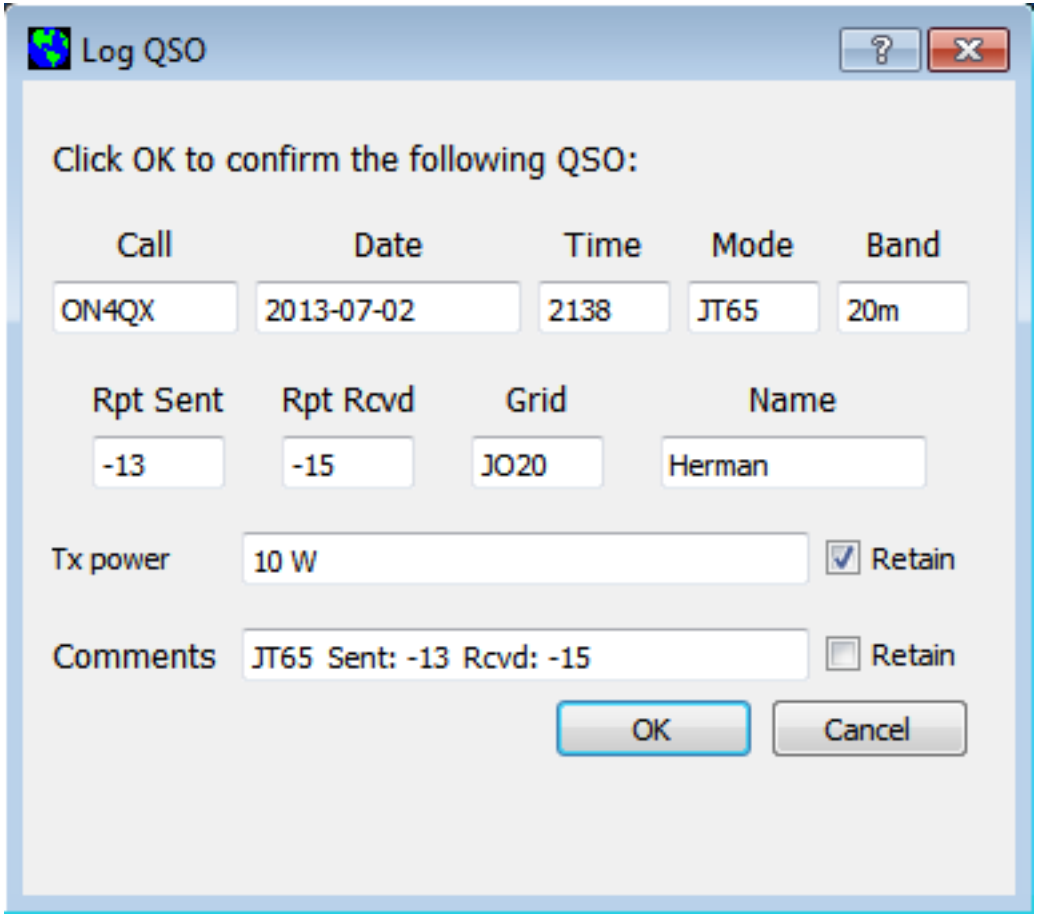
Reporting Settings in WSJT-X for the IC-7300



Advanced Settings in WSJT-X for the IC-7300



WSJT-X Log Dialog Box



Methods for initiating contacts

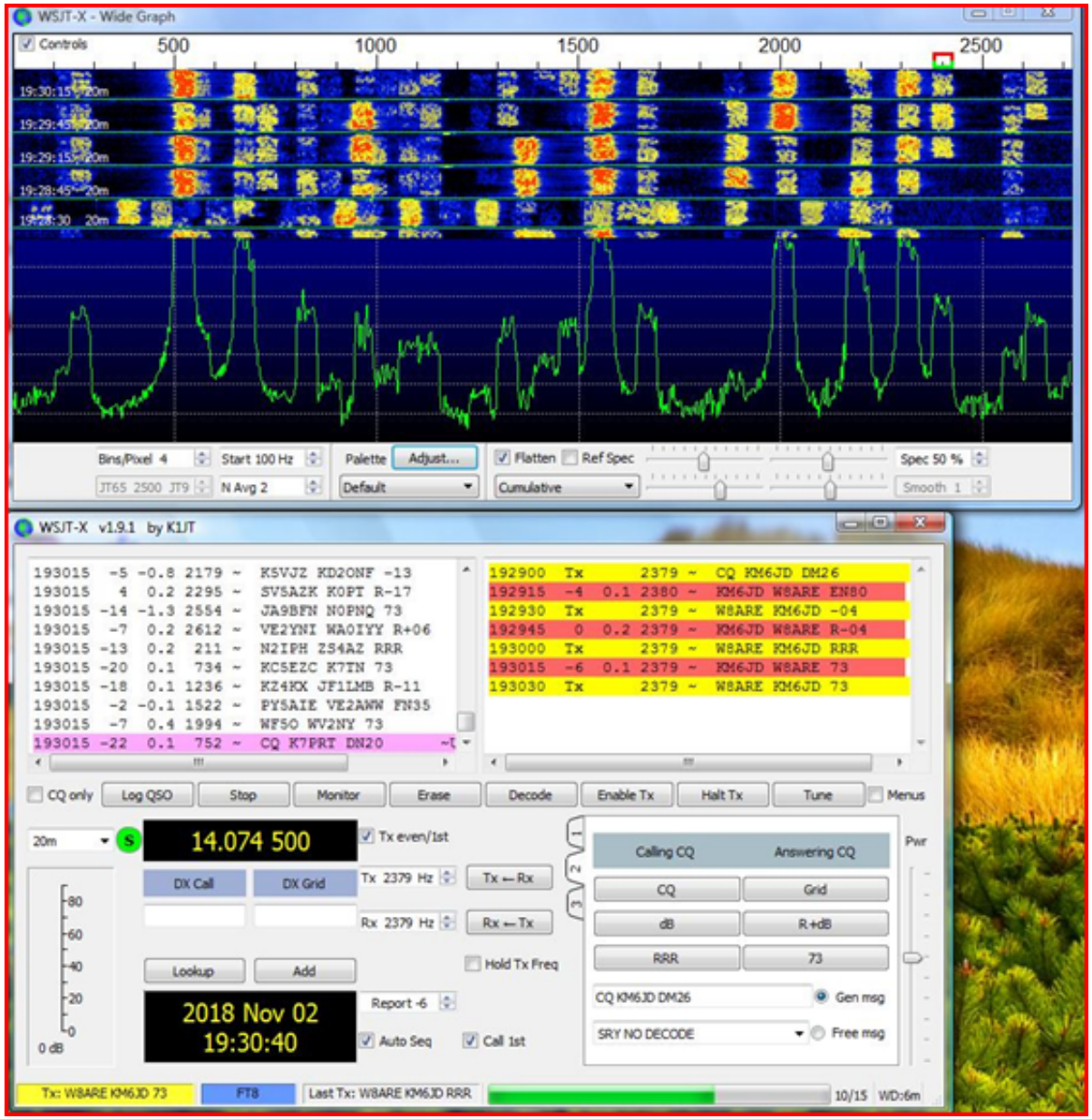
- Calling CQ (Ex. CQ KM6JD DM26)
- Responding to other stations calling CQ
- All messages containing CQ's are highlighted in blue EXCEPT those who you have worked before on that band which are highlighted in green.
- Calling a DX station using the split frequency method
- If you are calling a rare DX station it is strongly recommend that your transmitting frequency not be on their receive freq.
- Try your best by transmitting on a clear frequency
- DXpedition mode (Fox and Hound)
- WSJT-X v.2.0.0 now supports various contest modes including ARRL Field Day, ARRL RTTY Roundup, NA and EU VHF contests.
- More supported contest modes are in the pipeline.

Examples of contacts initiated by calling CQ or answering a CQ in WSJT-X

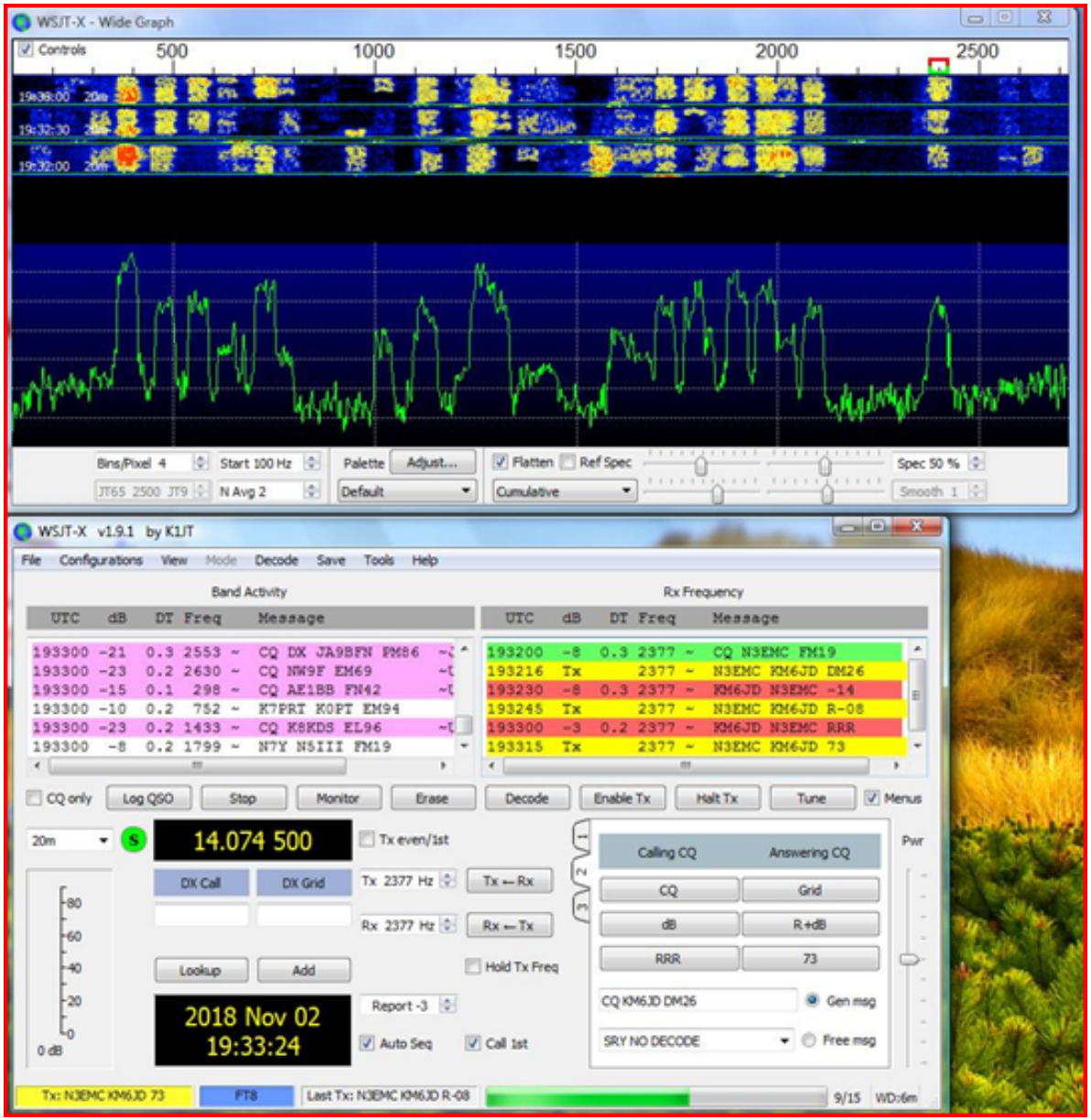
Calling CQ	Answering a CQ
CQ KM6JD DM26	W1AW KM6JD DM26
KM6JD W1AW FN31	KM6JD W1AW -07
W1AW KM6JD -04	W1AW KM6JD R-05
KM6JD W1AW R+02	KM6JD W1AW RR73
W1AW KM6JD RR73	W1AW KM6JD 73
KM6JD W1AW 73	

- CQ's are colored blue by default (green if already worked) and can be answered simply by double clicking.
- Use of the Auto-Sequencer greatly improves reliability and accuracy.

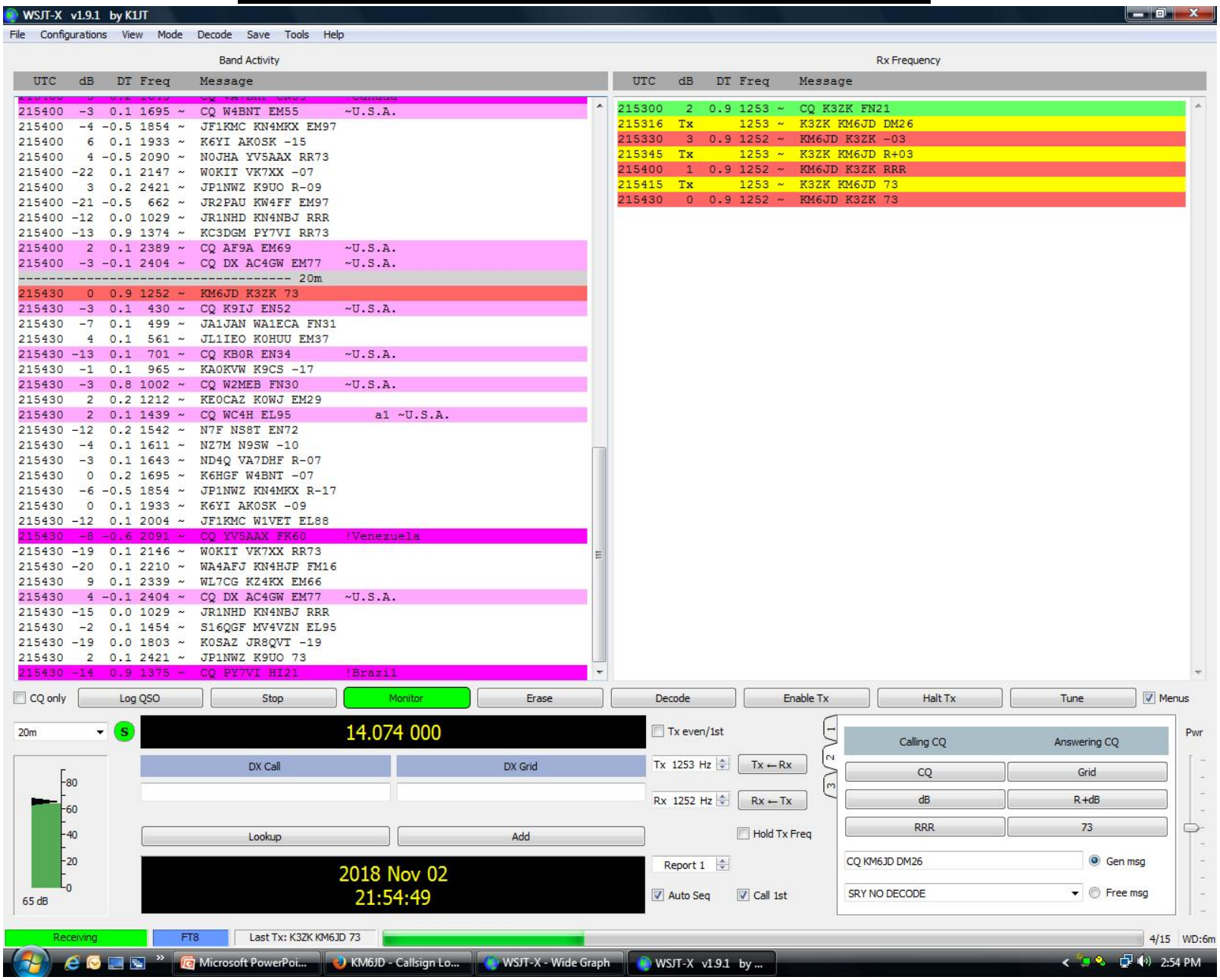
Example of Calling CQ (WSJT-X)



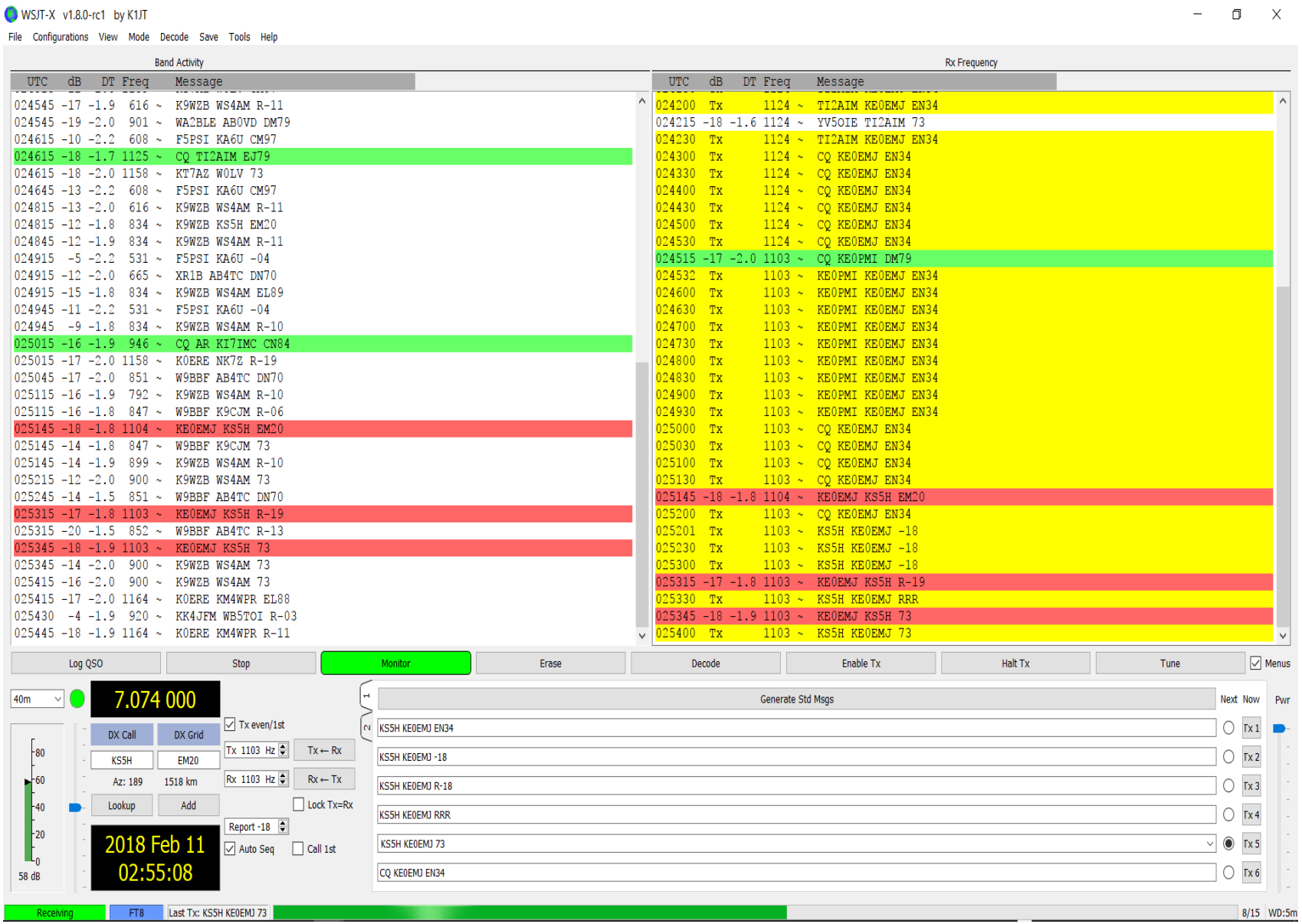
Example of answering a CQ (WSJT-X)



Sample QSO Full view (WSJT-X)

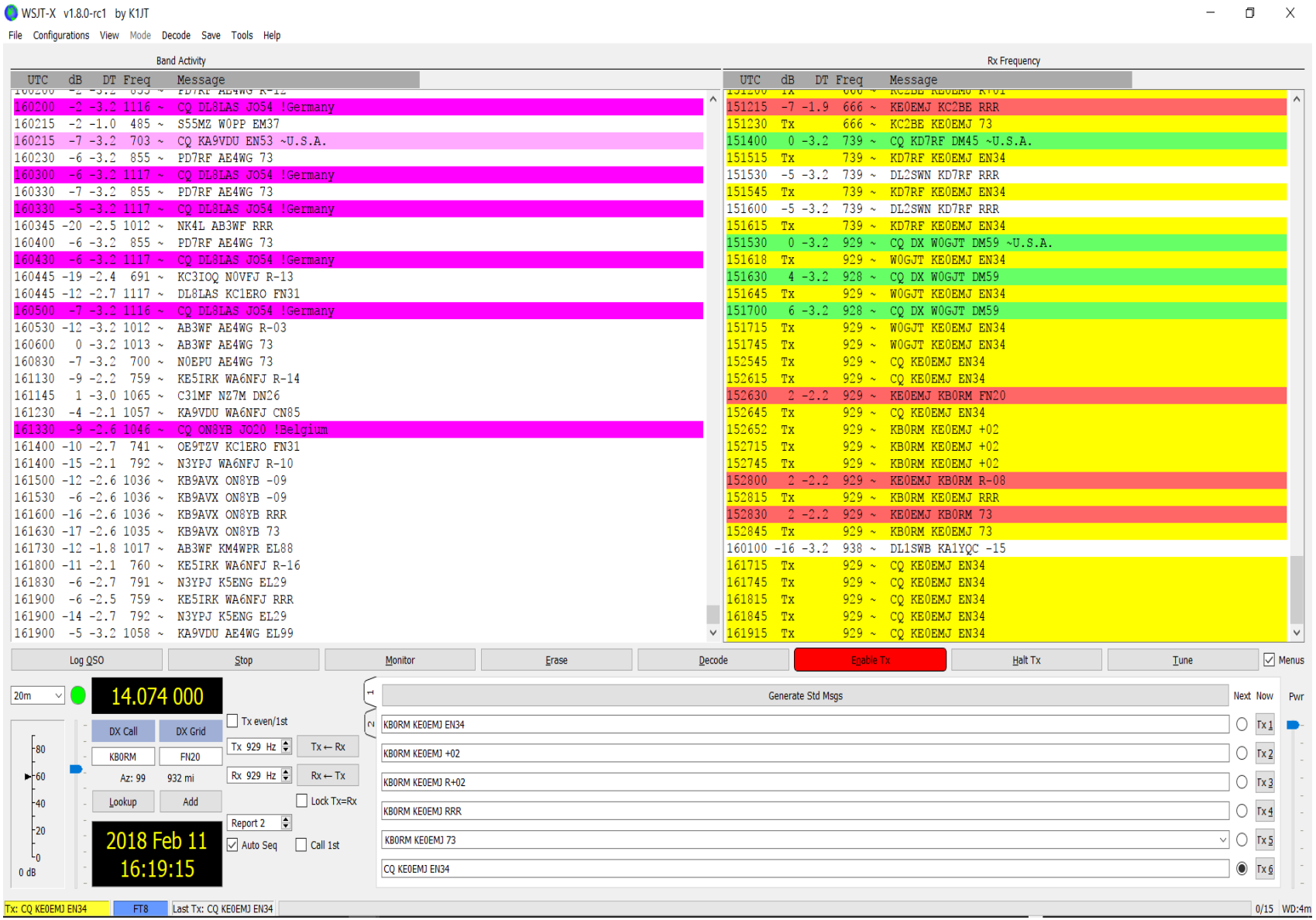


Example of QSO between KE0EMJ and KS5H



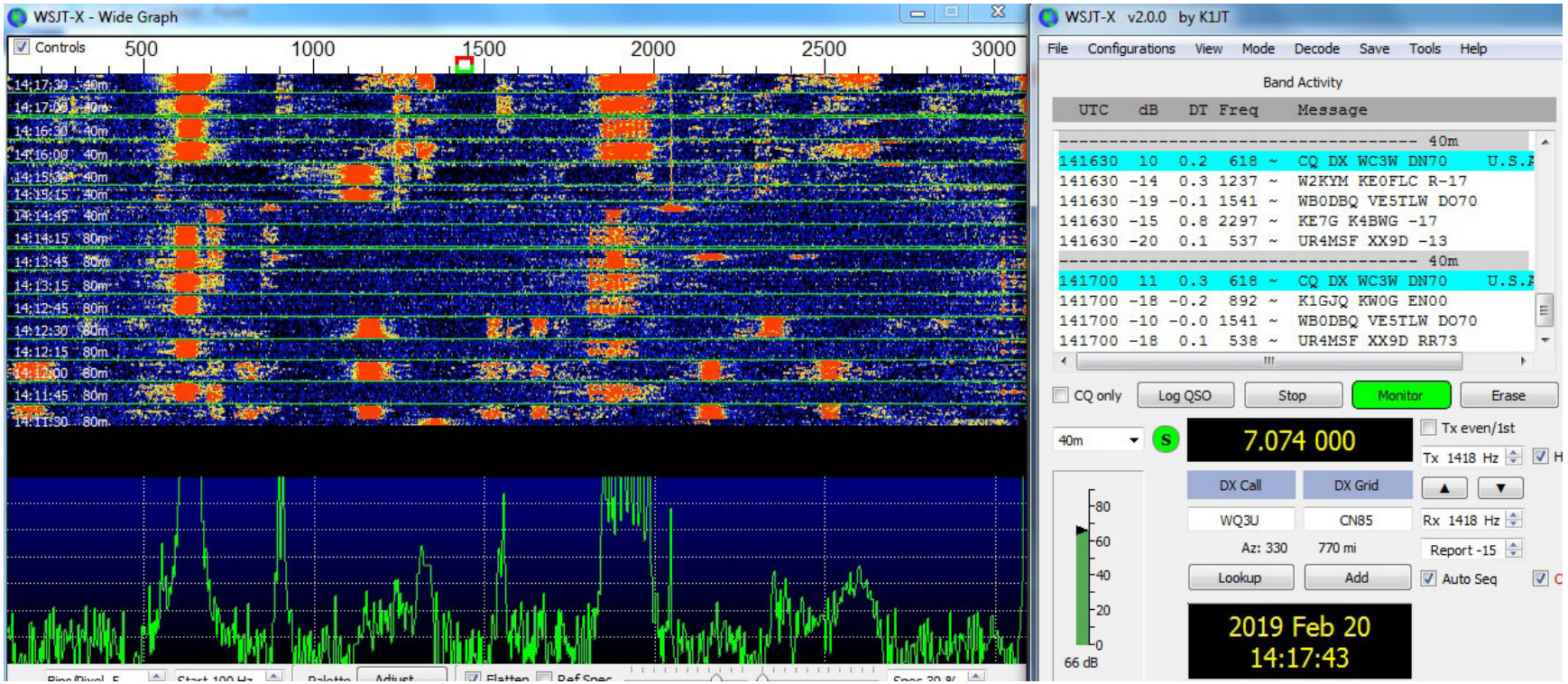
Courtesy of Kelly Boles, KE0EMJ

Example of QSO between KE0EMJ and KB0RM



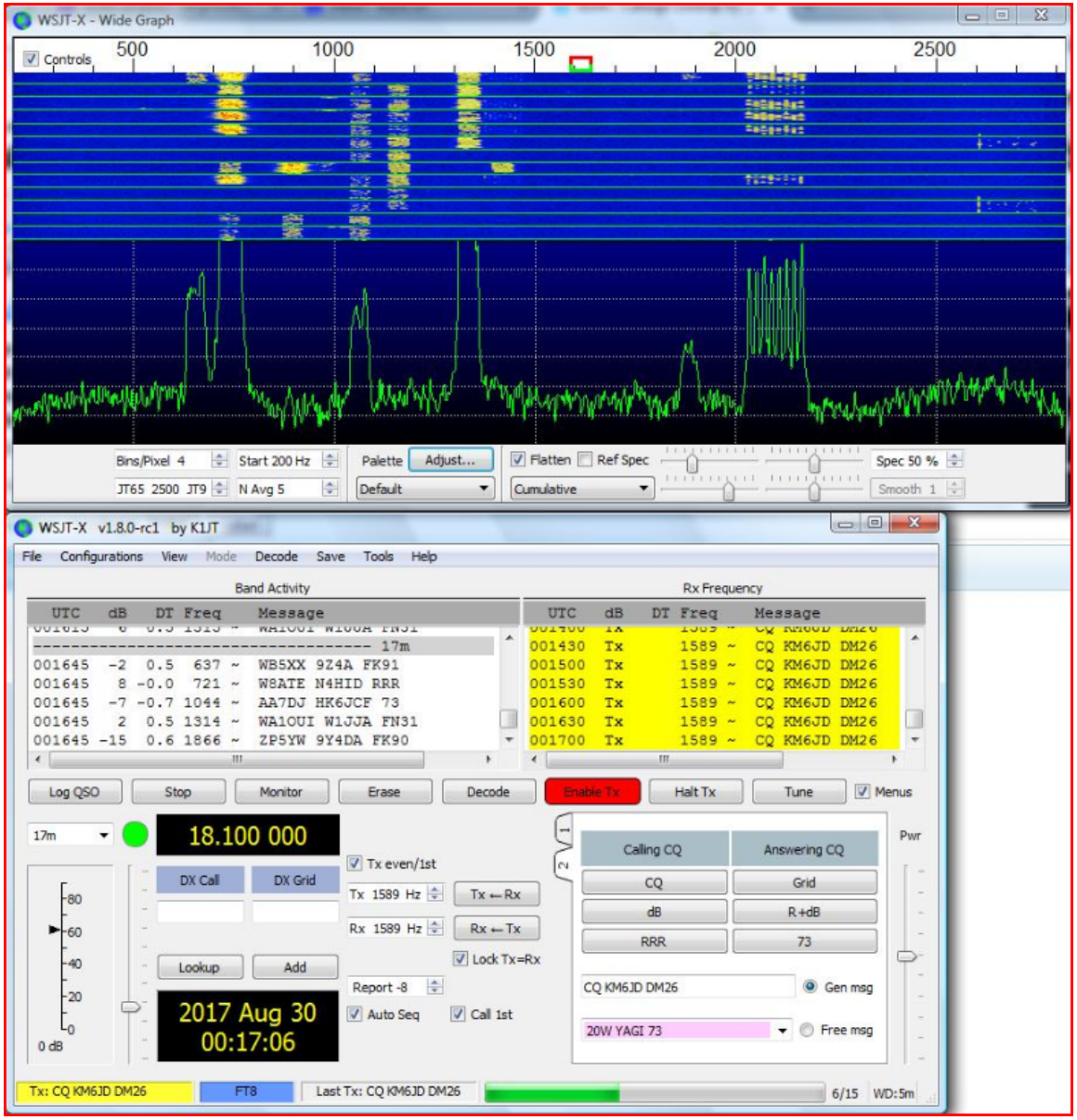
Courtesy of Kelly Boles, KE0EMJ

Examples of hams using too much power or ALC and their deleterious effects on the bands

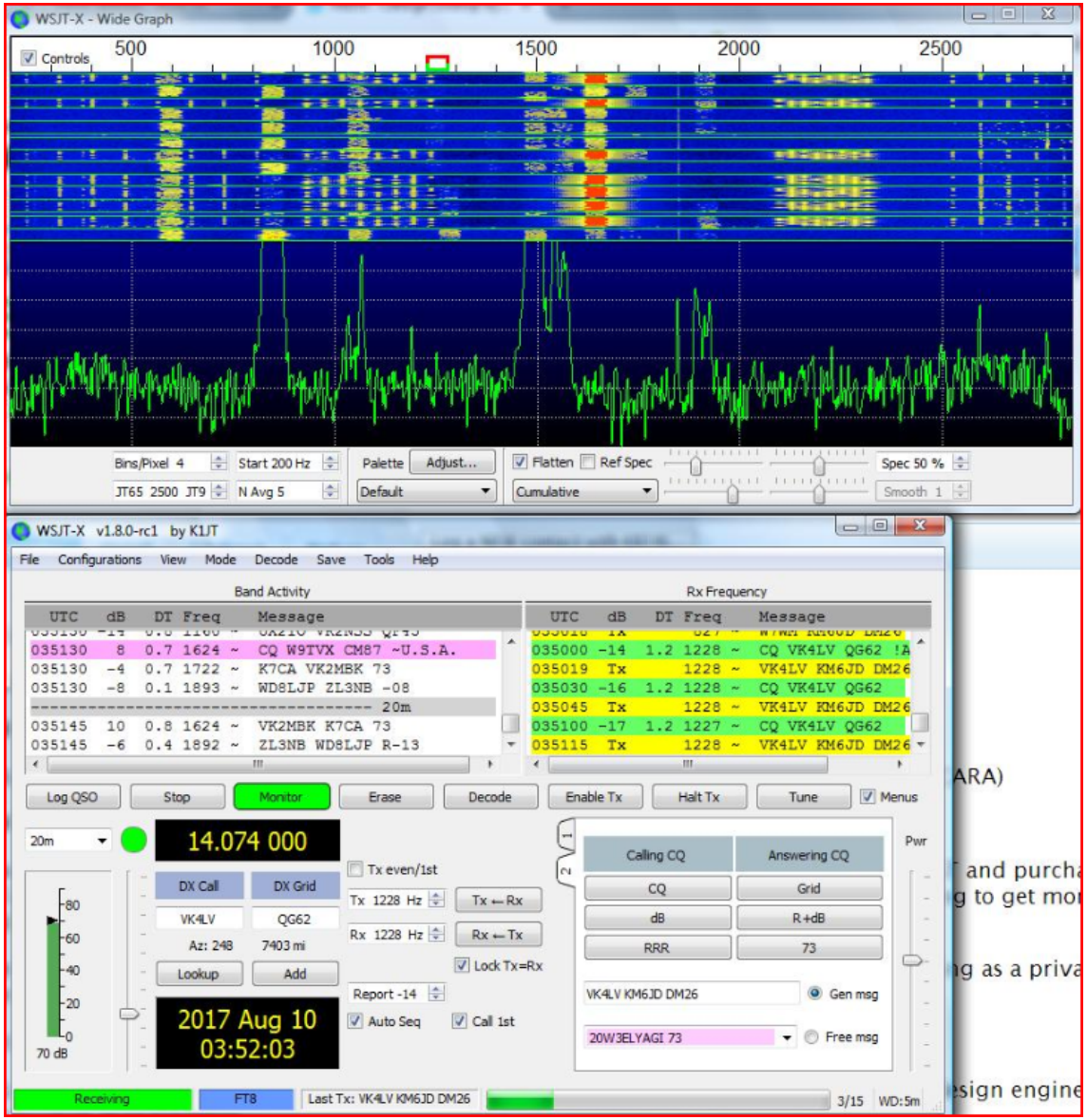


Courtesy of Joe Fitzpatrick, W1FIT

Examples of hams using too much power or ALC and their deleterious effects on the bands (cont'd)



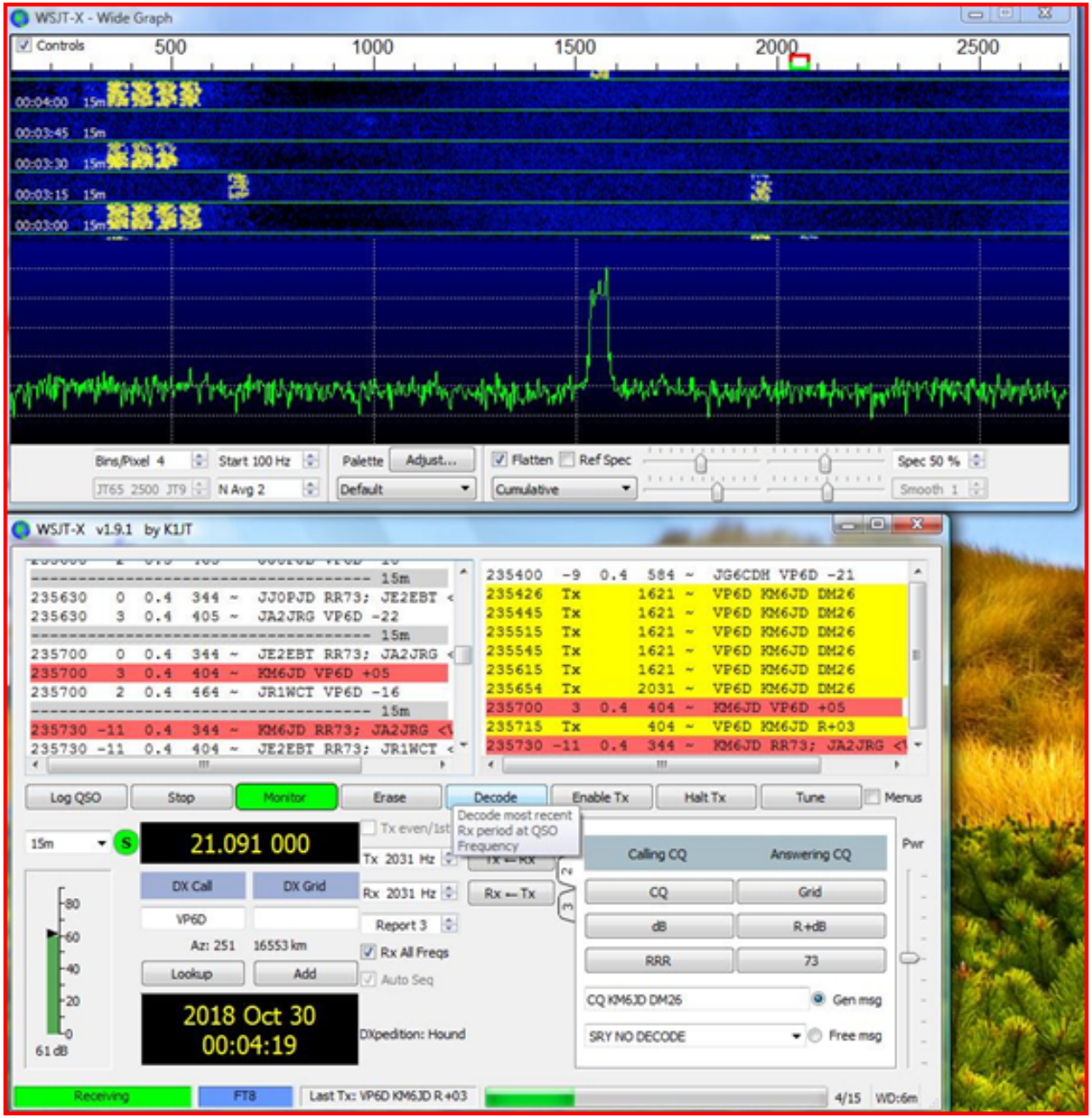
Examples of hams using too much power or ALC and their deleterious effects on the bands (cont'd)



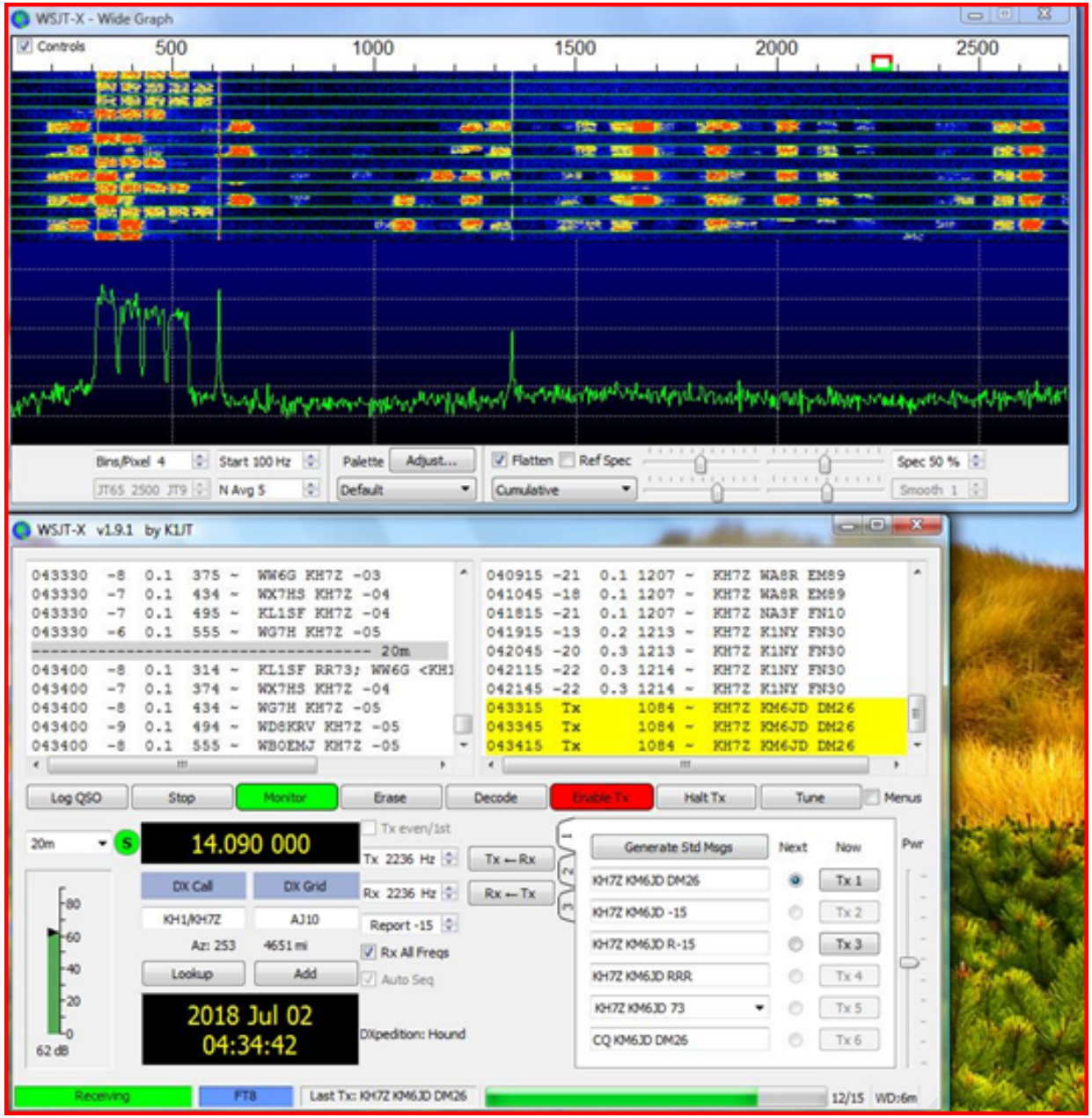
DXpedition mode in WSJT-X

- This mode is relatively new and somewhat experimental.
- It requires you to add additional frequencies and also to select “Hound” in the settings menu.
- The “Fox” is the rare DX station that all the Hounds wish to contact.
- The DX station (Fox) can run multiple streams (up to five).
- This means the Fox can initiate QSO’s with up to five hounds at a time. This therefore increases efficiency greatly.
- You must call the Fox above 1,000 Hz.
- Once the Fox calls you, your callsign will appear in red and the red transmit bracket will automatically track to his transmit frequency.

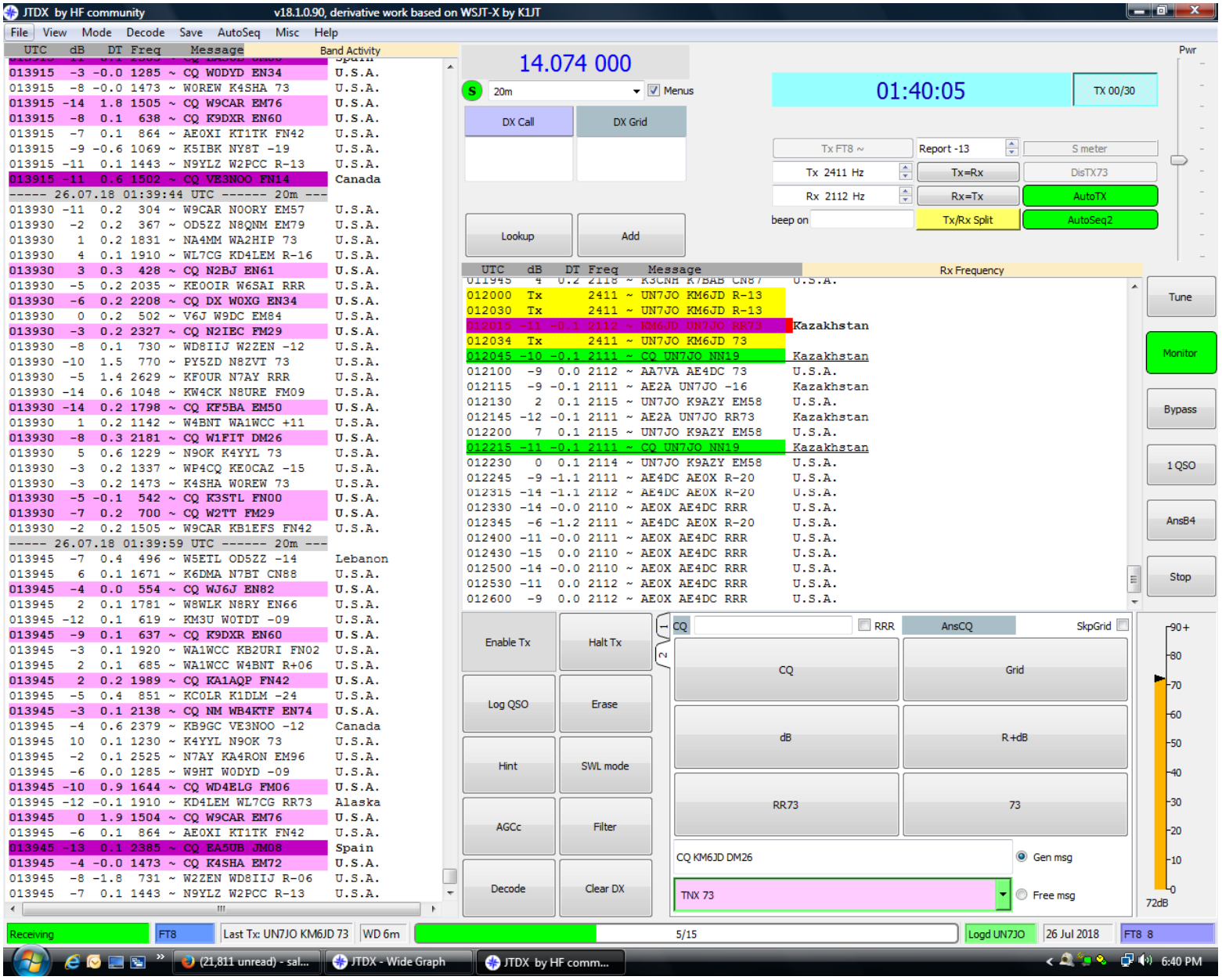
Examples of DXpedition mode



Examples of DXpedition mode (cont'd)



Examples of JTDX software and QSO's



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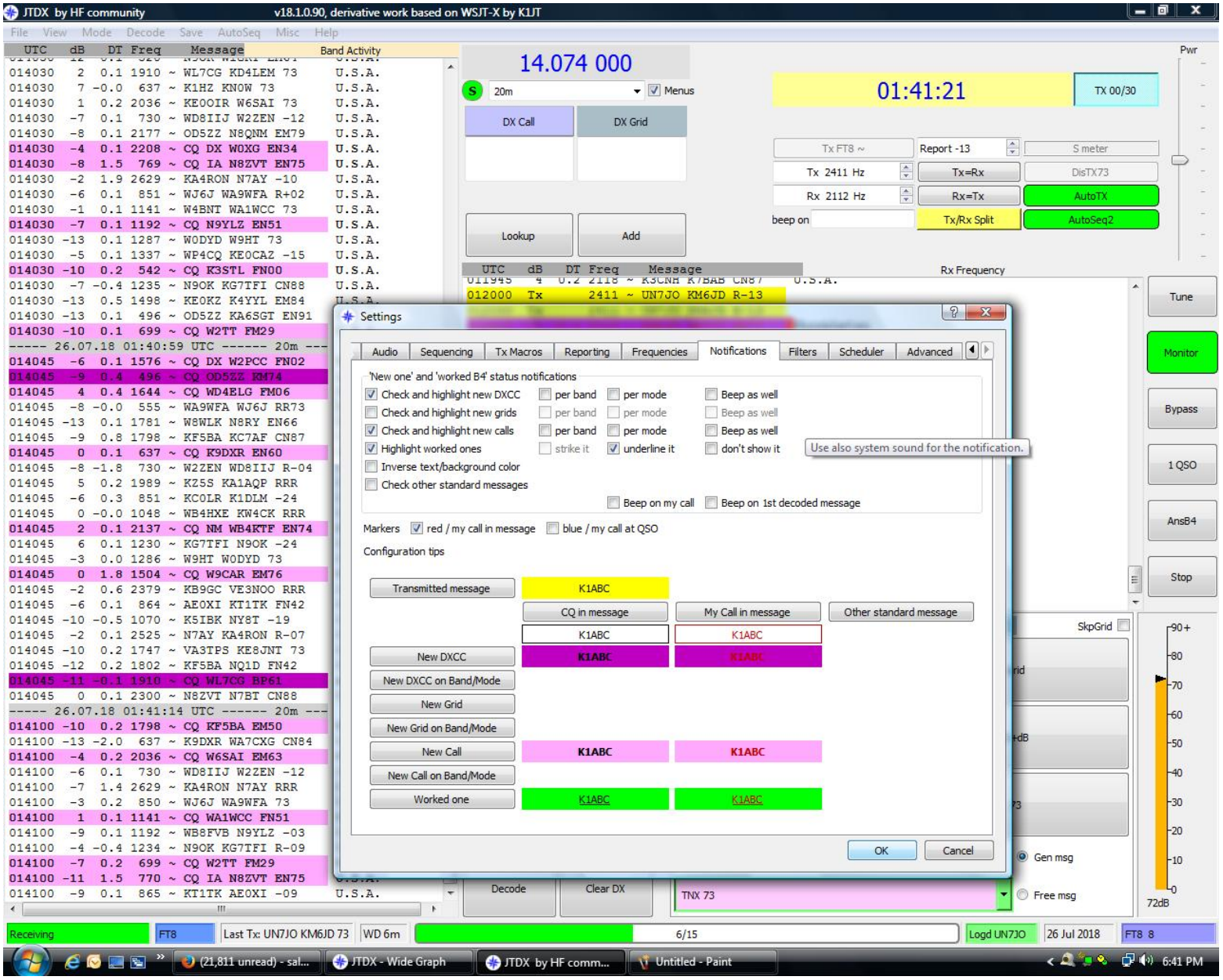

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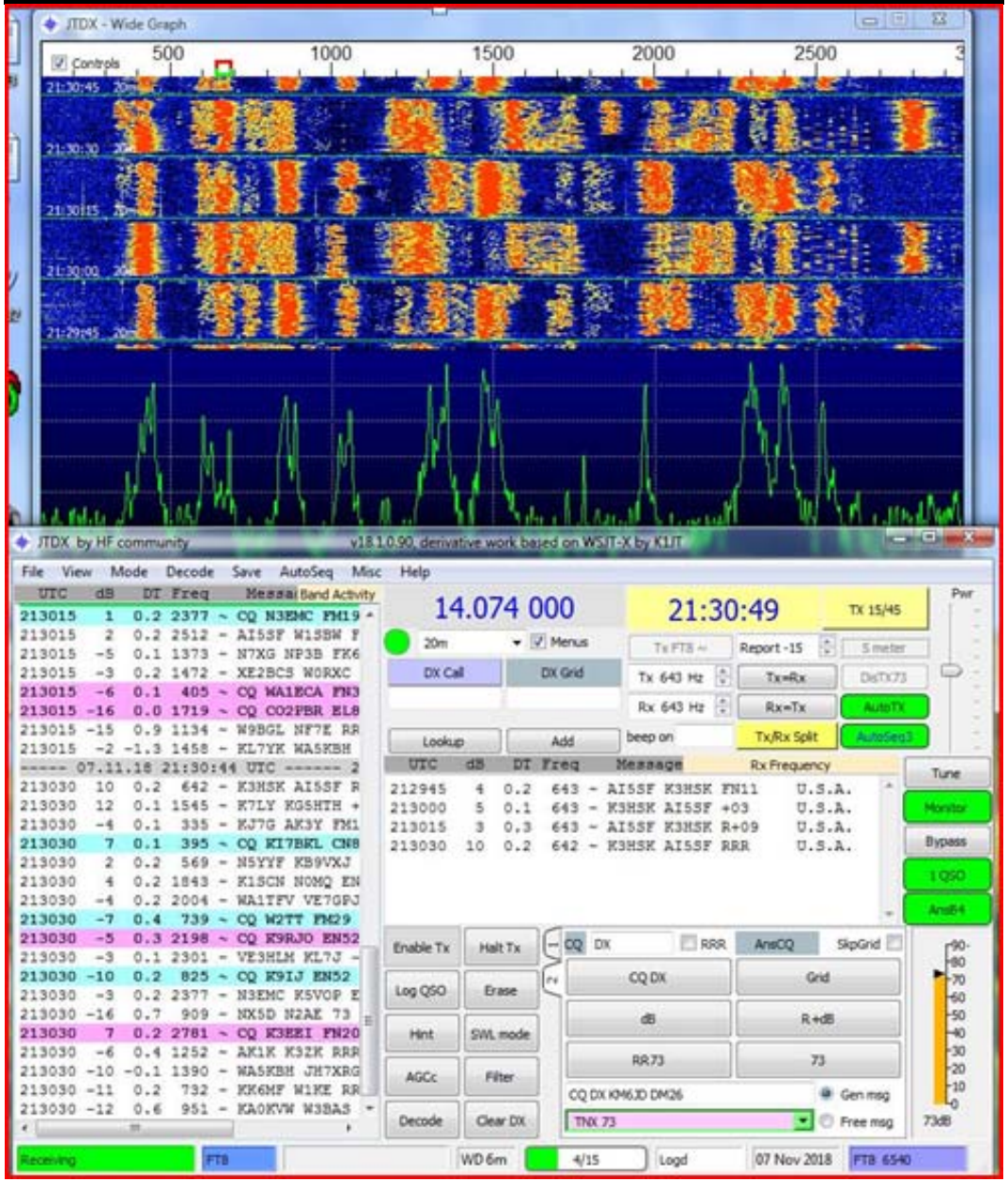

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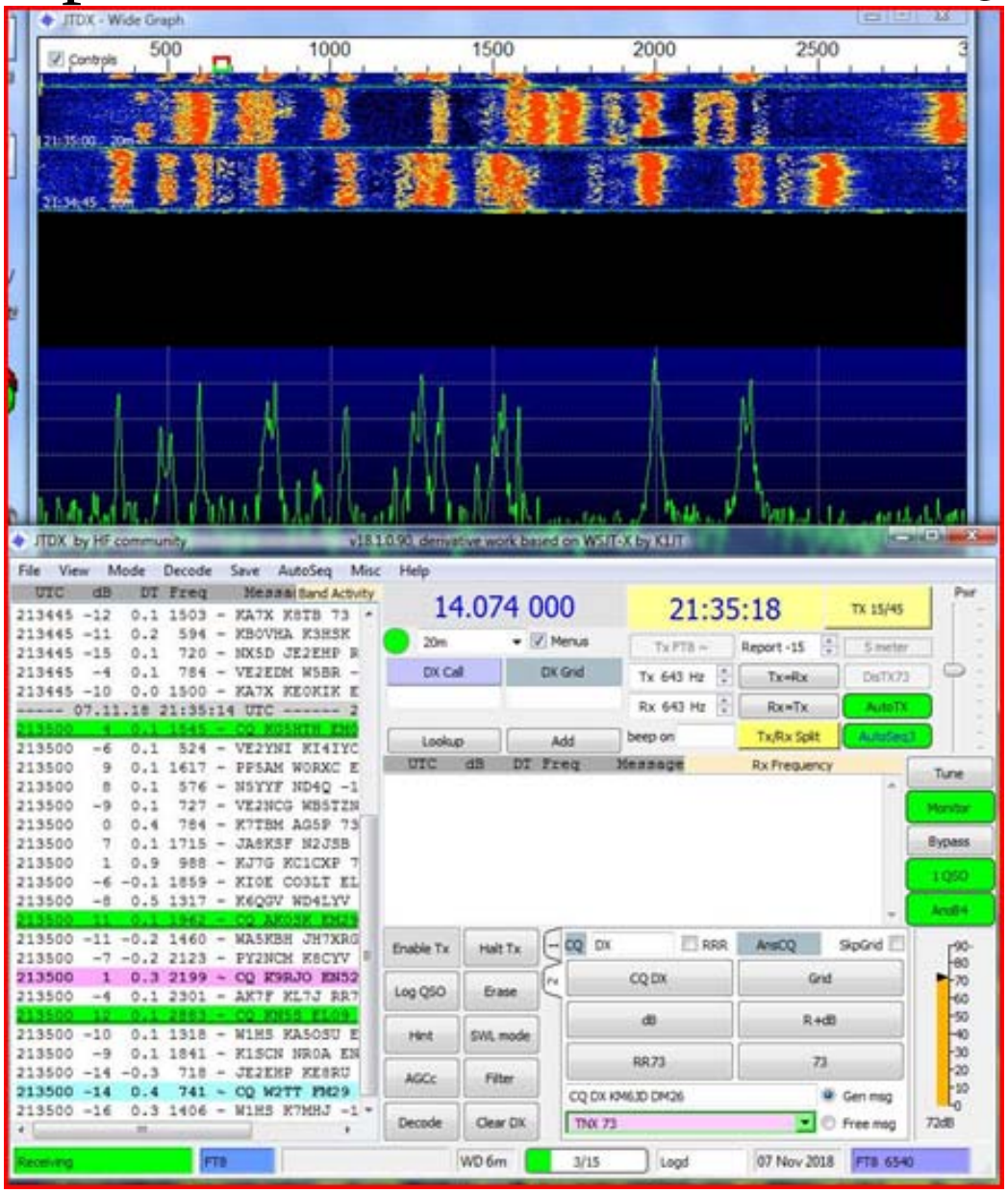

Useful Online Resources and Further Reading Material

- http://physics.princeton.edu/pulsar/k1jt/wsjtx-doc/wsjtx-main-2.0.0.html#_free_text_messages
- https://www.wsjtx.net/home/ft8-mode.html
- http://www.g4ifb.com/FT8_Hinson_tips_for_HF_DXers.pdf
- http://fbnews.jp/201712/technical_en/index.html
- https://www.jimcarson.com/2017/setting-up-ft8/
- https://ft8dmc.eu/
- https://en.wikipedia.org/wiki/WSJT_(amateur_radio_software)
- https://www.jtdx.tech/en/
- https://ft8dmc.eu/AWARDS
- http://www.w0wtn.org/downloads/n0dl/Introduction%20to%20Ham%20Radio%20Digital%20Mode%20FT8.pdf

How FT8 is encoded, transmitted and then decoded

- Each character in a 13-character free message is converted to a number .
- Then, those numbers are multiplied together forming a large integer of 71 binary bits.
- Standard messages consist of two 28-bit fields normally used for callsigns and a 15-bit field for a grid locator, report, acknowledgment, or “73” message, also totaling 71 bits.
- Six *message-type bits (flags) are appended, giving 77 bits.*
- These are the precious information payload. All the remaining bits in the FT8 messages are required for error-correction purposes, enabling the payload to be reliably communicated over a noisy radio channel.
- The LDPC is assembled as follows:
    - A 14-bit Cyclic Redundancy Check is calculated on the 77 bits and appended, giving 91 bits.
    - Next an 83-bit parity code is calculated and appended, giving 174 bits.
    - The 174 bits are grouped into 58 chunks of three bits each, which are then Gray coded.[4]

How FT8 is encoded, transmitted and then decoded (cont'd)

- Symbols are now assembled from a 7-chunk Costas array + the first 29 Gray-coded chunks + the 7 Costas + the remaining 29 Gray-coded chunks + the 7 Costas, resulting in 79 symbols for transmission.
- Those Costas arrays ("sync vectors") sent at the start, middle and end of each FT8 message are used to synchronize the receiver to the sender such that bits can be reliably timed within the transmissions.

Acknowledgements

The author would like to acknowledge the following Boulder Station FT8 Wednesday morning coffee Group members for their suggestions, help and guidance in preparing this presentation:

Arthur Brigida, AB7FB
Joseph Fitzpatrick, W1FIT
Larry S. Hinsdale, WG7H

REFERENCES

1.) QST, November, 2017, pp 34-9.

2.) *Ibid.*

3.) *Ibid.*

4.) FT8 Operating guide, version 2.12, G. Hinson, 2019, pp 62.

5.) QST, November, 2017, p 35.