

WSJT-X User's Guide

Version 1.0

Joe Taylor, K1JT

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Introduction

[WSJT-X](#) is a computer program designed to facilitate basic amateur radio communication using very weak signals. The first four letters in the program name stand for “Weak Signal communication by K1JT”, and the “-X” suffix indicates that *WSJT-X* started as an experimental branch of program *WSJT*.

Version 1.0 of *WSJT-X* offers a new mode called JT9, designed for use on the LF, MF, and HF bands. JT9 shares many characteristics with the modes JT65 and JT4 made popular in *WSJT*. All three modes are designed for making minimal QSOs under extreme weak-signal conditions. They use nearly identical message structure and source encoding. JT65 was designed for EME on the VHF/UHF bands and has also proved very effective for worldwide QRP communication at HF; JT4 is used mainly on the microwave bands. In contrast, JT9 is optimized for HF and lower frequencies. JT9 is about 2 dB more sensitive than JT65A while using less than 10% of the bandwidth. World-wide QSOs are possible with power levels around 1 W and compromise antennas. Several dozen JT9 signals fit easily into a 1 kHz slice of spectrum.

All WSJT modes use timed sequences of alternating transmission and reception. JT9 offers five choices for the sequence durations: submodes JT9-1, JT9-2, JT9-5, JT9-10, and JT9-30 use 1, 2, 5, 10, and 30 minutes, respectively. A minimal QSO with JT9-1 usually takes 4 to 6 minutes: 2 or 3 transmissions by each station, one transmitting in odd minutes and the other even. The remaining JT9 submodes take proportionally longer, so JT9-1 is the preferred submode under most circumstances. The sub-modes with longer transmissions trade reduced throughput for smaller bandwidth and increased sensitivity. The slowest sub-mode, JT9-30, has total bandwidth 0.4 Hz and operates at signal-to-noise ratios as low as –40 dB measured in the standard 2.5 kHz reference bandwidth. It requires very stable oscillators in both transmitter and receiver. JT9-1 is always the recommended submode unless you really need the additional sensitivity of a slower mode.

Plans for future program development call for *WSJT-X* and *WSJT* to merge together: *WSJT-X* will gradually acquire the modes JT65, JT4, FSK441, and ISCAT that are now supported in *WSJT*. The entire WSJT-related effort is an open-source project. If you have programming skills or would like to contribute to the project in other ways, please make your interests known to K1JT and the rest of the development team. The project’s source-code repository can be found at <http://developer.berlios.de/projects/wsjt/>.

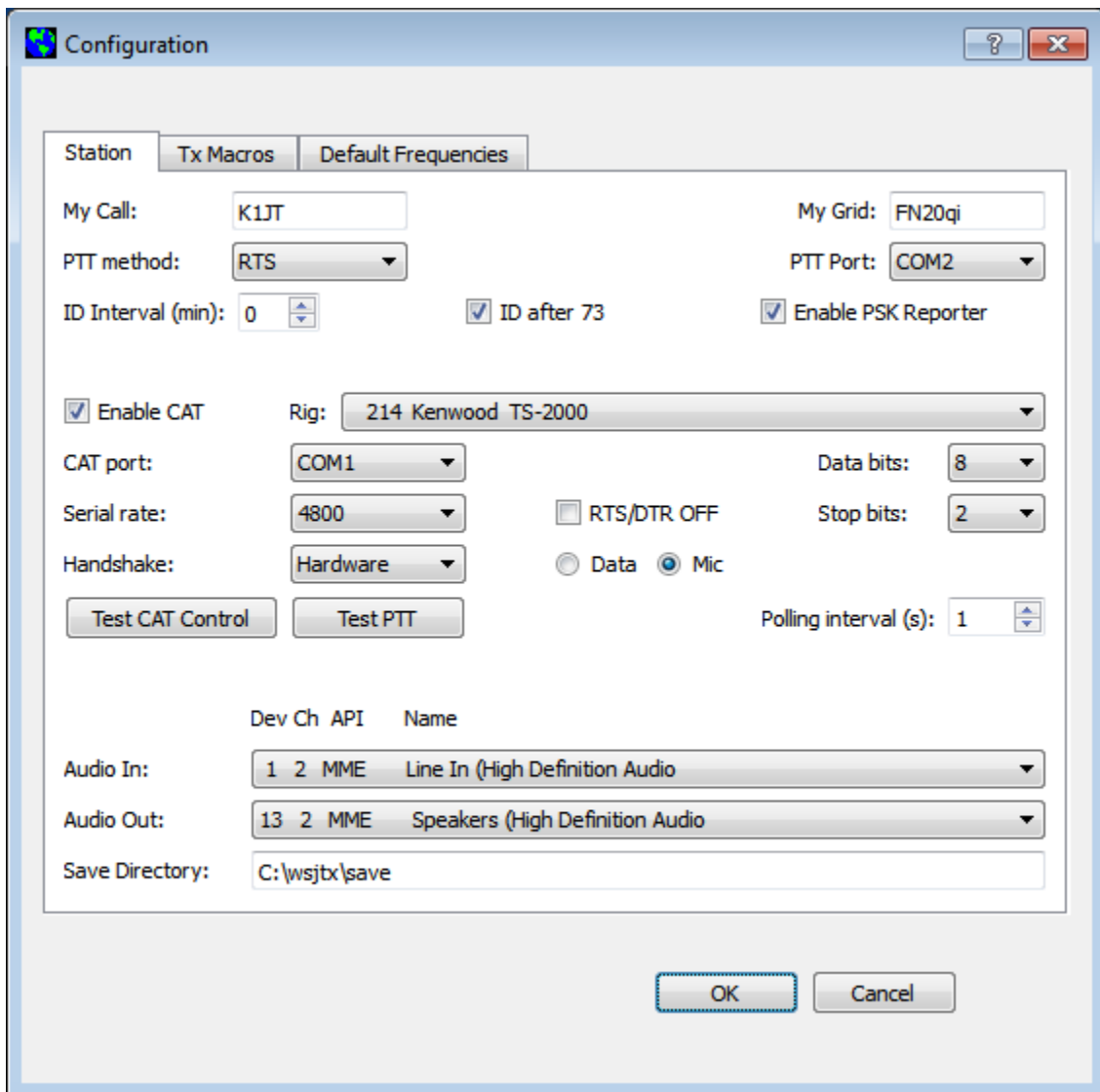
System Requirements

- SSB transceiver and antenna
- Computer running Windows XP or later. (*WSJT-X* also runs under Linux, OS X, and probably FreeBSD and other unix-like operating systems, but we do not yet provide click-to-install packages for them. See Appendix C.)
- 1.5 GHz or faster CPU and 512 MB of available memory
- Monitor with at least 1024 x 780 resolution (more is better)
- Audio input and output devices supported by your operating system
- Computer-to-radio interface using a serial port to key your PTT line, or CAT control. You can also use VOX control for T/R switching.
- Audio or equivalent USB connections between transceiver and computer
- A means for synchronizing your computer clock to UTC. The built-in Windows facility is usually not adequate. I recommend *Meinberg NTP*, see <http://www.satsignal.eu/ntp/setup.html> for installation instructions.

Installation and Setup

1. *WSJT-X* can be downloaded from the WSJT Home Page at <http://www.physics.princeton.edu/pulsar/K1JT/>. Click on the WSJT link at the left margin and then on the appropriate download link for *WSJT-X*. Especially during phases of active program development, consult also the project's ChangeLog at http://physics.princeton.edu/pulsar/K1JT/wsjitx_changelog.txt.
2. Under Windows, execute the downloaded file and follow its installation instructions. Install *WSJT-X* into its own directory (the suggested default is C:\WSJTX) rather than the conventional C:\Program Files\WSJTX. All files relating to *WSJT-X* will be stored in this directory and its subdirectories. Nothing is written to the Windows registry, so you can completely uninstall *WSJT-X* simply by removing the installation directory and its contents.
3. Start *WSJT-X* and Select **Configuration** from its **Setup** menu. Enter your callsign and Maidenhead grid locator as shown in the screen shot on the next page, and set the remaining parameters as required for your station. Many users will have other software controlling their radios, so *WSJT-X* does not attempt to implement full transceiver control. It simply provides a way to ensure that *WSJT-X* can know the radio's dial frequency and control T/R switching. The simplest CAT control is enabled by setting **Polling interval** to 0 (no polling for dial frequency). *WSJT-X* is then able to set the radio's frequency, but the program will be unaware of subsequent changes made with the radio's panel controls. With most radios you can set **Polling interval** to a reasonable small number (say 1 – 3 s) and the

program will then follow any frequency changes made at the radio. Some experimentation may be required, and you may need to refer to the documentation for your radio. Note: it is best to have the radio and any interface equipment turned on and connected before starting *WSJT-X*, and to exit the program before turning your equipment off.

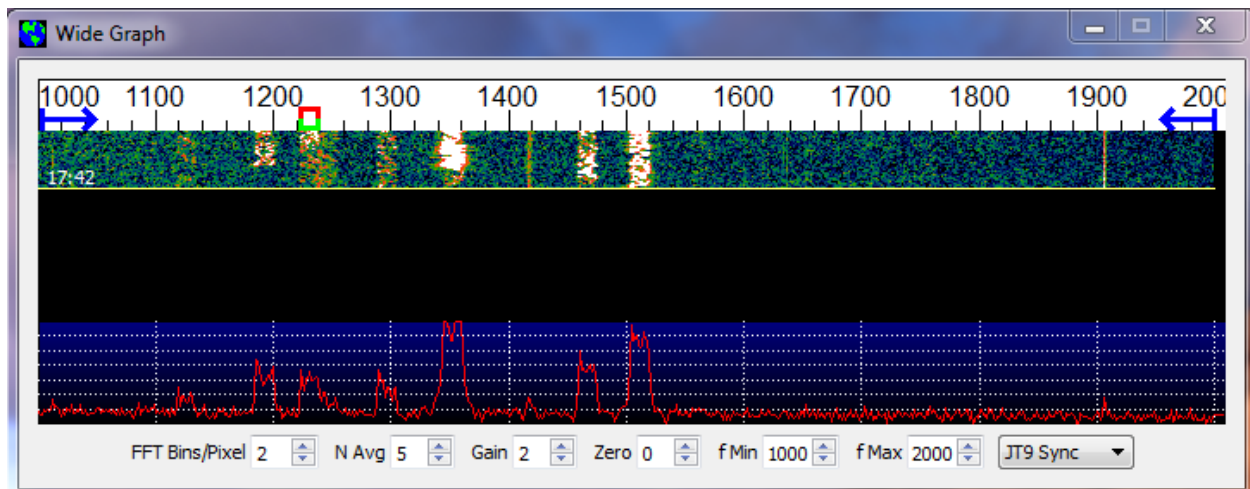


4. Try clicking the **Test CAT Control** and **Test PTT** buttons to see that you have established the desired control of station functions. Then click **OK** to dismiss the **Configuration** window.
5. WSJT-X expects your sound card to do its raw sampling at 48000 Hz. To ensure that this will be so when running under Windows, open the Sound control panel and select in turn the “Recording” and “Playback” devices you will use for audio input and

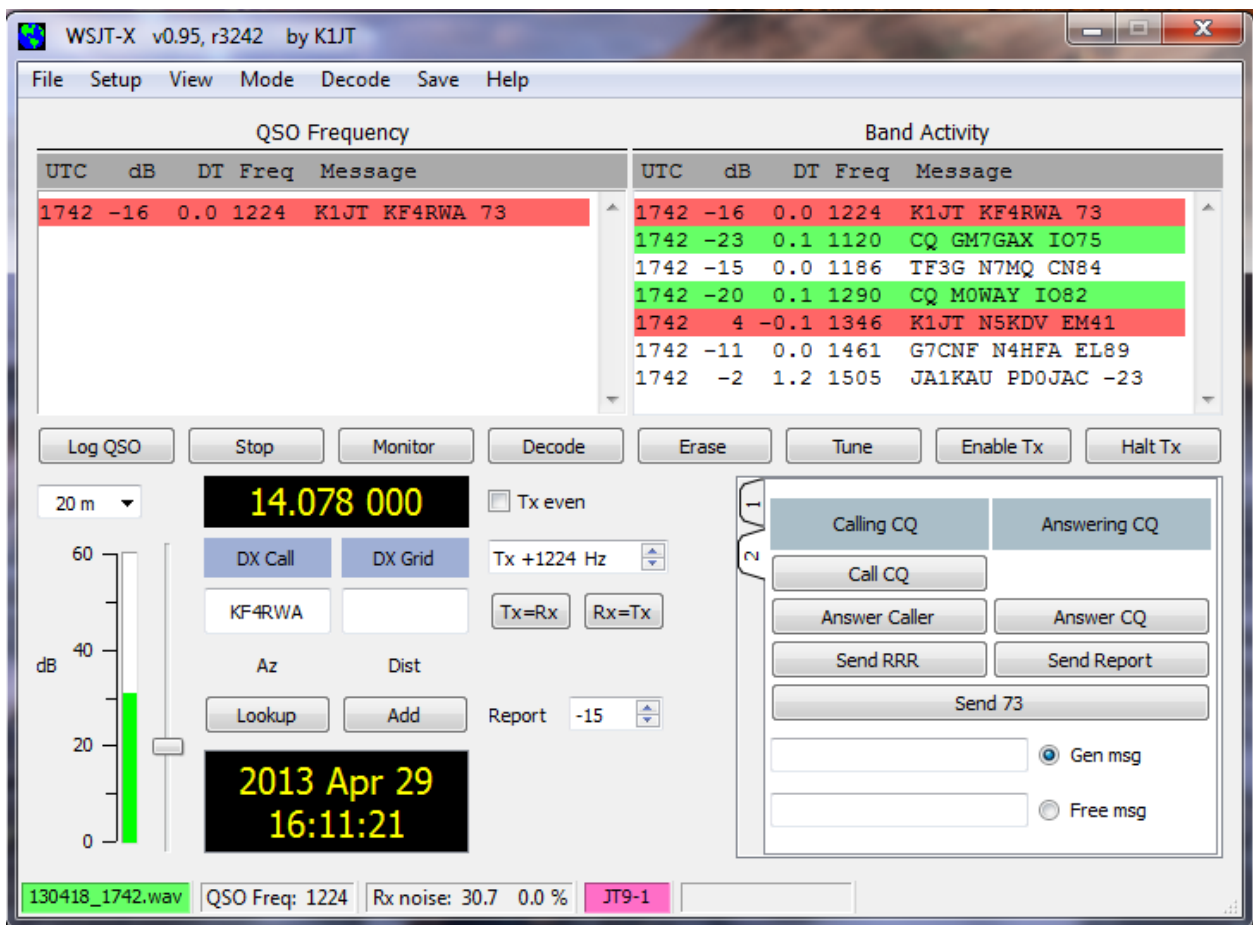
output. Click on Properties, then Advanced, and select “16 bit, 48000 Hz (DVD Quality).”

Basic Operating Tutorial

1. Click the **Stop** button on the main window to halt any data acquisition. Select submode **JT9-1** from the **Mode** menu and **Normal** from the **Decode** menu. On the Wide Graph window select **JT9 Sync** (rather than **Current** or **Cumulative**) for data display. Select **Tab 2** (just below the **Erase** button on the main window) to choose the alternative set of controls for generating and selecting messages to be transmitted. Then select **File | Open**, navigate to directory ...\Save\Samples under your WSJT-X installation directory, and open the example file 130418_1742.wav. You should see something like the screen shots below and on the next page.



2. Notice the green, red, and blue markers on the waterfall frequency scale. Decoding in JT9 mode takes place at the end of a receive sequence and is organized in two stages. The first decoding occurs at the selected Rx frequency, indicated by the green marker. Results appear in both the left (“QSO Frequency”) and right (“Band Activity”) text windows on the main screen. The decoder then finds and decodes all JT9 signals between the blue markers. The normal wideband decoding range is 1000 – 2000 Hz, but you can move the limits using the **f Min** and **f Max** spinner controls. The red marker indicates the Tx frequency.



- Note that at least eight JT9 signals are present in the example file; all but one of them are decodable. When this file was recorded KF4RWA was finishing a QSO with K1JT, and since the green marker was placed at his audio frequency, 1224 Hz, his message “K1JT KF4RWA 73” appears in both decoded text windows. The “Band Activity” window shows this message as well as all the other decodes at nearby frequencies: GM7GAX and M0WAY are calling CQ, N7MQ is calling TF3G, N4HFA is calling G7CNF, PD0JAC is sending a signal report to JA1KAU, and N5KDV is calling K1JT as a tail-ender, on a different Tx frequency. The CQ lines are highlighted in green, and lines containing “My Call”, in this case K1JT, are highlighted in red. (For this step and the next one, you may want to pretend you are K1JT by entering that call temporarily as “My Call” on the **Configuration** screen. Your results should then be identical to those shown here.)
- To gain some feeling for the controls you will use when making QSOs, try clicking with the mouse on the decoded text lines and on the waterfall spectral display. You should be able to confirm the following behavior:

- a. Double-click on either of the decoded lines highlighted in green. This action copies callsign and locator of a station calling CQ to the “DX Call” and “DX grid” entry fields. It also generates suitable messages for a minimal QSO and ticks (or clears) the **Tx even** box so that you will transmit in the proper odd or even minutes. Rx and Tx frequency markers will be moved to the CQing station’s frequency, and the **Gen Msg** (“generated message”) radio button at bottom right of the main window will be activated. If you had selected “Double-click on call sets Tx Enable” on the **Setup** menu, **Enable Tx** would also be activated, and you would start to transmit automatically, at the appropriate time.
 - b. Double-click on the decoded line with the message “K1JT N5KDV EM41”, highlighted in red. Results will be similar to (a), except the Tx frequency (red marker) is not moved. Such messages are usually in response to your own CQ, or from a tail-ender. You probably want your Tx frequency to stay where it was. By holding down the Ctrl key when double-clicking on the decoded line, you can cause both Tx and Rx frequencies to be moved.
 - c. Now double-click on the message from KF4RWA in either window. He is sending “73” to K1JT, signifying that the QSO is over. Most likely you want to call CQ again, so the message “CQ K1JT FN20” is automatically generated and selected for your next transmission.
 - d. Clicking on the waterfall moves the Rx frequency (green marker) to the selected frequency. Ctrl-click on waterfall moves both Rx and Tx frequencies.
 - e. Double-click on the waterfall moves the Rx frequency and causes a narrow-band decode there at the new QSO frequency. Decoded text appears in the left window only.
 - f. Ctrl-double-click moves both Rx and Tx frequencies and decodes at the new frequency. Again, decoded text appears in the left window.
 - g. Clicking **Erase** clears the left window. Double-clicking **Erase** clears both text windows.
5. Don’t forget to re-enter your own callsign as “My Call”. Click the **Monitor** button to return to normal receive operation, and be sure that your transceiver is set to USB (or USB Data) mode. Using the receiver gain control(s) and/or the Windows mixer controls, set the background noise level to around 30 dB on the thermometer scale at lower left of the *WSJT-X* main screen. If necessary you can also use the slider next to the scale, but note that the overall dynamic range will be best with the slider

close to mid-scale. When this is true, the dB scale is calibrated relative to the least significant bit of 16-bit samples from the soundcard.

6. You should now be ready to make QSOs with the JT9 modes in *WSJT-X*.

Making QSOs

By longstanding tradition, a minimal valid QSO requires the exchange of callsigns, a signal report or some other information, and acknowledgments. *WSJT-X* is designed to facilitate making such minimal QSOs using short, formatted messages. The process works best if you use them and follow standard operating practices.

The recommended basic QSO goes something like this:

- | | | |
|----|-----------------|------------------|
| 1. | CQ K1ABC FN42 | |
| 2. | | K1ABC G0XYZ IO91 |
| 3. | G0XYZ K1ABC -19 | |
| 4. | | K1ABC G0XYZ R-22 |
| 5. | G0XYZ K1ABC RRR | |
| 6. | | K1ABC G0XYZ 73 |

These standard messages consist of two callsigns (or CQ, QRZ, or DE and one callsign) followed by the transmitting station's grid locator, a signal report, or the acknowledgement "RRR" or sign-off "73". Such messages are compressed and encoded in a highly efficient and reliable way. Signal reports are given as signal-to-noise ratio in dB, using the standard reference noise bandwidth 2500 Hz. Thus, in example message #2 K1ABC is telling G0XYZ that his signal is 19 dB below the noise power in bandwidth 2500 Hz; in message #3 G0XYZ acknowledges receipt of that report and responds with a -22 dB signal report. For most operators, signals start to become audible around -15 dB on this scale. Signals are visible on the waterfall down to about -26 dB, and the JT9 decoder begins to fail at about this same limit.

Free-format messages such as "TNX JOE 73 GL" or "5W VERT 73 GL" can also be transmitted, up to a maximum of 13 characters. Users often add some friendly chit-chat as a final transmission, in place of message #6. It should be obvious, however, that JT9 is not a mode suitable for extensive conversations or "rag-chewing."

Before attempting your first QSO with JT9, be sure to go through the tutorial above and the following checklist:

- Your callsign and grid locator set to correct values
- PTT and CAT control (if used) properly configured and tested

- Computer clock properly synchronized with UTC to within ± 1 s.
- Radio set to USB (upper sideband) mode
- Remember that JT9 generally does not require high power. QRP is the rule!

On-Screen Controls

The following row of control buttons appears just under the decoded text windows:



Log QSO pops up a confirmation screen pre-filled with known information about a QSO you have just completed. You may edit or add to this information before clicking OK to log the QSO. If you select “Prompt me to log QSO” on the **Setup** menu (see below), the program will pop up the confirmation screen automatically when you send a “73” or free-text message.

Stop will stop normal data acquisition in case you want to open and explore previously recorded audio files.

Monitor restarts normal program operation in receive mode. This button is highlighted in green when the program is receiving.

Decode tells the program to repeat the decoding procedure at the QSO frequency (green marker on waterfall), using the most recently acquired sequence of Rx data.

Holding “Shift” down when clicking **Decode** will initiate decoding at the QSO frequency and then over the full frequency range, **f Min** to **f Max**.

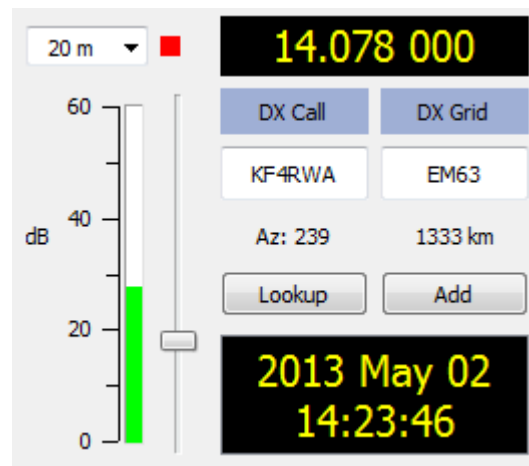
Erase clears the left (QSO frequency) window. Double-clicking **Erase** clears both text windows.

Tune may be used to switch into Tx mode and generate an unmodulated carrier at the specified Tx frequency (red marker on waterfall). This process may be useful for adjusting an antenna tuner, for example. Toggle the button a second time to terminate the **Tune** process.

Enable Tx puts the program into automatic Rx/Tx sequencing mode and highlights the button in red. A transmission will start at the beginning of the selected (odd or even) sequence.

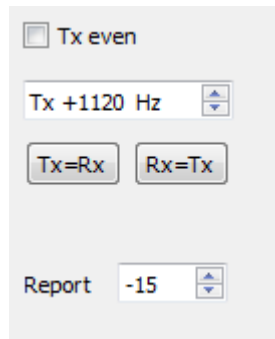
Halt Tx will terminate a transmission in progress and disable automatic Rx/Tx sequencing.

At lower left of the main window are controls and displays related to date and time, frequency, Rx audio level, and the station you may be in QSO with.



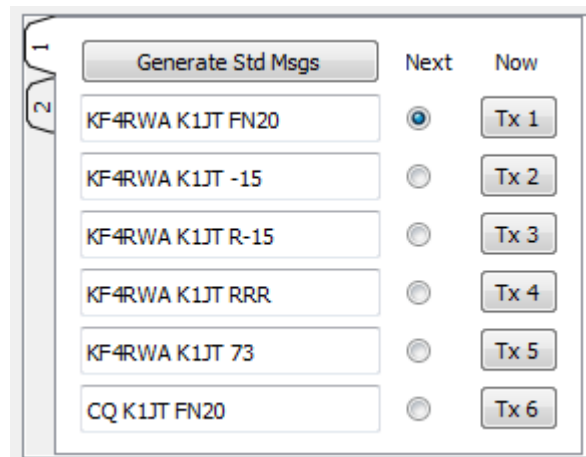
The drop-down **Band** selector at upper left lets you select the operating band and sets dial frequency to a default value taken from the **Setup | Configuration | Default Frequencies** tab. If you are using CAT control, a small colored square appears in red if the CAT control is two-way between *WSJT-X* and your radio, or orange if the control is only from program to radio. If the **Dx Grid** is known, the great-circle azimuth and distance are given. The program can keep a database of callsigns and locators, for future reference. Click **Add** to insert the present call and locator in the database; click **Lookup** to retrieve the locator for a previously stored callsign.

At center and right of the main window are a number of controls you will use when making QSOs. The following are near screen center:



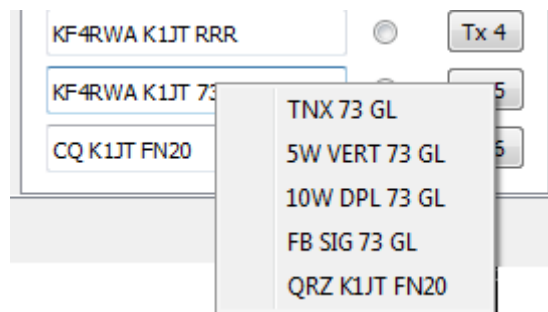
Select **Tx even** to transmit in even-numbered UTC minutes (or, for the slower JT9 submodes, even-numbered sequences, starting with 0 at the top of a UTC hour). Uncheck this box to transmit in the odd intervals. This selection is made automatically when you double-click on a decoded text line (as described in the Basic Operating Tutorial, pages 6 – 9). Your audio Tx frequency is displayed and can be controlled by the **Tx +xxxx Hz** spinner control. Again, this setting is normally handled automatically by the double-click procedure. The on-the-air frequency of your lowest JT9 tone will be the sum of dial and audio frequencies. You can force Tx frequency to the current Rx frequency by clicking the **Tx=Rx** button, and vice-versa for **Rx=Tx**. Finally, the **Report** spin control lets you change a signal report that may have been inserted automatically. Valid signal reports fall in the range –50 to +49 dB. For the JT9-1 submode most reports will fall in the range –26 to +10 dB. When signals are stronger than about 0 dB, you and your QSO partner should probably switch to CW or SSB, or reduce power. JT9 is supposed to be a *weak signal* mode!

Two configurations of controls are provided for generating and selecting Tx messages:



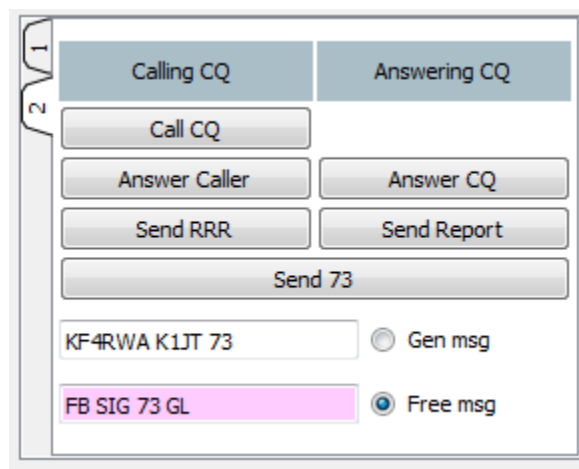
Traditional controls carried over from *WSJT* provide six fields for message entry. Pre-formatted messages for the standard minimal QSO (see page 9) are generated when you click **Generate Std Msgs**, or when you double-click on an appropriate line of decoded text. Select the next message to be transmitted (at the start of your next Tx sequence) by clicking on the circle under “Next”. To change to a specified Tx message immediately, perhaps after a transmission has already started, click on a rectangular button under the “Now” label. Changing Tx messages after a transmission has started necessarily reduces the probability of a correct decode by your QSO partner, but if you do it in the first 10 s or so of a Tx period, it will probably succeed.

Right-clicking on the entry field for message #5 pops up a list of free text messages you entered on the **Setup | Configuration | Tx Macros** dialog window, for example



You can select any of these pre-stored messages with the left mouse button.

The second configuration of message-selecting controls looks like this:



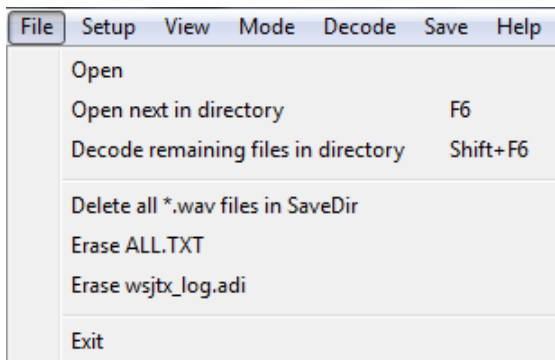
With this setup you will normally follow a top-to-bottom sequence of transmissions from the left column (if you are calling CQ) or the right column (if you are answering a CQ). Clicking a button puts the appropriate message in the **Gen Msg** box. If you are already

transmitting, it changes the Tx message immediately. (The actual message being transmitted always appears in the first box on the status bar, at the bottom left of the main screen.) You can put anything you like (up to 13 characters) in the **Free Msg** box. Right-clicking on this entry field pops up your previously defined list of Tx Macros.

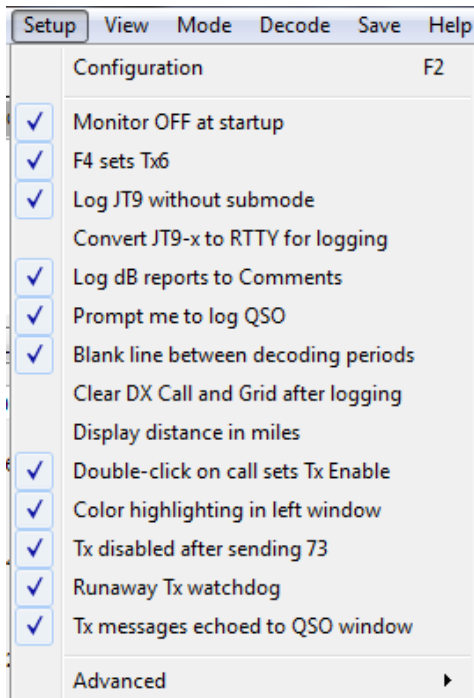
Menus

Program menus offer many options for configuration and operation. Explore them and test the resulting program actions. The actions caused by most menu items should be self-explanatory.

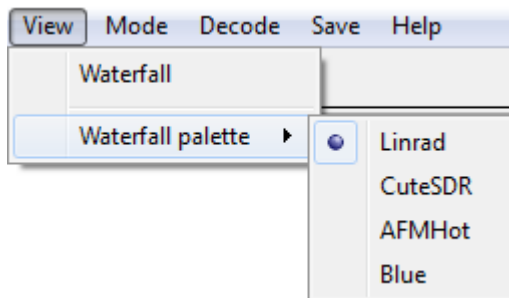
File menu



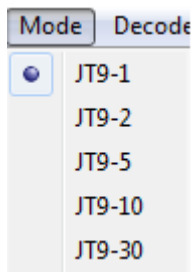
Setup menu



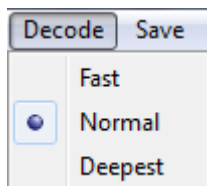
View menu



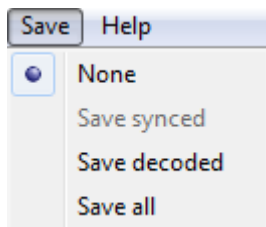
Mode menu



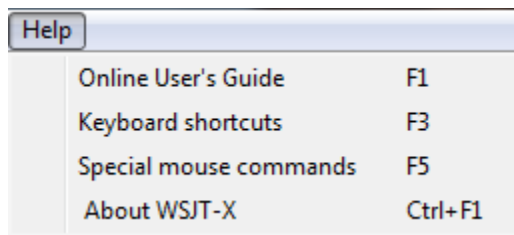
Decode menu



Save menu



Help menu



Keyboard Shortcuts

F1	Display online User's Guide in browser
Ctrl+F1	About WSJT-X
F2	Open the Setup Configuration window
F3	Display keyboard shortcuts
F4	Clear Dx Call and Dx Grid entries
Alt+F4	Exit program
F5	Display special mouse commands
F6	Open next in directory
Shift+F6	Decode all remaining files in directory
F11	Move Rx frequency down 1 Hz
Ctrl+F11	Move Rx and Tx frequencies down 1 Hz
F12	Move Rx frequency up 1 Hz
Ctrl+F12	Move Rx and Tx frequencies up 1 Hz
Alt+D	Decode again at QSO frequency
Shift+D	Full decode (both windows)
Alt+E	Erase()
Ctrl+F	Edit the free text message box
Alt+G	Generate standard messages
Alt+H	Halt Tx()
Ctrl+L	Lookup callsign in database, generate standard messages
Alt M	Monitor()
Alt+N	Enable Tx()
Alt+Q	Log QSO()
Alt+S	Stop()
Alt+T	Tune
Alt+V	Save the most recently completed *.wav file

Special Mouse Commands

Mouse-click on	Action
Waterfall	Set Rx frequency Double-click to set Rx frequency and decode there Ctrl-click to set Rx and Tx frequencies Ctrl-double-click to set Rx and Tx frequencies and decode there
Decoded text	Double-click to copy second callsign to Dx Call and locator to Dx Grid; change Rx and Tx frequencies to decoded signal's frequency; generate standard messages. If first callsign is your own, Tx frequency is changed only if Ctrl is held down when double-clicking.
Erase button	Click to erase QSO window Double-click to erase QSO and Band Activity windows
Tx5 Entry	Right-click to select a macro message

Under the Hood

Since its origin in 2001, an important goal of the WSJT project has been education — bringing to Amateur Radio a better understanding of 21st century communication theory and applications. I have needed (and acquired) plenty of this education, myself, while working on the project, and I think all of us contributing programming and other skills to the project feel that way. We hope that users of our software will, also. This brief section of the User's Guide provides some technical details on how *WSJT-X* and the JT9 protocol work.

Transmitting: Immediately before the start of a transmission, *WSJT-X* encodes a message and computes the sequence of tones to be sent. As described in Appendix B, a JT9 sequence consists of 85 tone intervals or “symbols,” each at one of 9 pre-defined frequencies. Tones are separated in frequency by the reciprocal of tone duration, so even for JT9-1, the fastest JT9 submode, the spacing is only 1.736 Hz — a difference scarcely perceptible to the human ear. A JT9 signal sounds almost like an unmodulated carrier.

Sixteen transmitted symbols — those at positions 1, 2, 5, 10, 16, 23, 33, 35, 51, 52, 55, 60, 66, 73, 83, and 85 in the sequence — are always transmitted at the lowest (“tone 0”) frequency. Their frequency and their pseudo-random spacing in time is used to establish time and frequency synchronization between transmitter and receiver. The

remaining 69 intervals use tones 1 through 8, and they effectively send $69 \times 3 = 207$ information-carrying bits on their way into the ether. *WSJT-X* computes the actual Tx audio waveform on-the-fly, using 16-bit integer samples and a 48000 Hz sample rate, maintaining phase continuity across symbol boundaries. The digital samples are converted to an analog waveform in the sound card or equivalent USB interface.

Receiving: The receiving side of *WSJT-X* acquires 16-bit integer samples from the sound card at a 12000 Hz rate. The real input signal is filtered and converted to a complex (“analytic”) signal sampled at 1500 Hz. Overlapping windowed spectra are computed for display and saved at intervals of half the symbol length. They are used to produce the red curve (“JT9 Sync”) normally displayed below the waterfall in the Wide Graph window. As shown in the screenshot on page 6, a JT9-1 signal appears in the red curve as an almost rectangular pulse about 16 Hz wide. A slightly higher peak at the left edge shows the frequency of the synchronizing tone. By convention, the nominal frequency of a JT9 signal is that of the sync tone.

Decoding: At the end of a reception sequence, about 50 seconds into the UTC minute for submode JT9-1, the acquired complex samples are sent to the decoder. For operator convenience the decoder goes through its full procedure twice: first covering a narrow range around the selected QSO Frequency,” and then over the full range between the blue markers at f_{\min} and f_{\max} . Each pass can be described as a sequence of discrete steps. For those who may wish to study the program’s source code, perhaps with an eye toward future improvements, the steps are presented here as blocks labeled with the names of functional procedures in the code.

sync9: Use sync symbols to find candidate JT9 signals
in specified frequency range

At the frequency of each plausible candidate:

downsam9: Mix, filter and downsample to 16 complex samples/symbol

peakdt9: Using sync symbols, time-align to start of JT9 symbol
sequence

afc9: Measure frequency offset and any possible drift

twkfreq: Remove frequency offset and drift

symspec2: Compute 8-bin spectra for 69 information-carrying
symbols, using the time- and frequency-aligned data;
transform to yield 206 single-bit soft symbols

interleave9: Remove single-bit symbol interleaving imposed at the
transmitter

decode9: Retrieve a 72-bit user message using the sequential "Fano" algorithm for convolutional codes

unpackmsg: Unpack a human-readable message from the 72-bit compressed format

It's useful to know that when conditions necessary for decoding are marginal, the sequential algorithm can have exponentially long times to completion. If the first step in the above sequence finds many seemingly worthy candidate signals, and if many of them turn out to be undecodable, the decoding loop can take a very long time. For this reason the **decode9** step in the above list is programmed to time out and report failure if it is taking too long. The menu choice **Decode | Fast / Normal / Deepest** gives you three-step control of the timeout limit.

Acknowledgments

Many users of *WSJT*, too numerous to mention here individually, have contributed suggestions and advice that have greatly aided the development of *WSJT-X* and its sister programs. Since 2005 the overall project (including *WSJT*, *MAP65*, *WSPR*, and *WSPR-X*) has been "open source", all code being licensed under the [GNU Public License \(GPL\)](#). For *WSJT-X* in particular, I wish to acknowledge the many recent contributions from PY2SDR, VK4BDJ, AC6SL, and AF5X. They have helped to bring the program's design, code, and documentation to its present state.

Appendix A: Installed and Generated Files

After installing *WSJT-X* as described in steps 1 and 2 on page 4, the following files will be present in the installation directory:

afmhot.dat	Data for AFMHot palette
blue.dat	Data for Blue palette
CALL3.TXT	Callsign database
hamlib-alinco.dll	Hamlib libraries
hamlib-amsat.dll	...
hamlib-flexradio.dll	
hamlib-icom.dll	
hamlib-jrc.dll	
hamlib-kachina.dll	
hamlib-kenwood.dll	
hamlib-kit.dll	
hamlib-tapr.dll	

hamlib-tentec.dll	
hamlib-winradio.dll	
hamlib-yaesu.dll	
jt9.exe	Executable for JT9 decoder
jt9code.exe	Test program to illustrate JT9 encoding
libfftw3f-3.dll	Optimized FFT library
libgcc_s_dw2-1.dll	gcc runtime
libhamlib-2.dll	
libstdc++-6.dll	standard C function library
libusb0.dll	USB interface functions
mingwm10.dll	MinGW library
mouse_commands.txt	Special mouse commands
palir-02.dll	Linrad functions
PSKReporter.dll	Library for PSK reporter
QtCore4.dll	Qt libraries
QtGui4.dll	...
QtNetwork4.dll	
QtSvg4.dll	
qwt.dll	Qwt library
save	Directory for saved *.wav files
shortcuts.txt	Keyboard shortcuts
unins000.dat	
unins000.exe	Executable for uninstalling WSJT-X
wsjt.ico	WSJT icon
wsjtx.exe	Executable for WSJT-X

You might be curious about additional files that appear in the *WSJT-X* installation directory after using the program for a while. These include:

ALL.TXT	Log of all received and transmitted messages
decoded.txt	Decoded text from the most recent Rx interval
timer.out	Diagnostic information for decoder optimization
wsjtx.ini	Saved configuration parameters
wsjtx_log.adi	ADIF log
wsjtx_status.txt	Information sent to companion program JT-Alert

Appendix B: The JT9 Protocol

JT9 is a mode designed for making QSOs at HF, MF, and LF. The mode uses essentially the same 72-bit structured messages as JT65. Error control coding (ECC) uses a strong convolutional code with constraint length $K=32$, rate $r=1/2$, and a zero tail, leading to an encoded message length of $(72+31) \times 2 = 206$ information-carrying bits. Modulation is 9-FSK: 8 tones are used for data, one for synchronization. Sixteen

symbol intervals are used for synchronization, so a transmission requires a total of $206 / 3 + 16 = 85$ (rounded up) channel symbols. Symbol durations are approximately $(TR_{\text{period}} - 8) / 85$, where TR_{period} is the T/R sequence length in seconds. Exact symbol lengths are chosen so that n_{sps} , the number of samples per symbol (at 12000 samples per second) is a number with no prime factor greater than 7. This choice makes for efficient FFTs. Tone spacing of the 9-FSK modulation is $df = 1 / t_{\text{sym}} = 12000 / n_{\text{sps}}$, equal to the keying rate. The total occupied bandwidth is $9 \times df$. The generated signal has continuous phase and constant amplitude, and there are no key clicks.

Parameters of five JT9 sub-modes are summarized in the following table, along with approximate S/N thresholds measured by simulation on an AWGN channel. Numbers following "JT9-" in the sub-mode names specify TR_{period} in minutes.

Submode	n_{sps}	Symbol Duration (s)	Tone Spacing (Hz)	Signal Bandwidth (Hz)	S/N Threshold* (dB)	QSO Time (minutes)
JT9-1	6912	0.58	1.736	15.6	-27	6
JT9-2	15360	1.28	0.781	7.0	-30	12
JT9-5	40960	3.41	0.293	2.6	-34	30
JT9-10	82944	6.91	0.145	1.3	-37	60
JT9-30	252000	21.00	0.048	0.4	-42	180

* Noise power measured in 2500 Hz bandwidth.

Appendix C: Source Code

WSJT-X is an open-source program released under the [GNU General Public License](https://www.gnu.org/licenses/gpl-3.0.html). Source code is available from the public repository at <http://developer.berlios.de/projects/wsjit/>. To compile the program you will need to install open source packages for Subversion, QtSDK, qwt, g++, g95 or gfortran, portaudio, fftw3, and hamlib. For compiling in Windows I recommend installing the MinGW package.

The full source code for *WSJT-X* can be downloaded by using the command

```
svn co svn://svn.berlios.de/wsjit/branches/wsjtx
```