

# *WSJT-X* User Guide

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Version 1.8.0

## Table of Contents

1. Introduction
  - 1.1. New in Version 1.8
  - 1.2. Documentation Conventions
  - 1.3. How You Can Contribute
2. System Requirements
3. Installation
  - 3.1. Windows
  - 3.2. Linux
  - 3.3. OS X and macOS
4. Settings
  - 4.1. General
  - 4.2. Radio
  - 4.3. Audio
  - 4.4. Tx Macros
  - 4.5. Reporting
  - 4.6. Frequencies
  - 4.7. Colors
  - 4.8. Advanced
5. Transceiver Setup
6. Basic Operating Tutorial
  - 6.1. Main Window Settings
  - 6.2. Download Samples
  - 6.3. Wide Graph Settings
  - 6.4. JT9
  - 6.5. JT9+JT65
  - 6.6. FT8
7. Making QSOs
  - 7.1. Standard Exchange
  - 7.2. Free-Text Messages
  - 7.3. Auto-Sequencing
  - 7.4. VHF Contest Mode
  - 7.5. Compound Callsigns
  - 7.6. Pre-QSO Checklist
8. VHF+ Features
  - 8.1. VHF Setup
  - 8.2. JT4
  - 8.3. JT65
  - 8.4. QRA64
  - 8.5. ISCAT

- 8.6. MSK144
- 8.7. Echo Mode
- 8.8. VHF+ Sample Files
- 9. WSPR Mode
  - 9.1. Band Hopping
- 10. On-Screen Controls
  - 10.1. Menus
  - 10.2. Button Row
  - 10.3. Left
  - 10.4. Center
  - 10.5. Tx Messages
  - 10.6. Status Bar
  - 10.7. Wide Graph
  - 10.8. Fast Graph
  - 10.9. Echo Graph
  - 10.10. Miscellaneous
- 11. Logging
- 12. Decoder Notes
  - 12.1. AP Decoding
  - 12.2. Decoded Lines
- 13. Measurement Tools
  - 13.1. Frequency Calibration
  - 13.2. Reference Spectrum
  - 13.3. Phase Equalization
- 14. Cooperating Programs
- 15. Platform Dependencies
- 16. Frequently Asked Questions
- 17. Protocol Specifications
  - 17.1. Overview
  - 17.2. Slow Modes
  - 17.3. Fast Modes
- 18. Astronomical Data
- 19. Utility Programs
- 20. Support
  - 20.1. Help with Setup
  - 20.2. Bug Reports
  - 20.3. Feature Requests
- 21. Acknowledgements
- 22. License

# 1. 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**,” while the suffix “-X” indicates that *WSJT-X* started as an extended and experimental branch of the program *WSJT*.

*WSJT-X* Version 1.8 offers nine different protocols or modes: **FT8**, **JT4**, **JT9**, **JT65**, **QRA64**, **ISCAT**, **MSK144**, **WSPR**, and **Echo**. The first five are designed for making reliable QSOs under extreme weak-signal conditions. They use nearly identical message structure and source encoding. JT65 and QRA64 were designed for EME (“moonbounce”) on the VHF/UHF bands and have also proven very effective for worldwide QRP communication on the HF bands. QRA64 has a number of advantages over JT65, including better performance on the very weakest signals. We imagine that over time it may replace JT65 for EME use. JT9 was originally designed for the LF, MF, and lower HF bands. Its submode JT9A is 2 dB more sensitive than JT65 while using less than 10% of the bandwidth. JT4 offers a wide variety of tone spacings and has proven highly effective for EME on microwave bands up to 24 GHz. These four “slow” modes use one-minute timed sequences of alternating transmission and reception, so a minimal QSO takes four to six minutes — two or three transmissions by each station, one sending in odd UTC minutes and the other even. FT8 is operationally similar but four times faster (15-second T/R sequences) and less sensitive by a few dB. On the HF bands, world-wide QSOs are possible with any of these modes using power levels of a few watts (or even milliwatts) and compromise antennas. On VHF bands and higher, QSOs are possible (by EME and other propagation types) at signal levels 10 to 15 dB below those required for CW.

**ISCAT**, **MSK144**, and optionally submodes **JT9E-H** are “fast” protocols designed to take advantage of brief signal enhancements from ionized meteor trails, aircraft scatter, and other types of scatter propagation. These modes use timed sequences of 5, 10, 15, or 30 s duration. User messages are transmitted repeatedly at high rate (up to 250 characters per second, for MSK144) to make good use of the shortest meteor-trail reflections or “pings”. ISCAT uses free-form messages up to 28 characters long, while MSK144 uses the same structured messages as the slow modes and optionally an abbreviated format with hashed call signs.

**WSPR** (pronounced “whisper”) stands for **Weak Signal Propagation Reporter**. The WSPR protocol was designed for probing potential propagation paths using low-power transmissions. WSPR messages normally carry the transmitting station’s callsign, grid locator, and transmitter power in dBm, and they can be decoded at signal-to-noise ratios as low as -28 dB in a 2500 Hz bandwidth. WSPR users with internet access can automatically upload reception reports to a central database called WSPRnet (<http://wsprnet.org/drupal/>) that provides a mapping facility, archival storage, and many other features.

**Echo** mode allows you to detect and measure your own station’s echoes from the moon, even if they are far below the audible threshold.

*WSJT-X* provides spectral displays for receiver passbands as wide as 5 kHz, flexible rig control for nearly all modern radios used by amateurs, and a wide variety of special aids such as automatic Doppler tracking for EME QSOs and Echo testing. The program runs equally well on Windows, Macintosh, and Linux systems, and installation packages are available for all three platforms.

## 1.1. New in Version 1.8

For quick reference, here's a short list of features and capabilities added to *WSJT-X* since Version 1.7.0:

- New mode **FT8** designed for fast QSOs
- New tool **FreqCal** for accurate frequency calibration of your radio
- Improved decoding performance for JT65, QRA64, and MSK144
- **SWL** option for third-party decoding short-format MSK144 messages
- Experimental phase equalization for MSK144
- Options to minimize screen space used by **Main** and **Wide Graph** windows
- New set of suggested default frequencies specific to the three IARU regions
- Enhanced scheme for managing table of suggested default operating frequencies
- Improved CAT control for many radios, including those controlled through Commander or OmniRig
- Bug fixes and minor tweaks to user interface

## 1.2. Documentation Conventions

In this manual the following icons call attention to particular types of information:



**Notes** containing information that may be of interest to particular classes of users.



**Tips** on program features or capabilities that might otherwise be overlooked.



**Warnings** about usage that could lead to undesired consequences.

## 1.3. How You Can Contribute

*WSJT-X* is part of an open-source project released under the GNU General Public License (<http://www.gnu.org/licenses/gpl-3.0.txt>) (GPL). If you have programming or documentation skills or would like to contribute to the project in other ways, please make your interests known to the development team. The project's source-code repository can be found at SourceForge (<http://sourceforge.net/p/wsjt/wsjt/HEAD/tree/>), and most communication among the developers takes place on the email reflector [wsjt-devel@lists.sourceforge.net](mailto:wsjt-devel@lists.sourceforge.net). Bug reports and suggestions for new features, improvements to the *WSJT-X* User Guide, etc., may also be sent to the WSJT Group (<https://groups.yahoo.com/neo/groups/wsjtgroup/info>) email reflector. You must join the relevant group before posting to either email list.

## 2. System Requirements

- SSB transceiver and antenna
- Computer running Windows (XP or later), Linux, or OS X
- 1.5 GHz or faster CPU and 200 MB of available memory; faster machines are better
- Monitor with at least 1024 x 780 resolution
- Computer-to-radio interface using a serial port or equivalent USB device for T/R switching, or CAT control, or VOX, as required for your radio-to-computer connections
- Audio input and output devices supported by the operating system and configured for sample rate 48000 Hz, 16 bits
- Audio or equivalent USB connections between transceiver and computer
- A means for synchronizing the computer clock to UTC within  $\pm 1$  second

## 3. Installation

Installation packages for released versions on Windows, Linux, and OS X are found on the [WSJT Home Page](http://physics.princeton.edu/pulsar/K1JT/) (<http://physics.princeton.edu/pulsar/K1JT/>). Click on the *WSJT-X* link at the left margin and select the appropriate package for your operating system.

### 3.1. Windows

Download and execute the package file [wsjitx-1.8.0-win32.exe](http://physics.princeton.edu/pulsar/K1JT/wsjitx-1.8.0-win32.exe) (<http://physics.princeton.edu/pulsar/K1JT/wsjitx-1.8.0-win32.exe>), following these instructions:

- Install *WSJT-X* into its own directory, for example `C:\WSJTX` or `C:\WSJT\WSJTX`, rather than the conventional location `C:\Program Files\WSJTX`.
- All program files relating to *WSJT-X* will be stored in the chosen installation directory and its subdirectories.
- Logs and other writeable files will normally be found in the directory `C:\Users\<username>\AppData\Local\WSJT-X`.



Your computer may be configured so that this directory is “invisible”. It’s there, however, and accessible. An alternative (shortcut) directory name is `%LOCALAPPDATA%\WSJT-X`.

- The built-in Windows facility for time synchronization is usually not adequate. We recommend the program *Meinberg NTP* (see [Network Time Protocol Setup](http://www.satsignal.eu/ntp/setup.html) (<http://www.satsignal.eu/ntp/setup.html>) for downloading and installation instructions) or *Dimension 4* from [Thinking Man Software](http://www.thinkman.com/dimension4/) (<http://www.thinkman.com/dimension4/>).
- *WSJT-X* expects your sound card to do its raw sampling at 48000 Hz. To ensure that this will be so when running under recent versions of Windows, open the system’s **Sound** control panel and select in turn the **Recording** and **Playback** tabs. Click on **Properties**, then **Advanced**, and select **16 bit, 48000 Hz (DVD Quality)**.
- You can uninstall *WSJT-X* by clicking its **Uninstall** link in the Windows **Start** menu, or by using **Uninstall a Program** on the Windows Control Panel.

### 3.2. Linux

Debian, Ubuntu, and other Debian-based systems including Raspbian:

- 32-bit: [wsjitx\\_1.8.0\\_i386.deb](http://physics.princeton.edu/pulsar/K1JT/wsjitx_1.8.0_i386.deb) ([http://physics.princeton.edu/pulsar/K1JT/wsjitx\\_1.8.0\\_i386.deb](http://physics.princeton.edu/pulsar/K1JT/wsjitx_1.8.0_i386.deb))
  - To install:

```
sudo dpkg -i wsjitx_1.8.0_i386.deb
```

- Uninstall:

```
sudo dpkg -P wsjtx
```

- 64-bit: [wsjtx\\_1.8.0\\_amd64.deb](http://physics.princeton.edu/pulsar/K1JT/wsjtx_1.8.0_amd64.deb) ([http://physics.princeton.edu/pulsar/K1JT/wsjtx\\_1.8.0\\_amd64.deb](http://physics.princeton.edu/pulsar/K1JT/wsjtx_1.8.0_amd64.deb))
  - To install:

```
sudo dpkg -i wsjtx_1.8.0_amd64.deb
```

- 64-bit: [wsjtx\\_1.8.0\\_armhf.deb](http://physics.princeton.edu/pulsar/K1JT/wsjtx_1.8.0_armhf.deb) ([http://physics.princeton.edu/pulsar/K1JT/wsjtx\\_1.8.0\\_armhf.deb](http://physics.princeton.edu/pulsar/K1JT/wsjtx_1.8.0_armhf.deb))
  - To install:

```
sudo dpkg -i wsjtx_1.8.0_armhf.deb
```

- Uninstall:

```
sudo dpkg -P wsjtx
```

You may also need to execute the following command in a terminal:

```
sudo apt install libqt5multimedia5-plugins libqt5serialport5 libfftw3-single3
```

Fedora, Red Hat, and other rpm-based systems:

- 32-bit: [wsjtx-1.8.0-i686.rpm](http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-i686.rpm) (<http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-i686.rpm>)
  - To install:

```
sudo rpm -i wsjtx-1.8.0-i686.rpm
```

- Uninstall:

```
sudo rpm -e wsjtx
```

- 64-bit: [wsjtx-1.8.0-x86\\_64.rpm](http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-x86_64.rpm) ([http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-x86\\_64.rpm](http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-x86_64.rpm))
  - To install:



```
sudo rpm -i wsjtx-1.8.0-x86_64.rpm
```

- Uninstall:

```
sudo rpm -e wsjtx
```

You may also need to execute the following command in a terminal:

```
sudo dnf install fftw-libs-single qt5-qtmultimedia qt5-qtserialport
```

### 3.3. OS X and macOS

**OS X 10.9** and later: Download the file [wsjtx-1.8.0-Darwin.dmg](http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-Darwin.dmg) (<http://physics.princeton.edu/pulsar/K1JT/wsjtx-1.8.0-Darwin.dmg>) to your desktop, double-click on it and consult its `ReadMe` file for important installation notes.

If you have already installed a previous version, you can retain it by changing its name in the **Applications** folder (say, from *WSJT-X* to *WSJT-X\_1.7*). You can then proceed to the installation phase.

Take note also of the following:

- Use the Mac's **Audio MIDI Setup** utility to configure your sound card for 48000 Hz, two-channel, 16-bit format.
- Use **System Preferences** to select an external time source to keep your system clock synchronized to UTC.
- To uninstall simply drag the *WSJT-X* application from **Applications** to the **Trash Can**.

## 4. Settings

Select **Settings** from the **File** menu or by typing **F2**. (On Macintosh select **Preferences** from the *WSJT-X* menu, or use the keyboard shortcut **Cmd+,**). The following sections describe setup options available on each of eight tabs selectable near the top of the window.

### 4.1. General

The screenshot shows the 'Settings' window with the 'General' tab selected. The window has a title bar with a question mark and a close button. Below the title bar is a tabbed interface with tabs for 'General', 'Radio', 'Audio', 'Tx Macros', 'Reporting', 'Frequencies', 'Colors', and 'Advanced'. The 'General' tab is active and contains three sections: 'Station Details', 'Display', and 'Behavior'.  
The 'Station Details' section includes fields for 'My Call:', 'My Grid:', and 'IARU Region:' (a dropdown menu set to 'All'). Below these is a dropdown for 'Message generation for type 2 compound callsign holders:' set to 'Full call in Tx3'.  
The 'Display' section has four checkboxes: 'Blank line between decoding periods', 'Display distance in miles', 'Tx messages to Rx frequency window', and 'Show DXCC entity and worked before status'. To the right of these are two buttons: 'Font...' and 'Decoded Text Font...'.  
The 'Behavior' section has eight checkboxes arranged in two columns: 'Monitor off at startup', 'Monitor returns to last used frequency', 'Double-click on call sets Tx enable', 'Disable Tx after sending 73', 'CW ID after 73', 'Enable VHF/UHF/Microwave features', 'Allow Tx frequency changes while transmitting', 'Single decode', and 'Decode after EME delay'. To the right of these are two spinners: 'Tx watchdog:' set to '6 minutes' and 'Periodic CW ID Interval:' set to '0'. At the bottom right are 'OK' and 'Cancel' buttons.

Select the **General** tab on the **Settings** window. Under *Station Details* enter your callsign, grid locator (preferably the 6-character locator) and IARU Region number. Region 1 is Europe, Africa, the Middle East, and Northern Asia; Region 2 the Americas; and Region 3 Southern Asia and the Pacific. This information will be sufficient for initial tests.

Meanings of remaining options on the **General** tab should be self-explanatory after you have made some QSOs using *WSJT-X*. You may return to set these options to your preferences later.

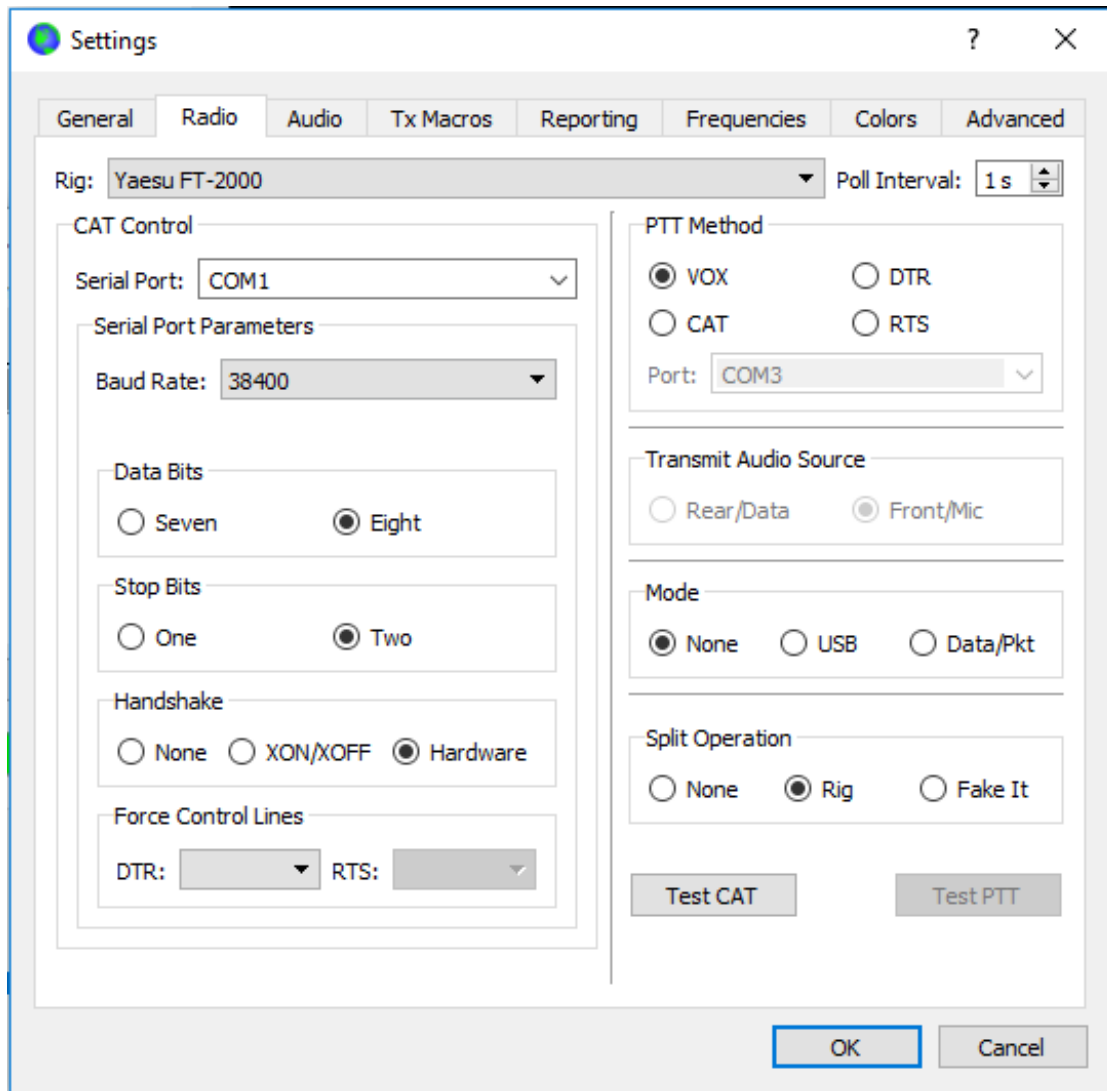


If you are using a callsign with an add-on prefix or suffix, or wish to work a station using such a call, be sure to read the section Compound Callsigns.



Enabling VHF/UHF/Microwave features necessarily disables the wideband multi-decode capability of JT65. In most circumstances you should turn this feature off when operating at HF.

## 4.2. Radio



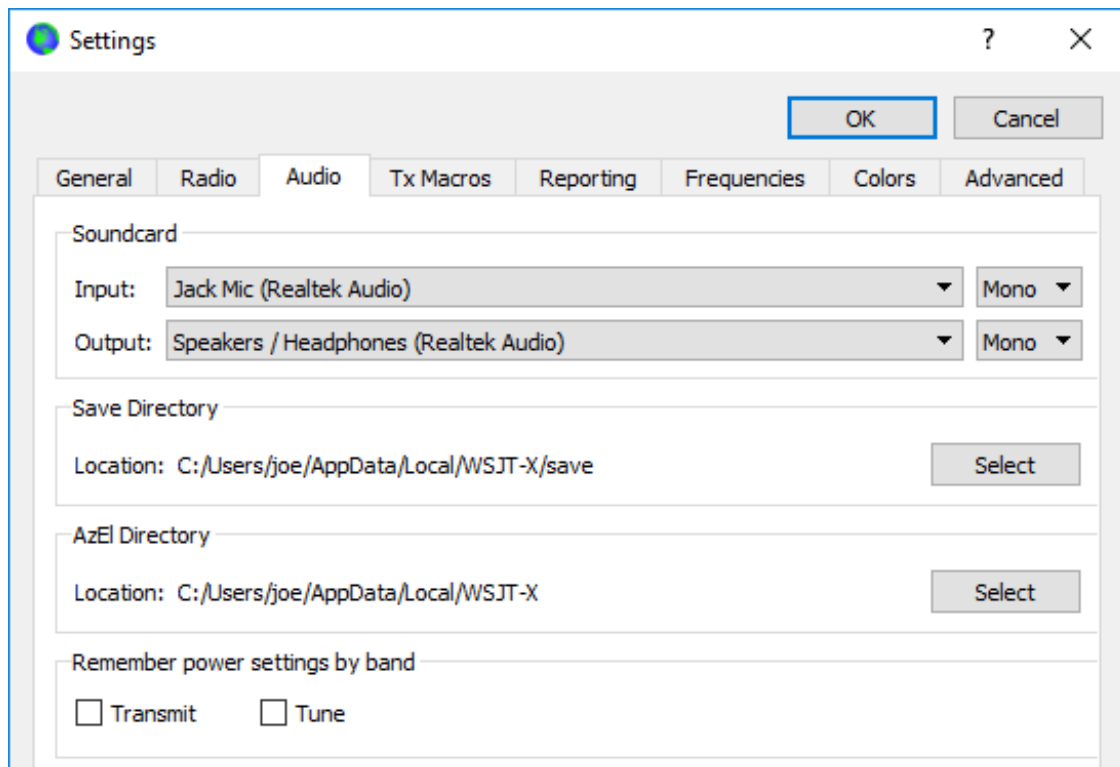
WSJT-X offers CAT (Computer Aided Transceiver) control of relevant features of most modern transceivers. To configure the program for your radio, select the **Radio** tab.

- Select your radio type from the drop-down list labeled **Rig**, or **None** if you do not wish to use CAT control.

- Alternatively, if you have configured your station for control by **DX Lab Suite Commander**, **Ham Radio Deluxe**, **Hamlib NET rigctl**, or **OmniRig**, you may select one of those program names from the **Rig** list. In these cases the entry field immediately under *CAT Control* will be relabeled as **Network Server**. Leave this field blank to access the default instance of your control program, running on the same computer. If the control program runs on a different computer and/or port, specify it here. Hover the mouse pointer over the entry field to see the required formatting details.
- Select **OmniRig Rig 1** or **OmniRig Rig 2** to connect to an *OmniRig* server running on the same computer. Note that *OmniRig* is available only under Windows.
- Set **Poll Interval** to the desired interval for *WSJT-X* to query your radio. For most radios a small number (say, 1 – 3 s) is suitable.
- *CAT Control*: To have *WSJT-X* control the radio directly rather than through another program, make the following settings:
  - Select the **Serial Port** used to communicate with your radio.
  - *Serial Port Parameters*: Set values for **Baud Rate**, **Data Bits**, **Stop Bits**, and **Handshake** method. Consult your radio's user guide for the proper parameter values.
  - *Force Control Lines*: A few station setups require the CAT serial port's **RTS** and/or **DTR** control lines to be forced high or low. Check these boxes only if you are sure they are needed (for example, to power the radio serial interface).
- *PTT Method*: select **VOX**, **CAT**, **DTR**, or **RTS** as the desired method for T/R switching. If your choice is **DTR** or **RTS**, select the desired serial port (which may be the same one as used for CAT control).
- *Transmit Audio Source*: some radios permit you to choose the connector that will accept Tx audio. If this choice is enabled, select **Rear/Data** or **Front/Mic**.
- *Mode*: *WSJT-X* uses upper sideband mode for both transmitting and receiving. Select **USB**, or choose **Data/Pkt** if your radio offers such an option and uses it to enable the rear-panel audio line input. Some radios also offer wider and/or flatter passbands when set to **Data/Pkt** mode. Select **None** if you do not want *WSJT-X* to change the radio's Mode setting.
- *Split Operation*: Significant advantages result from using **Split** mode (separate VFOs for Rx and Tx) if your radio supports it. If it does not, *WSJT-X* can emulate such behavior. Either method will result in a cleaner transmitted signal, by keeping the Tx audio always in the range 1500 to 2000 Hz so that audio harmonics cannot pass through the Tx sideband filter. Select **Rig** to use the radio's Split mode, or **Fake It** to have *WSJT-X* adjust the VFO frequency as needed, when T/R switching occurs. Choose **None** if you do not wish to use split operation.

When all required settings have been made, click **Test CAT** to test communication between *WSJT-X* and your radio. The button should turn green to indicate that proper communication has been established. Failure of the CAT-control test turns the button red and displays an error message. After a successful CAT test, toggle the **Test PTT** button to confirm that your selected method of T/R control is working properly. (If you selected **VOX** for *PTT Method*, you can test T/R switching later by using the **Tune** button on the main window.)

## 4.3. Audio



Select the **Audio** tab to configure your sound system.

- *Soundcard*: Select the audio devices to be used for **Input** and **Output**. Usually the **Mono** settings will suffice, but in special cases you can choose **Left**, **Right**, or **Both** stereo channels.
- Be sure that your audio device is configured to sample at 48000 Hz, 16 bits.



If you select the audio output device that is also your computer's default audio device, be sure to turn off all system sounds to prevent inadvertently transmitting them over the air.

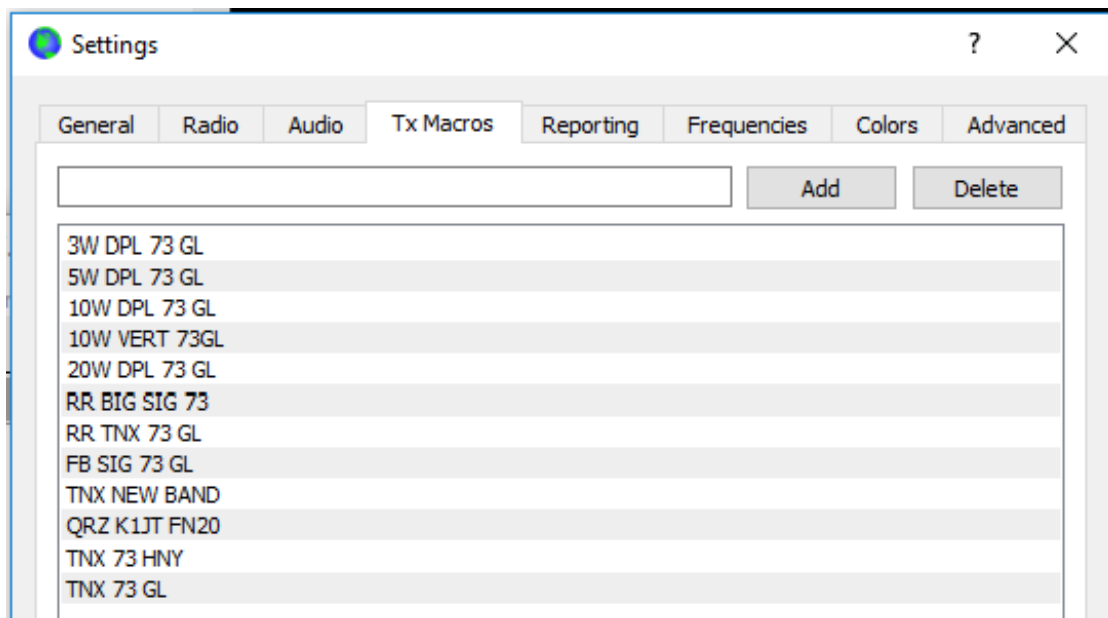


Windows Vista and later may configure audio devices using the Texas Instruments PCM2900 series CODEC for microphone input rather line input. (This chip is used in many radios with built-in USB CODECs, as well as various other audio interfaces.) If you are using such a device, be sure to set the mic level in the Recording Device Properties to 0 dB.

- *Save Directory*: *WSJT-X* can save its received audio sequences as `.wav` files. A default directory for these files is provided; you can select another location if desired.
- *AzEl Directory*: A file named `aze1.dat` will appear in the specified directory. The file contains information usable by another program for automatic tracking of the Sun or Moon, as well as calculated Doppler shift for the specified EME path. The file is updated once per second whenever the Astronomical Data window is displayed.

- *Remember power settings by band:* Checking either of these will cause *WSJT-X* to remember the **Pwr** slider setting for that operation on a band-by-band basis. For example, when **Tune** is checked here and you click the **Tune** button on the main window, the power slider will change to the most recent setting used for **Tune** on the band in use.

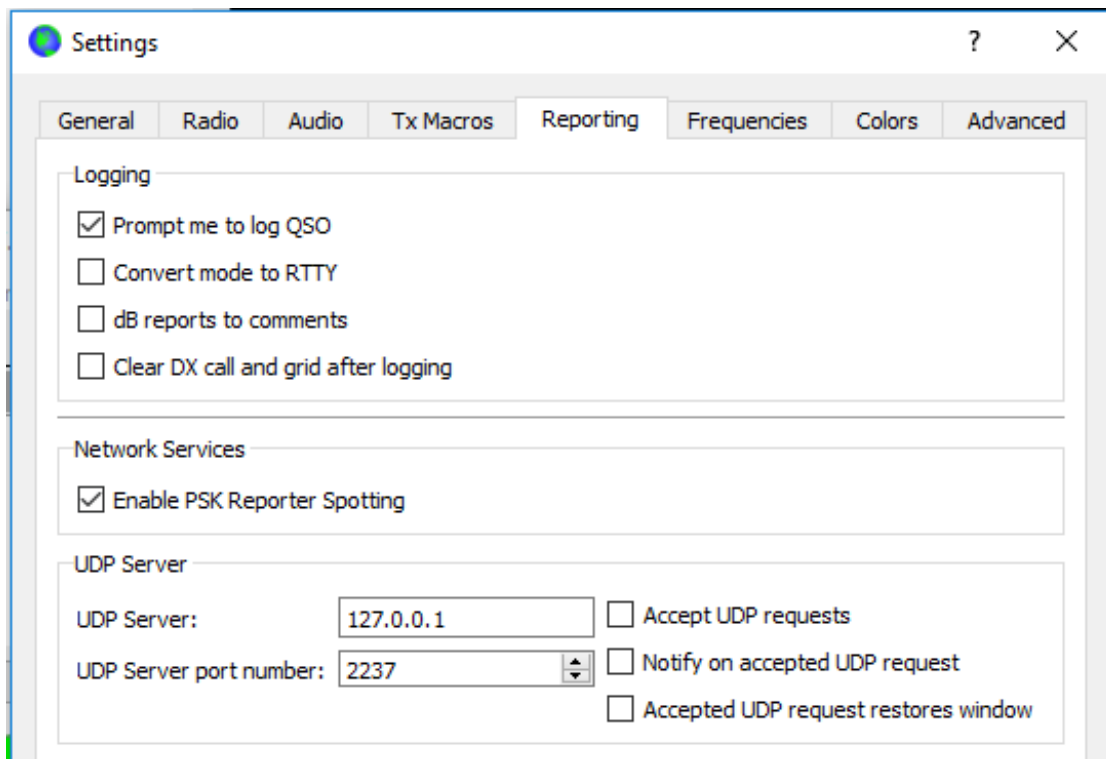
## 4.4. Tx Macros



**Tx Macros** are an aid for sending brief, frequently used free-text messages such as the examples shown above.

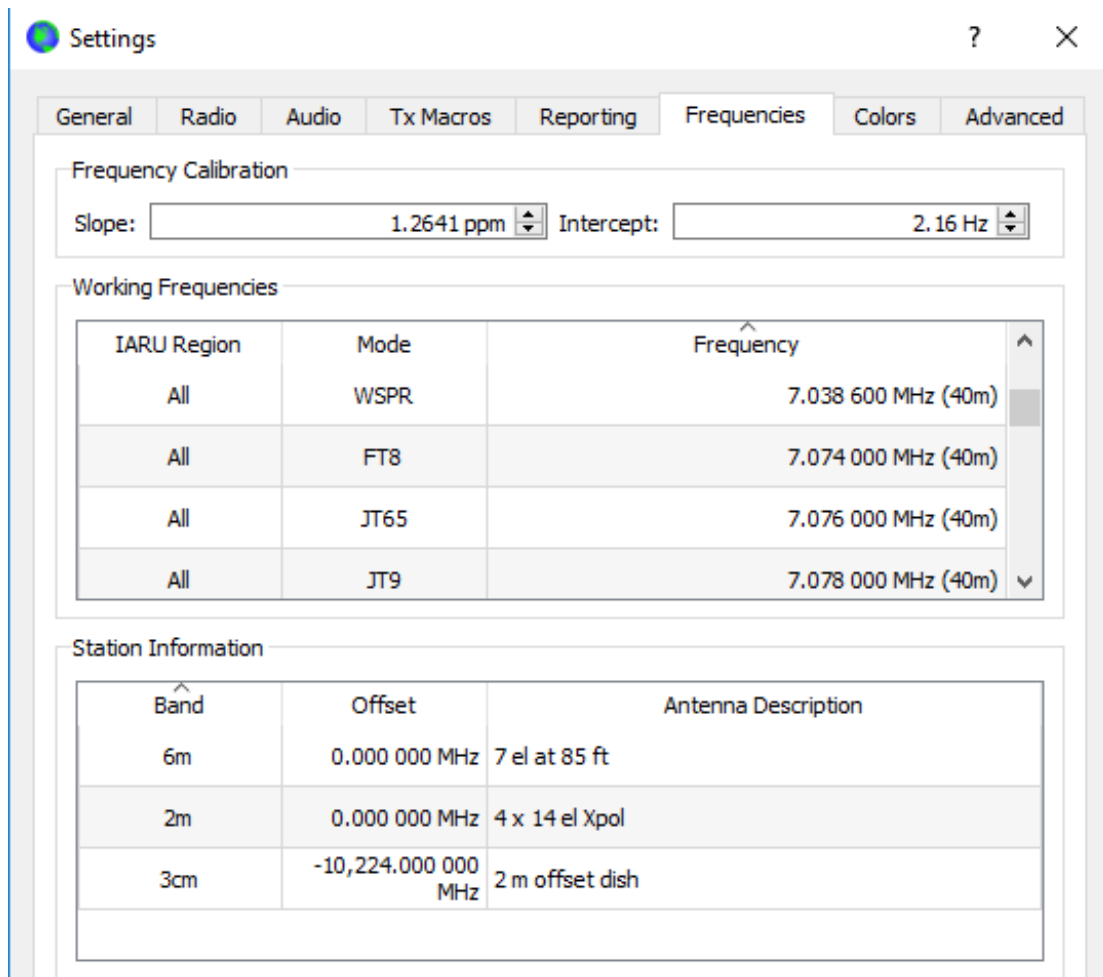
- To add a new message to the list, enter the desired text (up to 13 characters) in the entry field at top, then click **Add**.
- To remove an unwanted message, click on the message and then on **Delete**.
- You can reorder your macro messages by using drag-and-drop. The new order will be preserved when *WSJT-X* is restarted.
- Messages can also be added from the main window's **Tx5** field on Tab 1 or the **Free msg** field on Tab 2. Simply hit [Enter] after the message has been entered.

## 4.5. Reporting



- *Logging*: Choose any desired options from this group.
- *Network Services*: Check **Enable PSK Reporter Spotting** to send reception reports to the [PSK Reporter](http://pskreporter.info/pskmap.html) (<http://pskreporter.info/pskmap.html>) mapping facility.
- *UDP Server*: This group of options controls the network name or address and port number used by a program that will receive status updates from *WSJT-X*. Cooperating applications like *JTAlert* use this feature to obtain information about a running *WSJT-X* instance. If you are using *JTAlert*, be sure to check the three boxes at lower right.

## 4.6. Frequencies



**Working Frequencies:** By default the **Working Frequencies** table contains a list of frequencies conventionally used for modes JT4, JT9, JT65, MSK144, WSPR, and Echo. Conventions may change with time or by user preference; you can modify the frequency table as desired.

- To change an existing entry, double-click to edit it, type a desired frequency in MHz or select from the drop down list of options, then hit **Enter** on the keyboard. The program will format your changed entry appropriately.
- To add a new entry, right-click anywhere on the frequency table and select **Insert**. Enter a frequency in MHz in the pop-up box and select the desired mode (or leave the Mode selection as **All**). Then click **OK**. The table may include more than one frequency for a given band.
- To delete an entry, right-click it and select **Delete**, multiple entries can be deleted in a single operation by selecting them before right-clicking.
- Right-click any entry and click **Reset** button to return the table to its default configuration.

Other more advanced maintenance operations are available on the right-click context menu that should be self-explanatory.



*Frequency Calibration:* If you have calibrated your radio using WWV or other reliable frequency references, or perhaps with the technique described in [Accurate Frequency Measurements with your WSPR Setup](http://www.physics.princeton.edu/pulsar/K1JT/FMT_User.pdf) ([http://www.physics.princeton.edu/pulsar/K1JT/FMT\\_User.pdf](http://www.physics.princeton.edu/pulsar/K1JT/FMT_User.pdf)), enter the measured values for *Intercept* A and *Slope* B in the equation

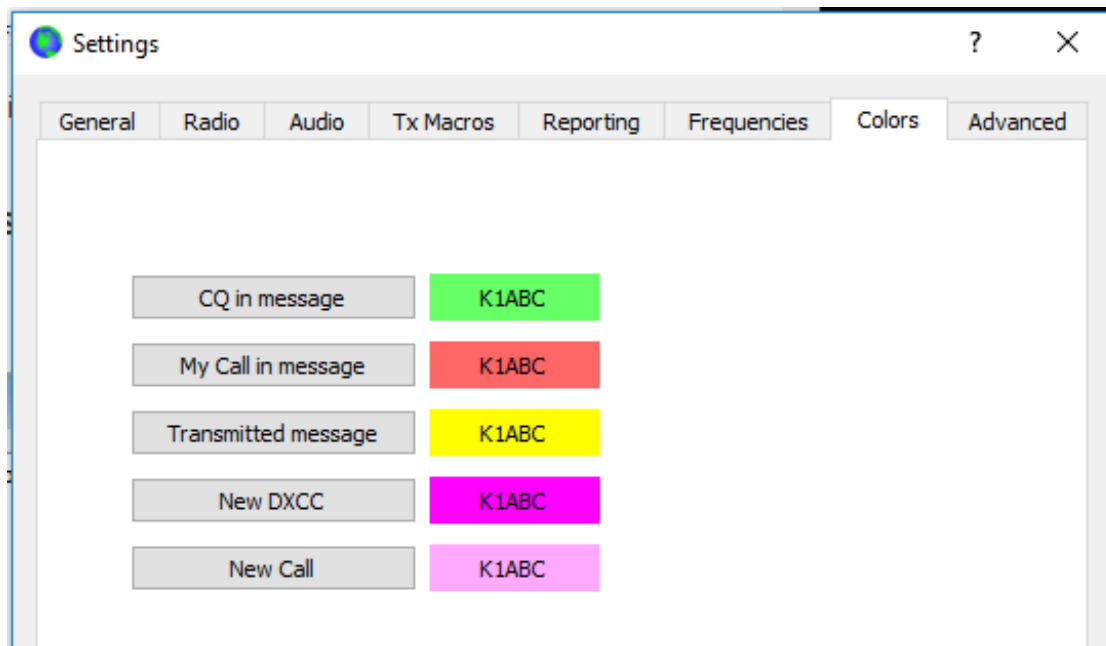
$$\text{Dial error} = A + B \cdot f$$

where “Dial error” and A are in Hz, f is frequency in MHz, and B is in parts per million (ppm). Frequency values sent to the radio and received from it will then be adjusted so that frequencies displayed by *WSJT-X* are accurate.

*Station Information:* You can save **Band**, **Offset** and **Antenna Description** information for your station. The antenna information will be included in reception reports sent to [PSK Reporter](http://pskreporter.info/pskmap.html) (<http://pskreporter.info/pskmap.html>). By default the frequency offset for each band is zero. Nonzero offsets may be added if (for example) a transverter is in use.

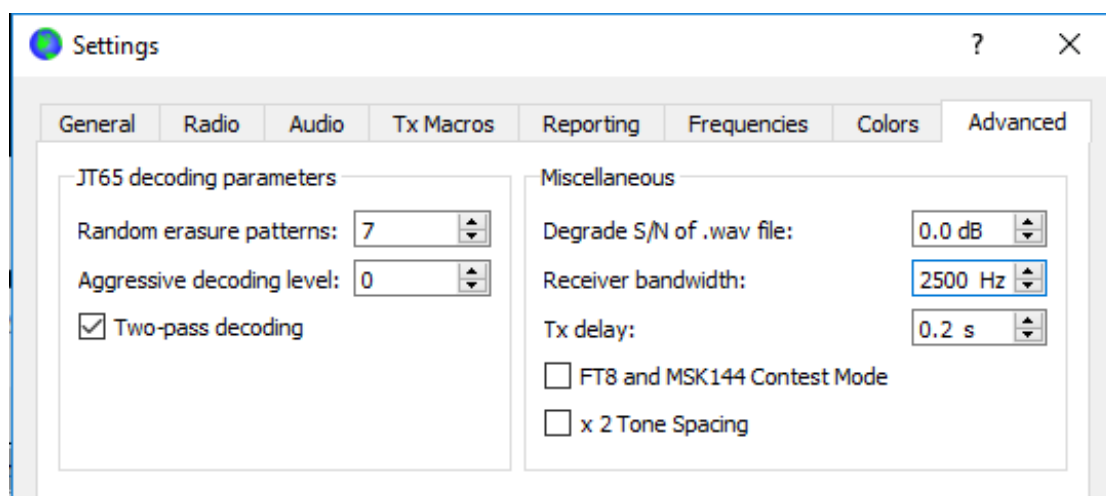
- To simplify things you might want to delete any unwanted bands — for example, bands where you have no equipment. Then click on a **Frequency** entry and type **Ctrl+A** to “select all,” and drag-and-drop the entries onto the *Station Information* table. You can then add any transverter offsets and antenna details.
- To avoid typing the same information many times, you can drag-and-drop entries between the lines of the *Station Information* table.
- When all settings have been configured to your liking, click **OK** to dismiss the **Settings** window.

## 4.7. Colors



*WSJT-X* uses colors to highlight decoded messages containing information of particular interest. Click on one of the buttons to select your preferred colors for any message category.

## 4.8. Advanced



### *JT65 decoding parameters*

- **Random erasure patterns** logarithmically scales the number of pseudo-random trials used by the Franke-Taylor JT65 decoder. Larger numbers give slightly better sensitivity but take longer. For most purposes a good setting is 6 or 7.
- **Aggressive decoding level** sets the threshold for acceptable decodes using Deep Search. Higher numbers will display results with lower confidence levels.
- Check **Two-pass decoding** to enable a second decoding pass after signals producing first-pass decodes have been subtracted from the received data stream.

### *Miscellaneous*

- Set a positive number in **Degrade S/N of .wav file** to add known amounts of pseudo-random noise to data read from a .wav file. To ensure that the resulting S/N degradation is close to the requested number of dB, set **Receiver bandwidth** to your best estimate of the receiver's effective noise bandwidth.
- Set **Tx delay** to a number larger than the default 0.2 s to create a larger delay between execution of a command to enable PTT and onset of Tx audio.



For the health of your T/R relays and external preamplifier, we strongly recommend using a hardware sequencer and testing to make sure that sequencing is correct.

- Check **FT8 and MSK144: NA VHF Contest Mode** to enable generation and auto-sequencing of messages using four-character grid locators in place of signal reports, as required for most North American VHF contests.
- Check **x 2 Tone spacing** to generate Tx audio with twice the normal tone spacing. This feature is intended for use with specialized LF/MF transmitters that divide the audio waveform by 2 before further processing.

## 5. Transceiver Setup

### *Receiver Noise Level*

- If it is not already highlighted in green, click the **Monitor** button to start normal receive operation.
- Be sure your transceiver is set to **USB** (or **USB Data**) mode.
- Use the receiver gain controls and/or the computer's audio mixer controls to set the background noise level (scale at lower left of main window) to around 30 dB when no signals are present. It is usually best to turn AGC off or reduce the RF gain control to minimize AGC action.

### *Bandwidth and Frequency Setting*

- If your transceiver offers more than one bandwidth setting in USB mode, it may be advantageous to choose the widest one possible, up to about 5 kHz. This choice has the desirable effect of allowing the **Wide Graph** (waterfall and 2D spectrum) to display the conventional JT65 and JT9 sub-bands simultaneously on most HF bands. Further details are provided in the Basic Operating Tutorial. A wider displayed bandwidth may also be helpful at VHF and above, where FT8, JT4, JT65, and QRA64 signals may be found over much wider ranges of frequencies.
- If you have only a standard SSB filter you won't be able to display more than about 2.7 kHz bandwidth. Depending on the exact dial frequency setting, on HF bands you can display the full sub-band generally used for one mode.
- Of course, you might prefer to concentrate on one mode at a time, setting your dial frequency to (say) 14.074 for FT8, 14.076 for JT65, or 14.078 for JT9. Present conventions have the nominal JT9 dial frequency 2 kHz higher than the JT65 dial frequency on most bands, and the FT8 frequency 2 kHz lower.

### *Transmitter Audio Level*

- Click the **Tune** button on the main screen to switch the radio into transmit mode and generate a steady audio tone.
- Listen to the generated audio tone using your radio's **Monitor** facility. The transmitted tone should be perfectly smooth, with no clicks or glitches. Make sure that this is true even when you simultaneously use the computer to do other tasks such as email, web browsing, etc.
- Adjust the **Pwr** slider (at right edge of main window) downward from its maximum until the RF output from your transmitter falls slightly. This is generally a good level for audio drive.
- Toggle the **Tune** button once more or click **Halt Tx** to stop your test transmission.

## 6. Basic Operating Tutorial

This section introduces the basic user controls and program behavior of *WSJT-X*, with particular emphasis on the JT9, JT65, and FT8 modes. We suggest that new users should go through the full HF-oriented tutorial, preferably while at your radio. Subsequent sections cover additional details on Making QSOs, WSPR mode and VHF+ Features.

### 6.1. Main Window Settings

- Click the **Stop** button on the main window to halt any data acquisition.
- Select **JT9** from the **Mode** menu and **Deep** from the **Decode** menu.
- Set the audio frequencies to **Tx 1224 Hz** and **Rx 1224 Hz**.

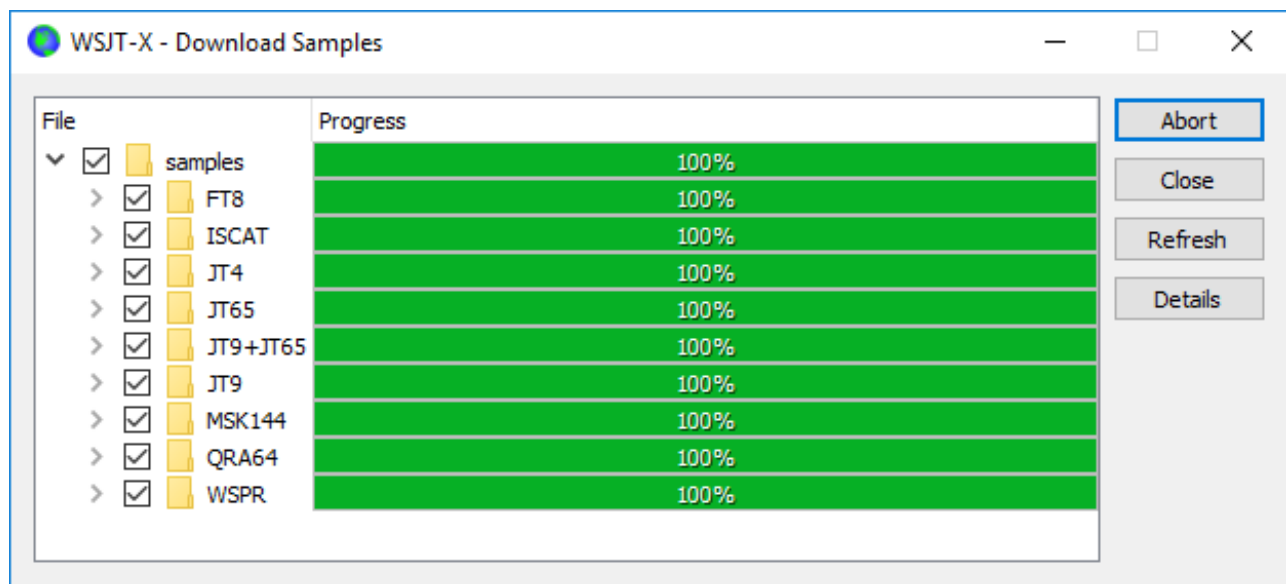


Sliders and spinner controls respond to **Arrow** key presses and **Page Up/Down** key presses, with the **Page** keys moving the controls in larger steps. You can also type numbers directly into the spinner controls or use the mouse wheel.

- Select **Tab 2** (below the **Decode** button) to choose the alternative set of controls for generating and selecting Tx messages.

### 6.2. Download Samples

- Select **Download samples...** from the **Help** menu.
- Download some or all of the available sample files using checkboxes on the screen shown below. For this tutorial you will need at least the JT9 and JT9+JT65 files.



### 6.3. Wide Graph Settings

- **Bins/Pixel = 4**

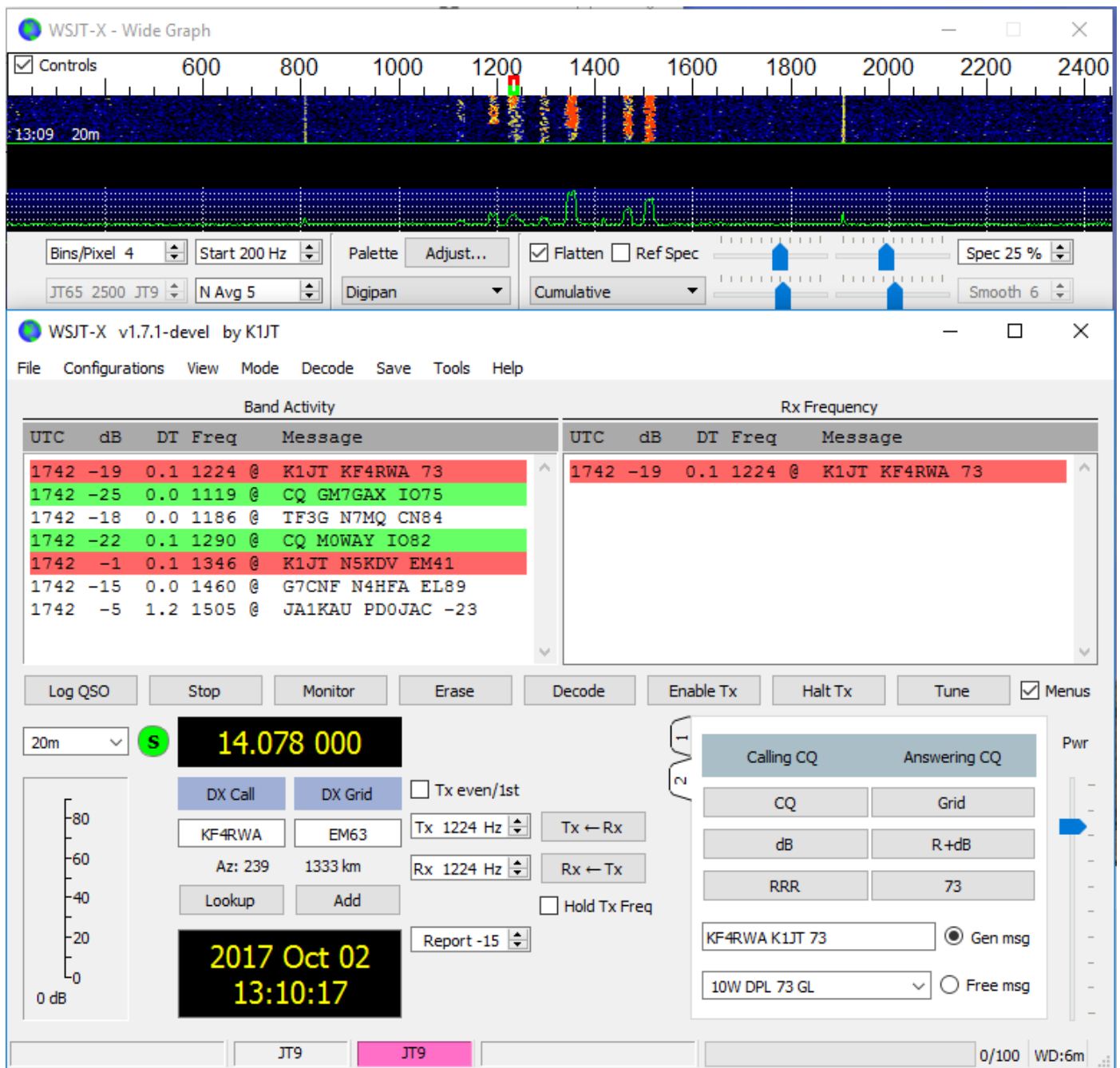
- **Start** = 200 Hz
- **N Avg** = 5
- **Palette** = Digipan
- **Flatten** = checked
- Select **Cumulative** for data display
- **Gain** and **Zero** sliders for waterfall and spectrum set near midscale
- **Spec** = 25%
- Use the mouse to grab the left or right edge of the **Wide Graph**, and adjust its width so that the upper frequency limit is about 2400 Hz.

## 6.4. JT9

For this step and the next, you may want to pretend you are K1JT by entering that callsign temporarily as **My Call** on the **Settings | General** tab. Your results should then be identical to those shown in the screen shot below.

### *Open a Wave File:*

- Select **File | Open** and select the file ...\\save\\samples\\JT9\\130418\_1742.wav. When the file opens you should see something similar to the following screen shot:



## Decoding Overview

Decoding takes place at the end of a receive sequence and proceeds in two steps. The first decode is done at the selected Rx frequency, indicated by the U-shaped green marker on the waterfall frequency scale. Results appear in both the left (**Band Activity**) and right (**Rx Frequency**) text windows on the main screen. The program then finds and decodes all signals in the selected mode over the displayed frequency range. The red marker on the waterfall scale indicates your Tx frequency.

Seven JT9 signals are present in the example file, all decodable. When this file was recorded KF4RWA was finishing a QSO with K1JT. Since the green marker was placed at his audio frequency, 1224 Hz, his message `K1JT KF4RWA 73` is decoded first and appears in the **Rx Frequency** window. The **Band Activity** window shows this message plus all decodes at other frequencies. By default lines containing `CQ` are highlighted in green, and lines with **My Call** (in this case K1JT) in red.

### *Decoding Controls*

To gain some feeling for controls frequently used 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:

- Double-click on either of the decoded lines highlighted in green. This action produces the following results:
  - Callsign and locator of a station calling CQ are copied to the **DX Call** and **DX Grid** entry fields.
  - Messages are generated for a standard minimal QSO.
  - The **Tx even** box is checked or cleared appropriately, so that you will transmit in the proper (odd or even) minutes.
  - The Rx frequency marker is moved to the frequency of the CQing station.
  - The **Gen Msg** (“generated message”) radio button at bottom right of the main window is selected.
  - If you had checked **Double-click on call sets Tx Enable** on the **Setup** menu, **Enable Tx** would be activated and a transmission would start automatically at the proper time.
  - You can modify the double-click behavior by holding down the **Shift** key to move only the Tx frequency or the **Ctrl** key to move both Rx and Tx frequencies.
- Double-click on the decoded message `K1JT N5KDV EM41`, highlighted in red. Results will be similar to those in the previous step. The Tx frequency (red marker) is not moved unless **Shift** or **Ctrl** is held down. Messages highlighted in red are usually in response to your own CQ or from a tail-ender, and you probably want your Tx frequency to stay where it was.



Double-clicking on decoded messages can be defaulted to simplex operation by checking **Double click on call sets Tx and Rx freqs** on the **Settings** → **General** tab.



You can prevent your Tx frequency from being changed by checking the box **Lock Tx Freq**.

- Click somewhere on the waterfall to set Rx frequency (green marker on waterfall scale).
- Shift-click on the waterfall to set Tx frequency (red marker).
- Ctrl-click on the waterfall to set both Rx and Tx frequencies.
- Double-click on a signal in the waterfall to set Rx frequency and start a narrow-band decode there. Decoded text will appear in the right window only.
- Ctrl-double-click on a signal to set both Rx and Tx frequencies and decode at the new frequency.

- Click **Erase** to clear the right window.
- Double-click **Erase** to clear both text windows.

## 6.5. JT9+JT65

### Main Window:

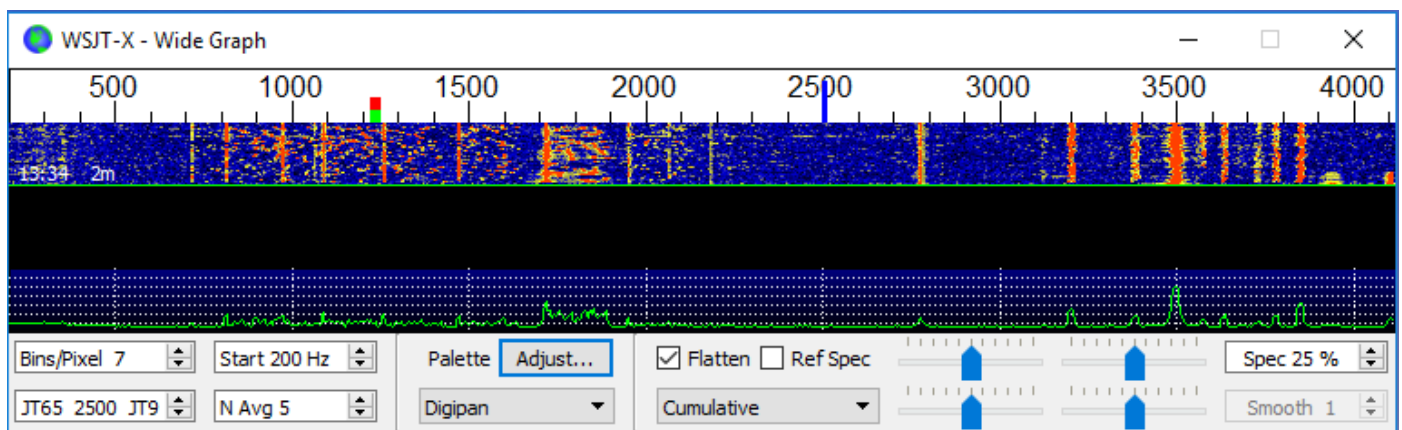
- Select **JT9+JT65** on the **Mode** menu.
- Toggle the **Tx mode** button to read **Tx JT65 #**, and set the Tx and Rx frequencies to 1718 Hz.
- Double-click on **Erase** to clear both text windows.

### Wide Graph Settings:

- **Bins/Pixel** = 7
- **JT65 .... JT9** = 2500
- Adjust the width of the Wide Graph window so that the upper frequency limit is approximately 4000 Hz.

### Open a Wave File:

- Select **File | Open** and navigate to ...\\save\\samples\\JT9+JT65\\130610\_2343.wav. The waterfall should look something like this:



The position of the blue marker on the waterfall scale is set by the spinner control **JT65 nnnn JT9**, where nnnn is an audio frequency in Hz. In **JT9+JT65** mode the program will automatically decode JT9 signals only above this frequency. JT65 signals will be decoded over the full displayed frequency range.

JT9 signals appear in the **Cumulative** spectrum as nearly rectangular shapes about 16 Hz wide. They have no clearly visible sync tone like the one at the low-frequency edge of all JT65 signals. By convention the nominal frequency of both JT9 and JT65 signals is taken to be that of the lowest tone, at the left edge of its spectrum.

This sample file contains 17 decodable signals — nine in JT65 mode (flagged with the character # in the decoded text windows), and eight in JT9 mode (flagged with @). On multi-core computers the decoders for JT9 and JT65 modes run simultaneously, so their results will be interspersed. The **Band Activity** window contains all decodes (you might need to



scroll back in the window to see some of them). A signal at the frequency specified by the green marker is given decoding priority, and its message is displayed also in the **Rx Frequency** window.

Band Activity					Rx Frequency				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
2343	-1	0.6	1718	# BG THX JOE 73	2343	-1	0.6	1718	# BG THX JOE 73
2343	-8	0.3	3196	@ WB8QPG IZ0MIT -11					
2343	-18	1.0	3372	@ KK4HEG KE0CO CN87					
2343	-7	0.3	815	# KK4DSD W7VP -16					
2343	14	0.1	3491	@ CQ AG4M EM75					
2343	-20	-1.4	3567	@ CQ TA4A KM37					
2343	-16	0.2	3627	@ CT1FBK IK5YZT R+02					
2343	-10	0.4	975	# CQ DL7ACA JO40					
2343	-23	0.3	3721	@ KF5SLN KB1SUA FN42					
2343	-8	0.7	1089	# N2SU W0JMW R-14					
2343	-17	0.1	3774	@ CQ M0ABA JO01					
2343	-10	0.7	1259	# YV6BFE F6GUU R-08					
2343	-9	1.6	1471	# VA3UG F1HMR 73					
2343	-14	1.3	1951	# RA3Y VE3NLS 73					
2343	-2	0.2	3843	@ EI3HGB DD2EE JO31					
2343	-21	1.8	1064	# WU7B K9EEI 73					
2343	-19	0.3	2065	# K2OI AJ4UU R-20					

- Confirm that mouse-click behavior is similar to that described earlier, in Example 1. *WSJT-X* automatically determines the mode of each JT9 or JT65 message.



When you double-click on a signal in the waterfall it will be properly decoded even if on the “wrong” side of the **JT65 nnnn JT9** marker. The Tx mode automatically switches to that of the decoded signal and the Rx and Tx frequency markers on the waterfall scale resize themselves accordingly. When selecting a JT65 signal, click on the sync tone at its left edge.

- Double-click on the waterfall near 815 Hz: a JT65 message originating from W7VP will be decoded and appear in the **Rx Frequency** window. Between the **UTC** and **Freq** columns on the decoded text line you will find **dB**, the measured signal-to-noise ratio, and **DT**, the signal’s time offset in seconds relative to your computer clock.

UTC	dB	DT	Freq	Mode	Message
2343	-7	0.3	815	#	KK4DSD W7VP -16

- Double-click on the waterfall at 3196 Hz. The program will decode a JT9 message from IZ0MIT:

UTC	dB	DT	Freq	Mode	Message
2343	-8	0.3	3196	@	WB8QPG IZ0MIT -11

- Scroll back in the **Band Activity** window and double-click on the message CQ DL7ACA J040 . The program will set **Tx mode** to JT65 and the Rx frequency to that of DL7ACA, 975 Hz. If you hold down the **Ctrl** key, both Rx and Tx frequencies will be moved. If you had checked **Double-click on call sets Tx Enable** on the **Setup** menu, the program would configure itself to begin a transmission and start a QSO with DL7ACA.
- Hold **Ctrl** down and double-click on the decoded JT65 message CQ TA4A KM37 . The program will set Tx mode to JT9 and the Rx and Tx frequencies to 3567 Hz. The program is now configured properly for a JT9 QSO with TA4A.

### *Reopen the First Sample File:*

- Select **File | Open** and navigate to ...\\save\\samples\\130418\_1742.wav .

Taking full advantage of the wide-band, dual-mode capability of *WSJT-X* requires a receiver bandwidth of at least 4 kHz. These data were recorded with a much narrower Rx bandwidth, roughly 200 to 2400 Hz. If you have no Rx filter wider than about 2.7 kHz, you will be using data like this. For best viewing, adjust **Bins/Pixel** and the width of the Wide Graph so that only the active part of the spectrum shows, say 200 to 2400 Hz. Re-open the example file after any change of **Bins/Pixel** or Wide Graph width, to refresh the waterfall.

The signals in this file are all JT9 signals. To decode them automatically in **JT9+JT65** mode you'll need to move the **JT65 nnnn JT9** delimiter down to 1000 Hz or less.

### *Waterfall Controls*

Now is a good time to experiment with the **Start** control and the sliders controlling gain and zero-point of the waterfall and spectrum plots. **Start** determines the frequency displayed at the left side of the waterfall scale. Sliders set the baseline level and gain for the waterfall and the several types of spectra. Good starting values should be close to mid-scale. You might want to uncheck **Flatten** when adjusting the sliders. Re-open the wave file after each change, to see the new results.

## 6.6. FT8

### *Main Window:*

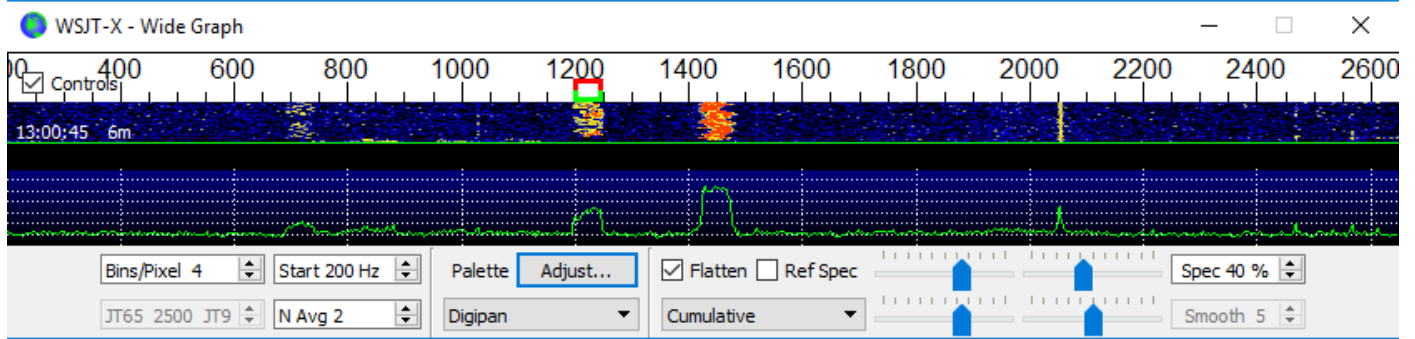
- Select **FT8** on the **Mode** menu.
- Set Tx and Rx frequencies to 1200 Hz.
- Double-click on **Erase** to clear both text windows.

### *Wide Graph Settings:*

- **Bins/Pixel** = 4, **Start** = 200 Hz, **N Avg** = 2
- Adjust the width of the Wide Graph window so that the upper frequency limit is approximately 2600 Hz.

### *Open a Wave File:*

- Select **File | Open** and navigate to ...\\save\\samples\\FT8\\170709\_135615.wav. The waterfall and decoded text window should look something like the following screen shots:



WSJT-X v1.7.1-devel by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity					
UTC	dB	DT	Freq	Message	
135615	-8	0.7	1200 ~	K1JT ZF1EJ EK99	
135615	-16	0.6	694 ~	CQ ON3LA JN29	
135615	2	0.6	1428 ~	KY7M N4AU +00	

- Click with the mouse anywhere on the waterfall display. The green Rx frequency marker will jump to your selected frequency, and the Rx frequency control on the main window will be updated accordingly.
- Do the same thing with the **Shift** key held down. Now the red Tx frequency marker and its associated control on the main window will follow your frequency selections.
- Do the same thing with the **Ctrl** key held down. Now the both colored markers and both spinner controls will follow your selections.
- Double-clicking at any frequency on the waterfall does all the things just described and also invokes the decoder in a small range around the Rx frequency. To decode a particular signal, double-click near the left edge of its waterfall trace.
- Now double-click on any of the the lines of decoded text in the main window. All three lines will show the same behavior, setting Rx frequency to that of the selected message and leaving Tx frequency unchanged. To change both Rx and Tx frequencies, hold **Ctrl** down when double-clicking.



To avoid QRM from competing callers, it is frequently desirable to answer a CQ on a different frequency from that of the CQing station. Choose a Tx frequency that appears to be not in use. The same is true when you tail-end another QSO.



The FT8 decoder can often copy several overlapping signals at nearly the same frequency. Keyboard shortcuts **Shift+F11** and **Shift+F12** provide an easy way to move your Tx frequency down or up in 60 Hz steps.



Further helpful tips on FT8 operating procedures are available [here](http://www.physics.princeton.edu/pulsar/K1JT/FT8_Operating_Tips.pdf)  
([http://www.physics.princeton.edu/pulsar/K1JT/FT8\\_Operating\\_Tips.pdf](http://www.physics.princeton.edu/pulsar/K1JT/FT8_Operating_Tips.pdf)). Thanks to ZL2IFB!



When finished with this Tutorial, don't forget to re-enter your own callsign as **My Call** on the **Settings | General** tab.

## 7. Making QSOs

### 7.1. Standard Exchange

By longstanding tradition, a minimally 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, structured messages. The process works best if you use these formats and follow standard operating practices. The recommended basic QSO goes something like this:

CQ K1ABC FN42		#K1ABC calls CQ
	K1ABC G0XYZ I091	#G0XYZ answers
G0XYZ K1ABC -19		#K1ABC sends report
	K1ABC G0XYZ R-22	#G0XYZ sends R+report
G0XYZ K1ABC RRR		#K1ABC sends RRR
	K1ABC G0XYZ 73	#G0XYZ sends 73

**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, R plus a signal report, or the final acknowledgements RRR or 73. These messages are compressed and encoded in a highly efficient and reliable way. In uncompressed form (as displayed on-screen) they may contain as many as 22 characters.

**Signal reports** are specified as signal-to-noise ratio (S/N) in dB, using a standard reference noise bandwidth of 2500 Hz. Thus, in the example message above, K1ABC is telling G0XYZ that his signal is 19 dB below the noise power in bandwidth 2500 Hz. In the message at 0004, G0XYZ acknowledges receipt of that report and responds with a -22 dB signal report. JT65 reports are constrained to lie in the range -30 to -1 dB, and values are significantly compressed above about -10 dB. JT9 supports the extended range -50 to +49 dB and assigns more reliable numbers to relatively strong signals.



Signals become visible on the waterfall around  $S/N = -26$  dB and audible (to someone with very good hearing) around -15 dB. Thresholds for decodability are around -20 dB for FT8, -23 dB for JT4, -25 dB for JT65, -27 dB for JT9.



Several options are available for circumstances where fast QSOs are desirable. Double-click the **Tx1** control under *Now* or *Next* to toggle use of the Tx2 message rather than Tx1 to start a QSO. Similarly, double-click the **Tx4** control to toggle between sending **RRR** and **RR73** in that message. The **RR73** message should be used only if you are reasonably confident that no repetitions will be required.

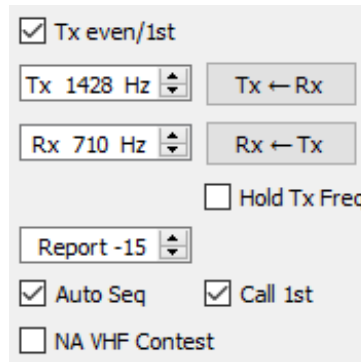
### 7.2. Free-Text Messages

Users often add some friendly chit-chat at the end of a QSO. Free-format messages such as "TNX ROBERT 73" or "5W VERT 73 GL" are supported, up to a maximum of 13 characters, including spaces. In general you should avoid the character / in free-text messages, as the program may then try to interpret your construction as part of a compound

callsign. It should be obvious that the JT4, JT9, and JT65 protocols are not designed or well suited for extensive conversations or rag-chewing.

### 7.3. Auto-Sequencing

The slow modes JT4, JT9, JT65, and QRA64 allow nearly 10 seconds at the end of each one-minute receiving sequence — enough time for you to inspect decoded messages and decide how to reply. The 15-second T/R cycles of FT8 allow only about two seconds for this task, which is often not enough. For this reason a basic auto-sequencing feature is offered. Check **Auto Seq** on the main window to enable this feature:



The screenshot shows the 'Auto Seq' settings in WSJT-X. It includes a checked box for 'Tx even/1st', frequency offset fields for 'Tx 1428 Hz' and 'Rx 710 Hz', buttons for 'Tx ← Rx' and 'Rx ← Tx', an unchecked 'Hold Tx Freq' box, a 'Report -15' field, and checked boxes for 'Auto Seq' and 'Call 1st'. The 'NA VHF Contest' box is unchecked.

When calling CQ you may also choose to check the box **Call 1st**. *WSJT-X* will then respond automatically to the first decoded responder to your CQ.



When **Auto-Seq** is enabled the program de-activates **Enable Tx** at the end of each QSO. It is not intended that *WSJT-X* should make fully automated QSOs.

### 7.4. VHF Contest Mode

A special **NA VHF Contest** mode can be activated for FT8 and MSK144 modes by checking a box on the main window. This mode is configured especially for contests in which four-character grid locators are the required exchange. When **NA VHF Contest** mode is active, the standard QSO sequence looks like this:

```
CQ K1ABC FN42
K1ABC W9XYZ EN37
W9XYZ K1ABC R FN42
K1ABC W9XYZ RRR
W9XYZ K1ABC 73
```

In contest circumstances K1ABC might choose to call CQ again rather than sending 73 for his third transmission.



Do not use VHF Contest Mode on an HF band or in conditions where worldwide propagation is available. See Protocol Specifications for further details.

## 7.5. Compound Callsigns

Compound callsigns such as xx/K1ABC or K1ABC/x are handled in one of two possible ways:

### *Messages containing Type 1 compound callsigns*

A list of about 350 of the most common prefixes and suffixes can be displayed from the **Help** menu. A single compound callsign involving one item from this list can be used in place of the standard third word of a message (normally a locator, signal report, RRR, or 73). The following examples are all acceptable messages containing **Type 1** compound callsigns:

```
CQ ZA/K1ABC
CQ K1ABC/4
ZA/K1ABC G0XYZ
G0XYZ K1ABC/4
```

The following messages are *not* valid, because a third word is not permitted in any message containing a **Type 1** compound callsign:

```
ZA/K1ABC G0XYZ -22      #These messages are invalid; each would
G0XYZ K1ABC/4 73        # be sent without its third "word"
```

A QSO between two stations using **Type 1** compound-callsign messages might look like this:

```
CQ ZA/K1ABC              ZA/K1ABC G0XYZ
G0XYZ K1ABC -19          K1ABC G0XYZ R-22
G0XYZ K1ABC RRR          K1ABC G0XYZ 73
```

Notice that the full compound callsign is sent and received in the first two transmissions. After that, the operators omit the add-on prefix or suffix and use the standard structured messages.

### *Type 2 Compound-Callsign Messages*

Prefixes and suffixes *not* found in the displayable short list are handled by using **Type 2** compound callsigns. In this case the compound callsign must be the second word in a two- or three-word message, and the first word must be CQ, DE, or QRZ. Prefixes can be 1 to 4 characters, suffixes 1 to 3 characters. A third word conveying a locator, report, RRR, or 73 is permitted. The following are valid messages containing **Type 2** compound callsigns:

```
CQ W4/G0XYZ FM07
QRZ K1ABC/VE6 D033
DE W4/G0XYZ FM18
DE W4/G0XYZ -22
DE W4/G0XYZ R-22
DE W4/G0XYZ RRR
DE W4/G0XYZ 73
```

In each case, the compound callsign is treated as **Type 2** because the add-on prefix or suffix is *not* one of those in the fixed list. Note that a second callsign is never permissible in these messages.



During a transmission your outgoing message is displayed in the first label on the **Status Bar** and shown exactly as another station will receive it. You can check to see that you are actually transmitting the message you wish to send.

QSOs involving **Type 2** compound callsigns might look like either of the following sequences:

```
CQ K1ABC/VE1 FN75
G0XYZ K1ABC -19
G0XYZ K1ABC RRR
K1ABC G0XYZ I091
K1ABC G0XYZ R-22
K1ABC/VE1 73
```

```
CQ K1ABC FN42
G0XYZ K1ABC -19
G0XYZ K1ABC RRR
DE G0XYZ/W4 FM18
K1ABC G0XYZ R-22
DE G0XYZ/W4 73
```

Operators with a compound callsign use its full form when calling CQ and possibly also in a 73 transmission, as may be required by licensing authorities. Other transmissions during a QSO may use the standard structured messages without callsign prefix or suffix.



If you are using a compound callsign, you may want to experiment with the option **Message generation for type 2 compound callsign holders** on the **Settings | General** tab, so that messages will be generated that best suit your needs.

## 7.6. Pre-QSO Checklist

Before attempting your first QSO with one of the WSJT modes, be sure to go through the Basic Operating Tutorial above as well as 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 to UTC within  $\pm 1$  s
- Audio input and output devices configured for sample rate 48000 Hz, 16 bits
- Radio set to **USB** (upper sideband) mode
- Radio filters centered and set to widest available passband (up to 5 kHz).



Remember that in many circumstances FT8, JT4, JT9, JT65, and WSPR do not require high power. Under most HF propagation conditions, QRP is the norm.

## 8. VHF+ Features

WSJT-X v1.8 supports a number of features designed for use on the VHF and higher bands. These features include:

- **FT8**, a mode designed for making fast QSOs with weak, fading signals
- **JT4**, a mode particularly useful for EME on the microwave bands
- **JT9** fast modes, useful for scatter propagation on VHF bands
- **QRA64**, a mode for EME using a “Q-ary Repeat Accumulate” code, a low-density parity-check (LDPC) code using a 64-character symbol alphabet
- **MSK144**, a mode for meteor scatter using a binary LDPC code and Offset Quadrature Phase-Shift Keying (OQPSK). The resulting waveform is sometimes called Minimum Shift Keying (MSK).
- **ISCAT**, intended for aircraft scatter and other types of scatter propagation
- **Echo** mode, for detecting and measuring your own lunar echoes
- **Doppler tracking**, which becomes increasingly important for EME on bands above 1.2 GHz.

### 8.1. VHF Setup

To activate the VHF-and-up features:

- On the **Settings | General** tab check **Enable VHF/UHF/Microwave features** and **Single decode**.
- For EME, check **Decode at t = 52 s** to allow for extra path delay on received signals.
- If you will use automatic Doppler tracking and your radio accepts frequency-setting commands while transmitting, check **Allow Tx frequency changes while transmitting**. Transceivers known to permit such changes include the IC-735, IC-756 Pro II, IC-910-H, FT-847, TS-590S, TS-590SG, TS-2000 (with Rev 9 or later firmware upgrade), Flex 1500 and 5000, HPSPDR, Anan-10, Anan-100, and KX3. To gain full benefit of Doppler tracking your radio should allow frequency changes under CAT control in 1 Hz steps.

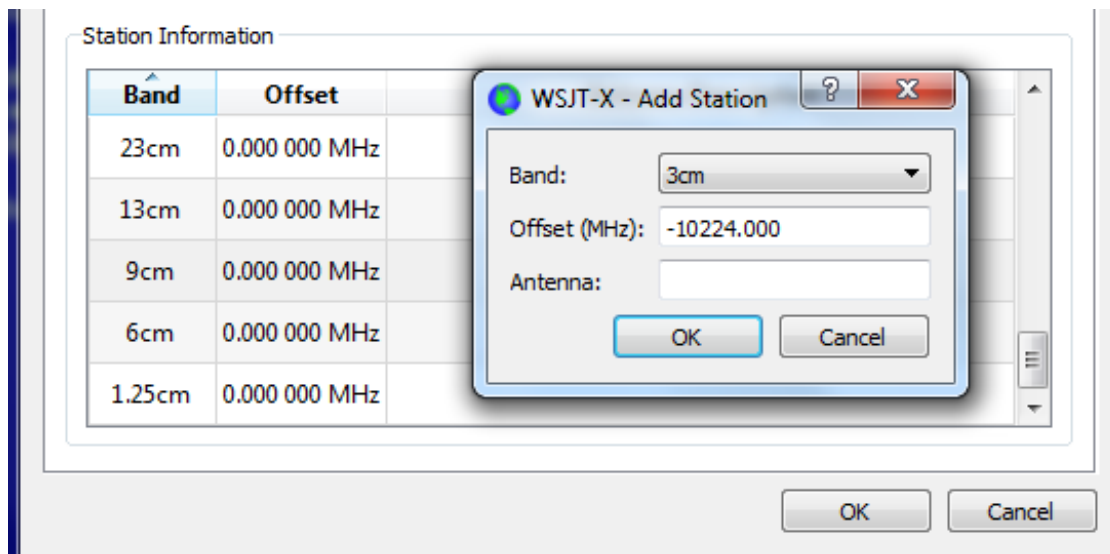


If your radio does not accept commands to change frequency while transmitting, Doppler tracking will be approximated with a single Tx frequency adjustment before a transmission starts, using a value computed for the middle of the Tx period.

- On the **Radio** tab select **Split Operation** (use either **Rig** or **Fake It**; you may need to experiment with both options to find one that works best with your radio).
- On the right side of the main window select **Tab 1** to present the traditional format for entering and choosing Tx messages.

The main window will reconfigure itself as necessary to display controls supporting the features of each mode.

- If you are using transverters, set appropriate frequency offsets on the **Settings | Frequencies** tab. Offset is defined as (transceiver dial reading) minus (on-the-air frequency). For example, when using a 144 MHz radio at 10368 MHz, **Offset (MHz) = (144 - 10368) = -10224.000**. If the band is already in the table, you can edit the offset by double clicking on the offset field itself. Otherwise a new band can be added by right clicking in the table and selecting **Insert**.



- On the **View** menu, select **Astronomical data** to display a window with important information for tracking the Moon and performing automatic Doppler control. The right-hand portion of the window becomes visible when you check **Doppler tracking**.

2017 Aug 03  
UTC: 13:38:39  
Az: 355.1  
El: -68.7  
SelfDop: -81  
Width: 140  
Delay: 2.74  
DxAz: 323.2  
DxEI: -57.3  
DxDop: -3115  
DxWid: 122  
Dec: -19.1  
SunAz: 101.9  
SunEl: 40.2  
Freq: 10368  
Tsky: 3  
Dpol: -21.4  
MNR: 2.7  
Dgrd: -2.6

☒ Doppler tracking

Doppler tracking

☐ Full Doppler to DX Grid  
☐ Receive only  
☐ Constant frequency on Moon  
☒ None

Sked frequency

Rx: 10,368.200 000  
Tx: 10,368.200 000

Press and hold the CTRL key to adjust the sked frequency manually with the rig's VFO dial or enter frequency directly into the band entry field on the main window.

Single-Period Decodes

UTC	dB	DT	Freq	Message

Log QSO Stop Monitor Erase

3cm S 10,368.200 000 ☐ Tx even/1st

Az: 305 1668 km

Lookup Add

2017 Aug 03 13:38:39 ☒ Sh

JT4F

Three different types of Doppler tracking are provided:

- Select **Full Doppler to DX Grid** if you know your QSO partner's locator and he/she will not be using any Doppler control.
- Select **Receive only** to enable EME Doppler tracking of your receive frequency to a specific locator. Your Tx frequency will remain fixed.
- Select **Constant frequency on Moon** to correct for your own one-way Doppler shift to or from the Moon. If your QSO partner does the same thing, both stations will have the required Doppler compensation. Moreover, anyone else using this option will hear both of you without the need for manual frequency changes.
- See Astronomical Data for details on the quantities displayed in this window.

## 8.2. JT4

JT4 is designed especially for EME on the microwave bands, 2.3 GHz and above.

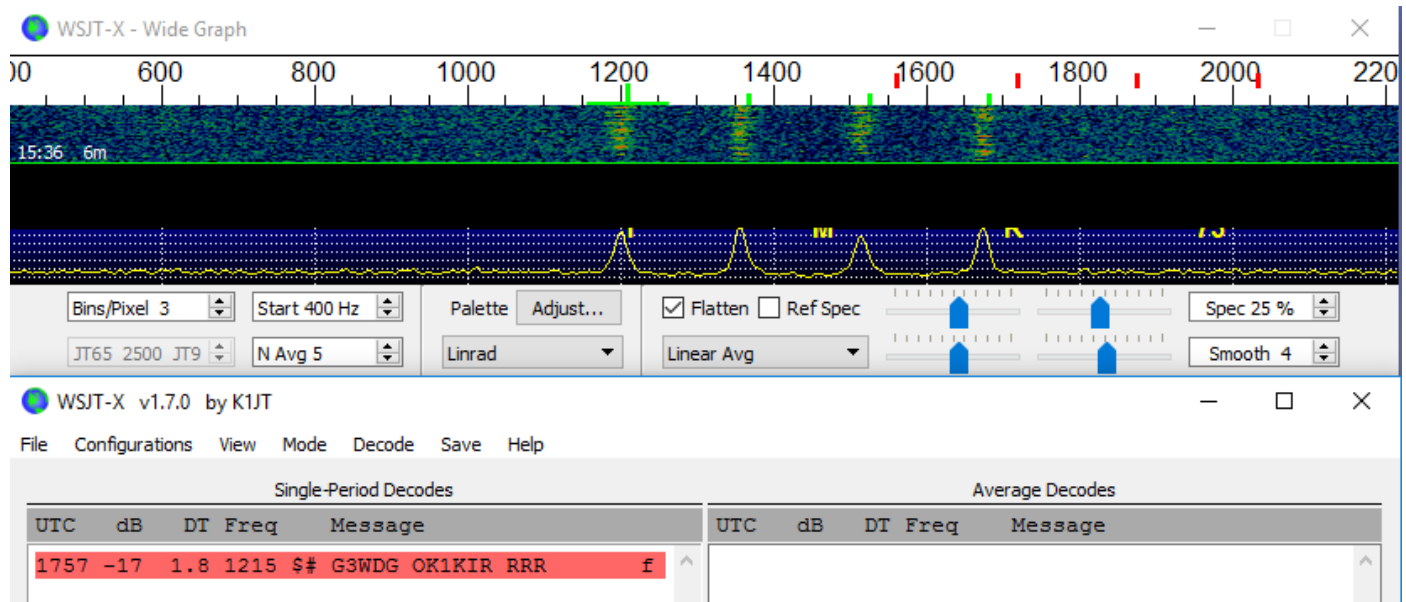
- Select **JT4** from the **Mode** menu. The central part of the main window will look something like this:

☐ Tx even/1st  
 Tx 1000 Hz    Tx ← Rx  
 Rx 1000 Hz    Rx ← Tx  
 F Tol 100    ☐ Hold Tx Freq  
 Report -15    Submode F  
 Sync 0  
☒ Sh    ☐ Tx6

- Select the desired **Submode**, which determines the spacing of transmitted tones. Wider spacings are used on the higher microwave bands to allow for larger Doppler spreads. For example, submode JT4F is generally used for EME on the 5.7 and 10 GHz bands.
- For EME QSOs some operators use short-form JT4 messages consisting of a single tone. To activate automatic generation of these messages, check the box labeled **Sh**. This also enables the generation of a single tone at 1000Hz by selecting Tx6, to assist in finding signals initially. The box labeled **Tx6** toggles the Tx6 message from 1000Hz to 1250Hz to indicate to the other station that you are ready to receive messages.
- Select **Deep** from the **Decode** menu. You may also choose to **Enable averaging** over successive transmissions and/or **Enable deep search** (correlation decoding).

Decode    Save    Tools    Help  
 Fast  
 Normal  
☒ Deep  
☒ Enable AP

The following screen shot shows one transmission from a 10 GHz EME QSO using submode JT4F.

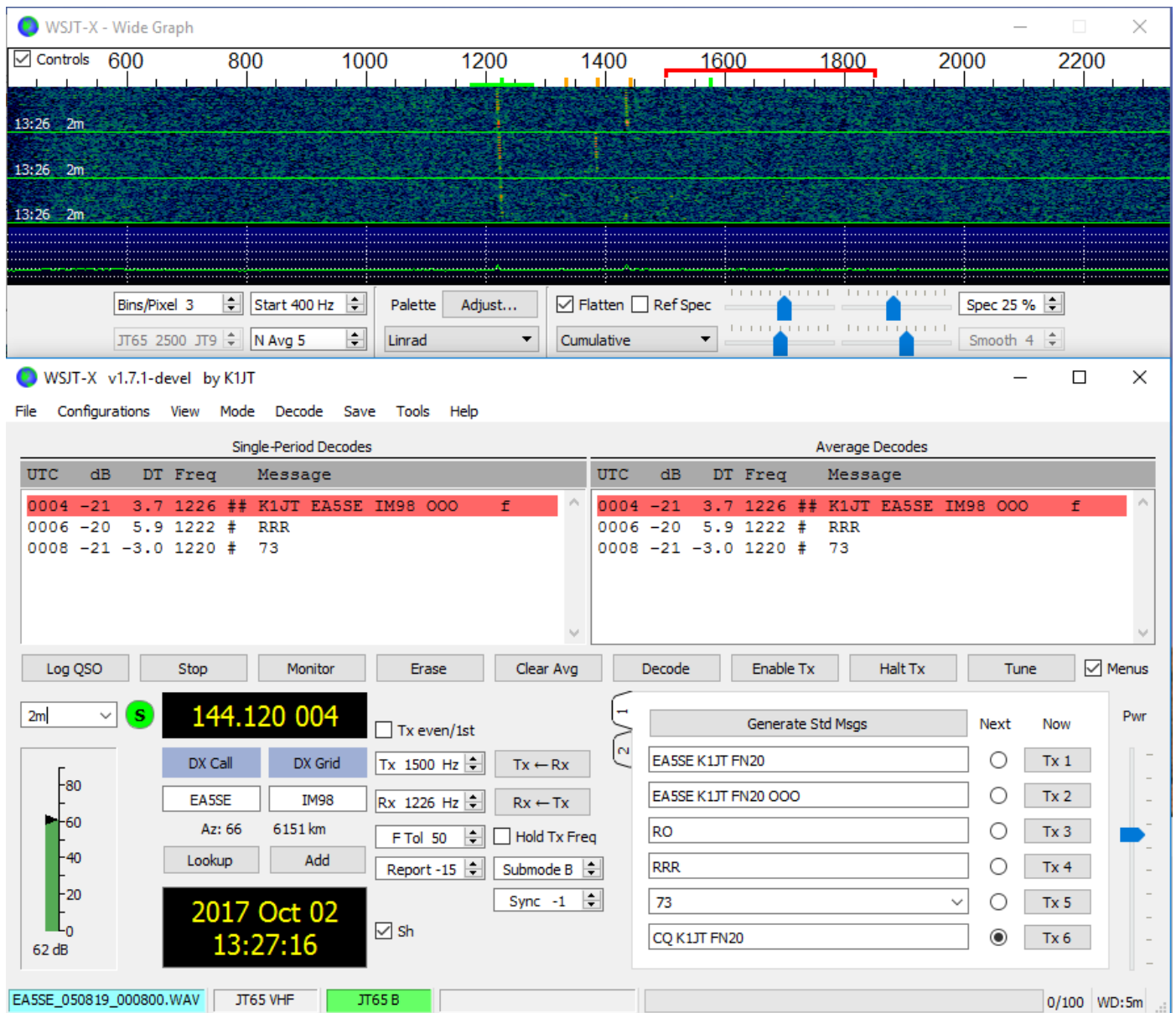


### 8.3. JT65

In many ways JT65 operation on VHF and higher bands is similar to HF usage, but a few important differences should be noted. Typical VHF/UHF operation involves only a single signal (or perhaps two or three) in the receiver passband. You may find it best to check **Single decode** on the **Settings** → **General** tab. There will be little need for **Two pass decoding** on the **Advanced** tab. With VHF features enabled the JT65 decoder will respond to special message formats often used for EME: the OOO signal report and two-tone shorthand messages for RO, RRR, and 73. These messages are always enabled for reception; they will be automatically generated for transmission if you check the shorthand message box **Sh**.

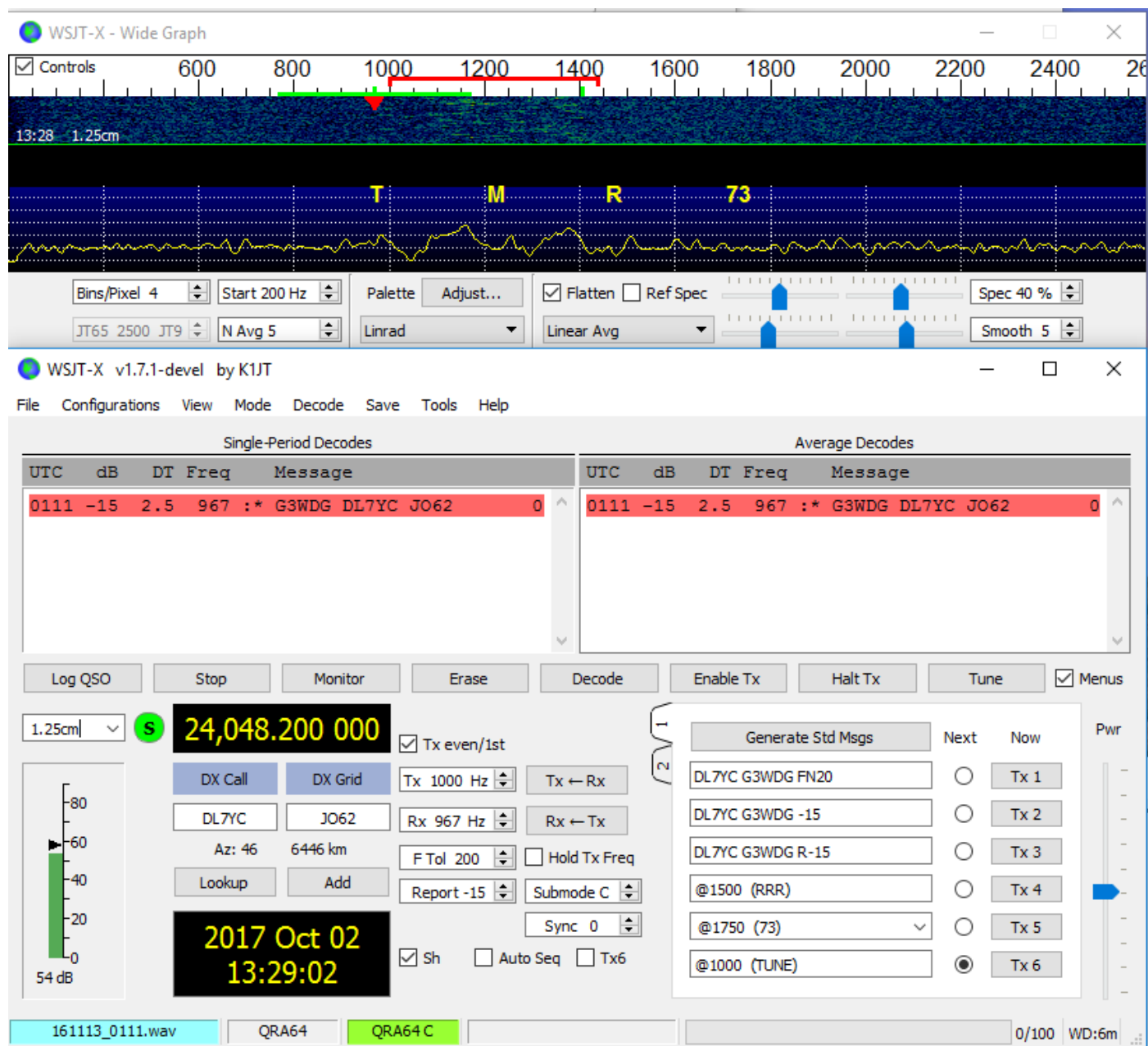
Be sure to check **Deep** on the **Decode** menu; you may optionally include **Enable averaging** and **Deep search**.

The following screen shot shows three transmissions from a 144 MHz EME QSO using submode JT65B and shorthand messages. Take note of the colored tick marks on the Wide Graph frequency scale. The green marker at 1220 Hz indicates the selected QSO frequency (the frequency of the JT65 Sync tone) and the **F ToI** range. A green tick at 1575 Hz marks the frequency of the highest JT65 data tone. Orange markers indicate the frequency of the upper tone of the two-tone signals for RO, RRR, and 73.



## 8.4. QRA64

QRA64 is designed for EME on VHF and higher bands; its operation is generally similar to JT4 and JT65. The following screen shot shows an example of a QRA64C transmission from DL7YC recorded at G3WDG over the EME path at 24 GHz. Doppler spread on the path was 78 Hz, so although the signal is reasonably strong its tones are broadened enough to make them hard to see on the waterfall. The triangular red marker below the frequency scale shows that the decoder has achieved synchronization with a signal at approximately 967 Hz.



The QRA64 decoder makes no use of a callsign database. Instead, it takes advantage of *a priori* (AP) information such as one's own callsign and the encoded form of message word CQ. In normal usage, as a QSO progresses the available AP information increases to include the callsign of the station being worked and perhaps also his/her 4-digit grid locator. The decoder always begins by attempting to decode the full message using no AP information. If this attempt fails, additional attempts are made using available AP information to provide initial hypotheses about the message content. At the end of each iteration the decoder computes the extrinsic probability of the most likely value for each of the message's 12 six-bit information symbols. A decode is declared only when the total probability for all 12 symbols has converged to an unambiguous value very close to 1.



For EME QSOs some operators use short-form QRA64 messages consisting of a single tone. To activate automatic generation of these messages, check the box labeled **Sh**. This also enables the generation of a single tone at 1000Hz by selecting Tx6, to assist in finding signals initially, as the QRA64 tones are often not visible on the waterfall. The box labeled **Tx6** switches the Tx6 message from 1000Hz to 1250Hz to indicate to the other station that you are ready to receive messages.



QRA64 is different from JT65 in that the decoder attempts to find and decode only a single signal in the receiver passband. If many signals are present you may be able to decode them by double-clicking on the lowest tone of each one in the waterfall.



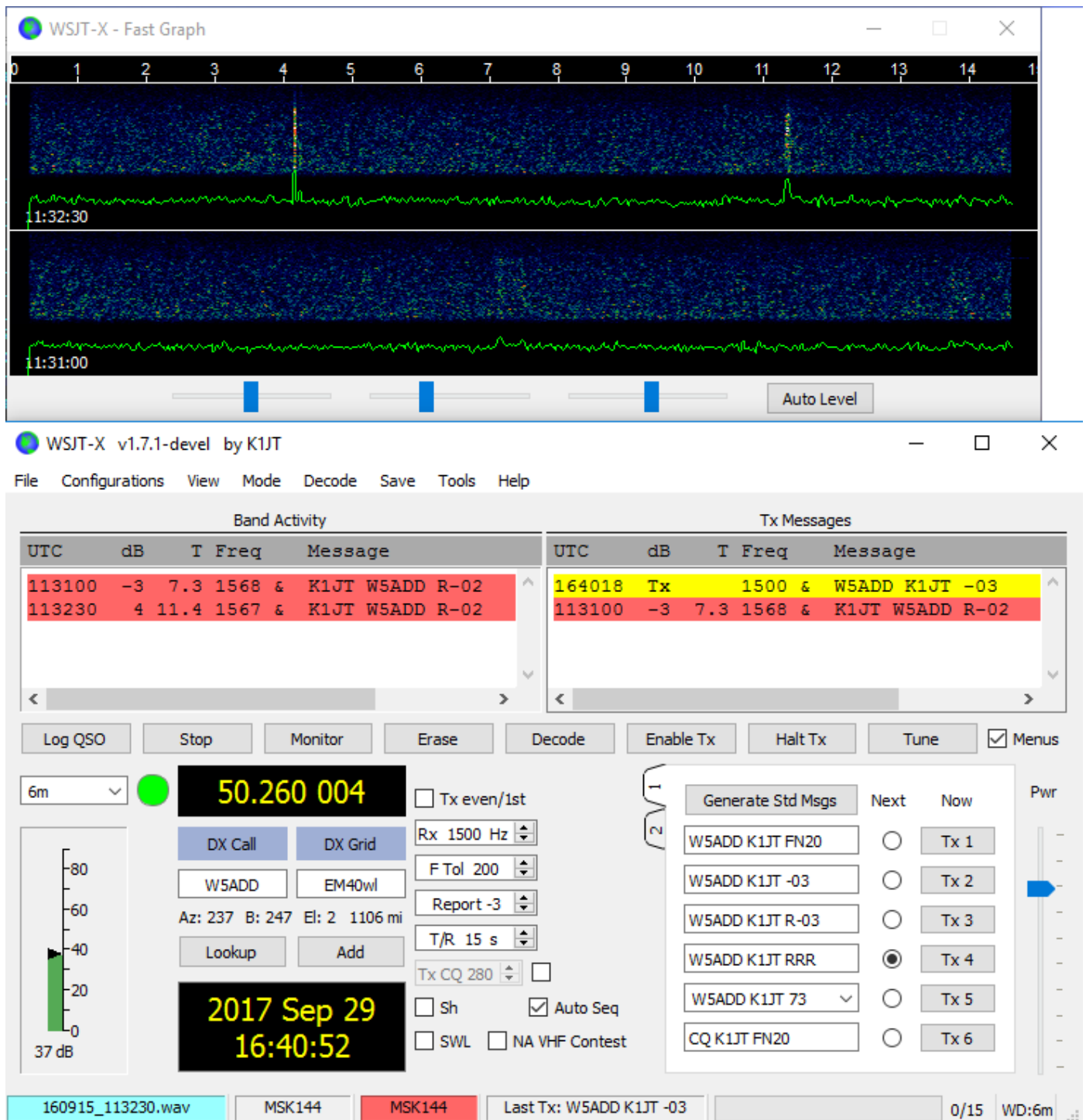
G3WDG has prepared a more detailed tutorial on using [QRA64 for microwave EME](http://physics.princeton.edu/pulsar/K1JT/QRA64_EME.pdf) ([http://physics.princeton.edu/pulsar/K1JT/QRA64\\_EME.pdf](http://physics.princeton.edu/pulsar/K1JT/QRA64_EME.pdf)).

## 8.5. ISCAT

ISCAT is a useful mode for signals that are weak but more or less steady in amplitude over several seconds or longer. Aircraft scatter at 10 GHz is a good example. ISCAT messages are free-format and may have any length from 1 to 28 characters. This protocol includes no error-correction facility.

## 8.6. MSK144

Meteor-scatter QSOs can be made any time on the VHF bands at distances up to about 2100 km (1300 miles). Completing a QSO takes longer in the evening than in the morning, longer at higher frequencies, and longer at distances close to the upper limit. But with patience, 100 Watts or more, and a single yagi it can usually be done. The following screen shot shows two 15-second MSK144 transmissions from W5ADD during a 50 MHz QSO with K1JT, at a distance of about 1800 km (1100 mi). The decoded segments have been marked on the **Fast Graph** spectral display.

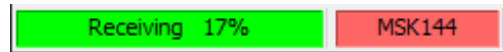


Unlike other *WSJT-X* modes, the MSK144 decoder operates in real time during the reception sequence. Decoded messages will appear on your screen almost as soon as you hear them.

To configure *WSJT-X* for MSK144 operation:

- Select **MSK144** from the **Mode** menu.

- Select **Fast** from the **Decode** menu.
- Set the audio receiving frequency to **Rx 1500 Hz**.
- Set frequency tolerance to **F Tol 100**.
- Set the **T/R** sequence duration to 15 s.
- To match decoding depth to your computer's capability, click **Monitor** (if it's not already green) to start a receiving sequence. Observe the percentage figure displayed on the *Receiving* label in the Status Bar:



- The displayed number (here 17%) indicates the fraction of available time being used for execution of the MSK144 real-time decoder. If this number is well below 100% you may increase the decoding depth from **Fast** to **Normal** or **Deep**, and increase **F Tol** from 100 to 200 Hz.



Most modern multi-core computers can easily handle the optimum parameters **Deep** and **F Tol 200**. Older and slower machines may not be able to keep up at these settings; at the **Fast** and **Normal** settings there will be a small loss in decoding capability (relative to **Deep**) for the weakest pings.

- T/R sequences of 15 seconds or less requires selecting your transmitted messages very quickly. Check **Auto Seq** to have the computer make the necessary decisions automatically, based on the messages received.
- For operation at 144 MHz or above you may find it helpful to use short-format **Sh** messages for Tx3, Tx4, and Tx5. These messages are 20 ms long, compared with 72 ms for full-length MSK144 messages. Their information content is a 12-bit hash of the two callsigns, rather than the callsigns themselves, plus a 4-bit numerical report, acknowledgment (RRR), or sign-off (73). Only the intended recipient can decode short-messages. They will be displayed with the callsigns enclosed in <> angle brackets, as in the following model QSO

```
CQ K1ABC FN42
W9XYZ K1ABC +02
<W9XYZ K1ABC> RRR
K1ABC W9XYZ EN37
<K1ABC W9XYZ> R+03
<K1ABC W9XYZ> 73
```



There is little or no advantage to using MSK144 **Sh** messages at 50 or 70 MHz. At these frequencies, most pings are long enough to support standard messages — which have the advantage of being readable by anyone listening in.

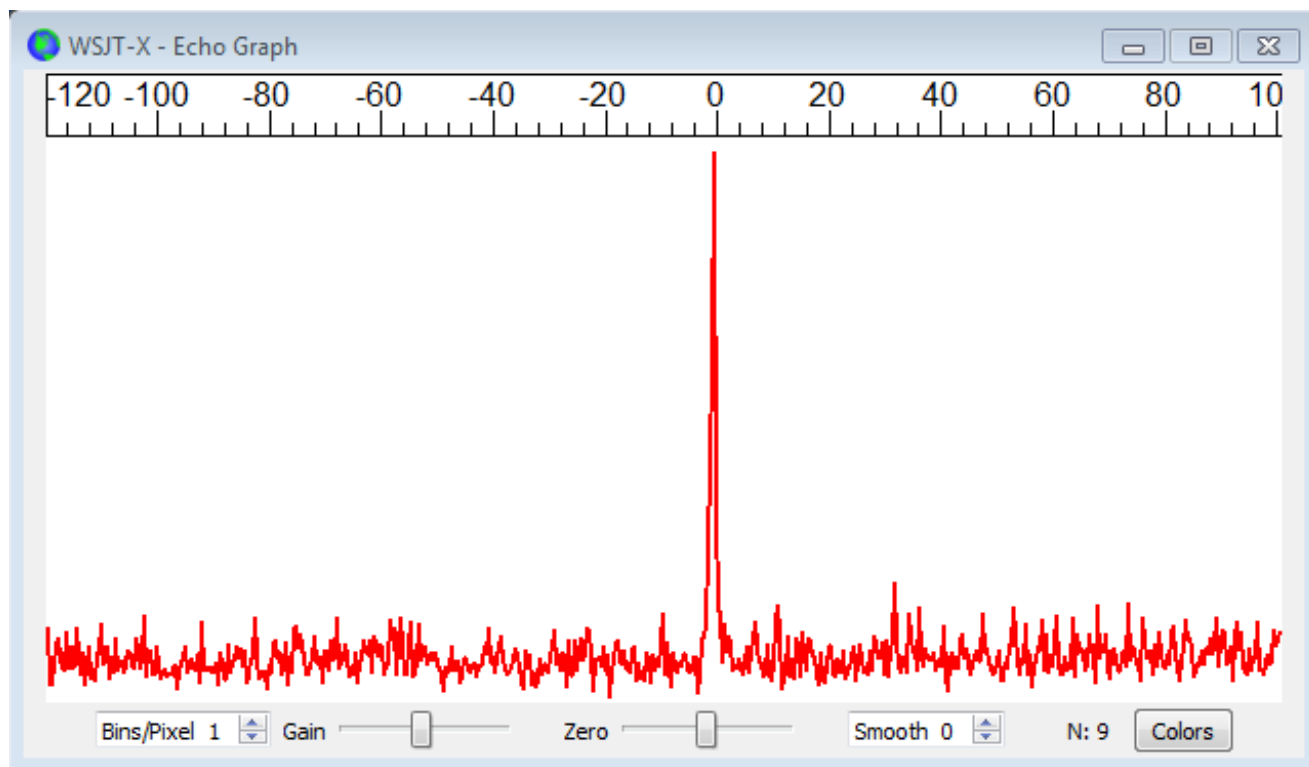
## 8.7. Echo Mode

**Echo** mode allows you to make sensitive measurements of your own lunar echoes even when they are too weak to be heard. Select **Echo** from the **Mode** menu, aim your antenna at the moon, pick a clear frequency, and toggle click **Tx Enable**. *WSJT-X* will then cycle through the following loop every 6 seconds:

1. Transmit a 1500 Hz fixed tone for 2.3 s
2. Wait about 0.2 s for start of the return echo
3. Record the received signal for 2.3 s
4. Analyze, average, and display the results
5. Repeat from step 1

To make a sequence of echo tests:

- Select **Echo** from the **Mode** menu.
- Check **Doppler tracking** and **Constant frequency on the Moon** on the Astronomical Data window.
- Be sure that your rig control has been set up for *Split Operation*, using either **Rig** or **Fake It** on the **Settings | Radio** tab.
- Click **Enable Tx** on the main window to start a sequence of 6-second cycles.
- *WSJT-X* calculates and compensates for Doppler shift automatically. As shown in the screen shot below, when proper Doppler corrections have been applied your return echo should always appear at the center of the plot area on the Echo Graph window.



The 'WSJT-X - Astronomical Data' window contains the following information:

**2016 Oct 25**  
**UTC:** 16:09:05  
**Az:** 243.1  
**El:** 39.1  
**SelfDop:** -275  
**Width:** 2  
**Delay:** 2.60  
**DxAz:** 240.9  
**DxEl:** 48.3  
**DxDop:** -266  
**DxWid:** 2  
**Dec:** 8.1  
**SunAz:** 169.8  
**SunEl:** 36.7  
**Freq:** 144  
**Tsky:** 201  
**Dpol:** -4.1  
**MNR:** 0.1  
**Dgrd:** -1.7

**Doppler tracking**

- ☐ Full Doppler to DX Grid
- ☐ Receive only
- ☒ Constant frequency on Moon
- ☐ None

**Sked frequency**

**Rx:** 144.107 000  
**Tx:** 144.107 000

Press and hold the CTRL key to adjust the sked frequency manually with the rig's VFO dial or enter directly into the band edit.

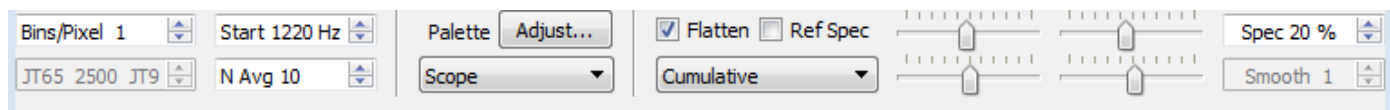
☒ Doppler tracking

## 8.8. VHF+ Sample Files

Sample recordings typical of QSOs using the VHF/UHF/Microwave modes and features of *WSJT-X* are available for download. New users of the VHF-and-up features are strongly encouraged to practice decoding the signals in these files.

## 9. WSPR Mode

- Select **WSPR** from the **Mode** menu. The main window will reconfigure itself to the WSPR interface, removing some controls not used in WSPR mode.
- Set the Wide Graph controls as suggested below.



- Use the mouse to drag the width and height of the main window to the desired size.
- Select an active WSPR frequency (for example, 10.1387 or 14.0956 MHz).



If you will transmit in the 60 m band, be sure to choose a frequency that conforms with your local regulations.

- Click **Monitor** to start a 2-minute WSPR receiving period.
- If you will be transmitting as well as receiving, select a suitable value for **Tx Pct** (average percentage of 2-minute sequences devoted to transmitting) and activate the **Enable Tx** button. Transmitting periods are also 2 minutes duration, and will occur randomly in time to reduce the chance of clashing with other stations you may be monitoring.
- Select your Tx power (in dBm) from the drop-down list.

### 9.1. Band Hopping

WSPR mode allows those with CAT-controlled radios to investigate propagation on many bands without user intervention. Coordinated hopping enables a sizable group of stations around the world to move together from band to band, thereby maximizing the chances of identifying open propagation paths.

- To enable automatic band hopping, check the **Band Hopping** box on the main window.
- Click **Schedule** to open the **WSPR Band Hopping** window, and select the bands you wish to use at each time of day.



- Band-switching occurs after each 2-minute interval. Preferred bands are identified with time slots in a repeating 20-minute cycle, according to the following table:

Band:	160	80	60	40	30	20	17	15	12	10
UTC minute:	00	02	04	06	08	10	12	14	16	18
	20	22	24	26	28	30	32	34	36	38
	40	42	44	46	48	50	52	54	56	58

- If the preferred band is not active according to your band-hopping schedule, a band will be selected at random from among the active bands.
- If the box labeled **Tune** is checked for a particular band, *WSJT-X* transmits an unmodulated carrier for several seconds just after switching to that band and before the normal Rx or Tx period starts. This feature can be used to activate an automatic antenna tuner (ATU) to tune a multi-band antenna to the newly selected band.
- Depending on your station and antenna setup, band changes might require other switching besides retuning your radio. To make this possible in an automated way, whenever *WSJT-X* executes a successful band-change command to a CAT-controlled radio, it looks for a file named `user_hardware.bat`, `user_hardware.cmd`, `user_hardware.exe`, or `user_hardware` in the working directory. If one of these is found, *WSJT-X* tries to execute the command

```
user_hardware nnn
```

- In the above command `nnn` is the band-designation wavelength in meters. You must write your own program, script, or batch file to do the necessary switching at your station.

The following screen shot is an example of WSPR operation with band hopping enabled:



WSJT-X v1.7.0 by K1JT

File
Configurations
View
Mode
Decode
Save
Help

UTC	dB	DT	Freq	Drift	Call	Grid	dBm	km	
0146	-22	0.1	7.040064	0	I2GPG	JN45	30	6534	
0146	-12	0.2	7.040094	0	M0XDC	JO01	37	5728	
0146	-18	0.0	7.040124	0	IK2AOS	JN45	23	6534	
0146	-15	-2.8	7.040137	0	EA5CYA	IM99	23	6102	
0146	-27	0.3	7.040162	0	DL8YCA	JO31	27	6116	
0146	-23	0.1	7.040170	0	K9AN	EN50	33	1215	
0146	-18	0.7	7.040172	0	AG6NS	CM97	27	3984	
0146	-4	0.2	7.040183	0	NV00	EM28	37	1758	
----- 30m									
0148	-21	-0.0	10.140200	0	KC5MO	EM10	23	2293	
0150	----- Transmitting WSPR -----							20m	
----- 160m									
0152	4	0.0	1.838081	0	W8AC	EN91	37	549	
0152	-29	0.0	1.838122	0	KD4RLD	EM95	10	773	
0152	-11	0.2	1.838191	0	K9PAW	EN61	30	1046	
----- 40m									
0154	-8	0.1	7.040036	0	HB9CQK	JN47	33	6433	
0154	-22	0.2	7.040056	0	WA3DNM	FM29	37	97	
0154	-8	0.5	7.040067	0	N6RY	DM13	37	3809	
0154	-8	0.7	7.040089	0	VE3FAL	EN58	37	1454	
0154	7	0.7	7.040092	0	AB4QS	EL88	37	1518	
0154	-10	0.1	7.040094	0	K5CZD	EM32	37	1854	
0154	-14	0.1	7.040110	0	DF5FF	JO40	37	6290	
0154	-1	0.1	7.040118	0	KD6RF	EM22	37	2013	
0154	-21	-0.4	7.040135	0	EA4URA	IN80	20	5900	
0154	-21	0.6	7.040140	0	K3FEF	FN21	37	133	
0154	-22	0.3	7.040145	0	DL2XL/P		23		
0154	-6	0.1	7.040146	0	LZ1UBO	KN12	33	7663	
0154	-17	0.1	7.040168	0	DL2ZQ	JO42	27	6199	
0154	-17	0.7	7.040173	0	AG6NS	CM97	27	3984	
----- 80m									
0156	-21	-0.3	3.594101	0	K4EH	EM73	37	1191	
0156	-28	-0.1	3.594148	0	G0IDE	IO83	37	5403	
0158	----- Transmitting WSPR -----							30m	

Stop

Monitor

Erase

Decode

Enable Tx

Halt Tx

Tune

30m

10.138 700

60+

50

40

30

20

10

0

2016 Oct 24

01:50:12

Tx 1500 Hz

Tx Pct 20 %

Band Hopping

Schedule ...

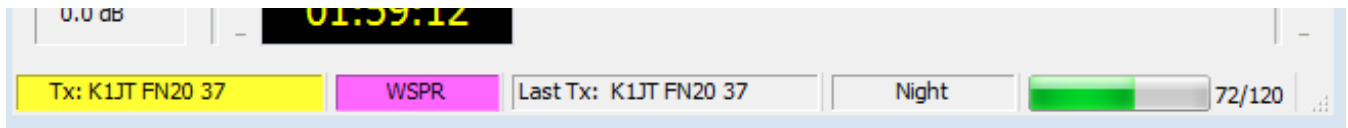
Upload spots

Prefer type 1 messages

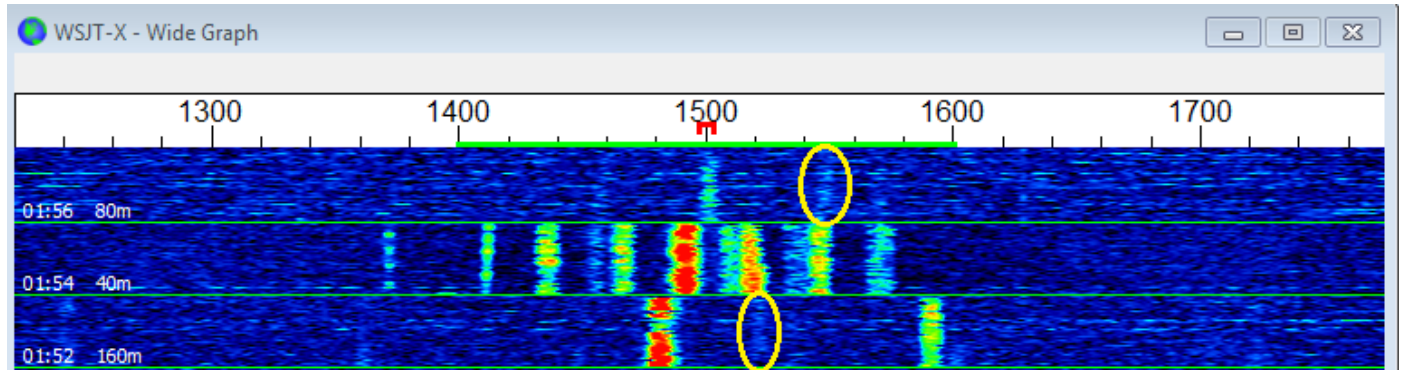
Tx Next

37 dBm 5 W

Pwr



A careful look at the screen shot above illustrates some of the impressive capabilities of the WSPR decoder. For example, look at the decodes at UTC 0152, 0154, and 0156 along with the corresponding minutes from the waterfall display below. Yellow ovals have been added to highlight two isolated signals decoded at -28 and -29 dB in the first and third two-minute interval. At 0154 UTC signals from VE3FAL, AB4QS, and K5CZD fall within a 5 Hz interval near audio frequency 1492 Hz; similarly, K3FEF, DL2XL/P, and LZ1UBO fall within a 6 Hz interval near 1543 Hz. Each of the overlapping signals is decoded flawlessly.

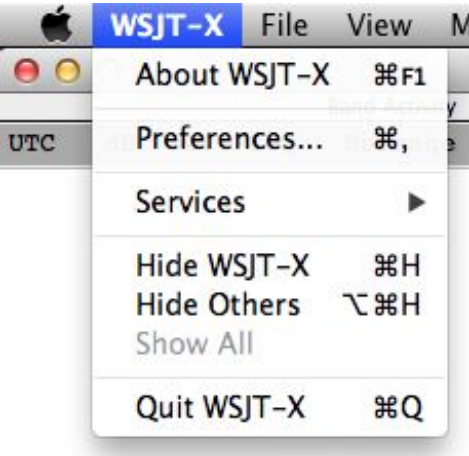


# 10. On-Screen Controls

## 10.1. Menus

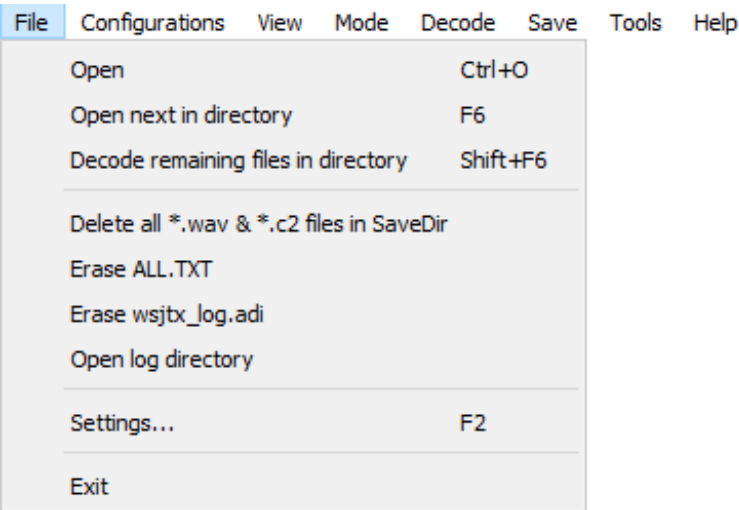
Menus at top of the main window offer many options for configuration and operation. Most of the items are self-explanatory; a few additional details are provided below. Keyboard shortcuts for some frequently used menu items are listed at the right edge of the menu.

### 10.1.1. WSJT-X menu

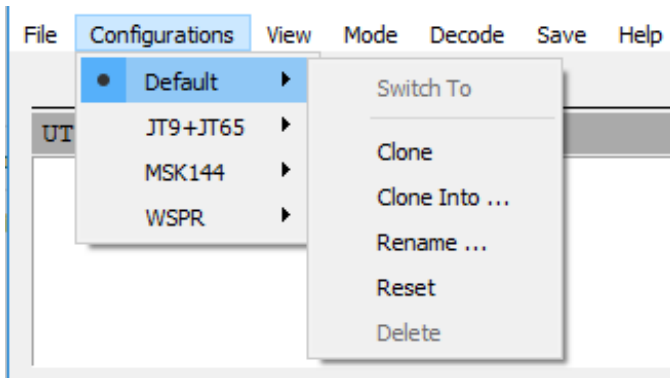


This menu appears on the Macintosh only. **Settings** appears here, labeled as **Preferences**, rather than on the **File** menu. **About WSJT-X** appears here rather than on the **Help** menu.

### 10.1.2. File menu



### 10.1.3. Configuration Menu

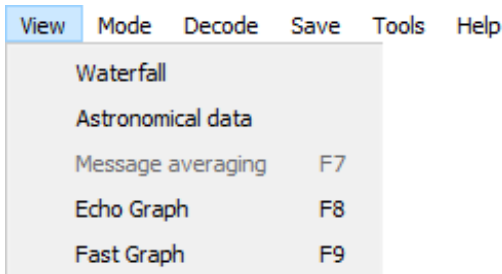


Many users prefer to create and use entries on the **Configurations** menu for switching between modes. Simply **Clone** the **Default** entry, **Rename** it as desired, and then make all desired settings for that configuration. These settings will be restored whenever you select that configuration.

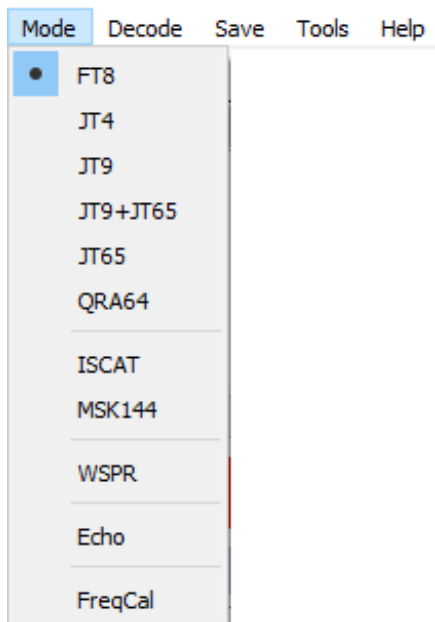
As well as switching between configurations while running *WSJT-X* you can also start the application from the command line in any desired configuration. Use the command-line option `--config <configuration-name>`, or `-c` for short, as in these examples for configurations `FT8` and `Echo` :

```
wsjtx --config FT8
wsjtx -c Echo
```

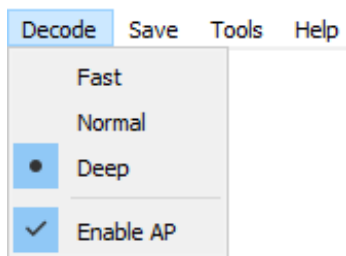
#### 10.1.4. View Menu



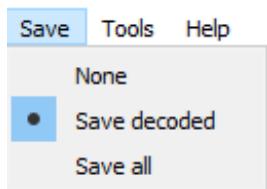
#### 10.1.5. Mode Menu



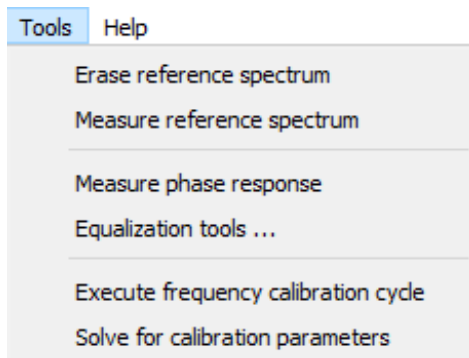
#### 10.1.6. Decode Menu



#### 10.1.7. Save Menu



#### 10.1.8. Tools Menu



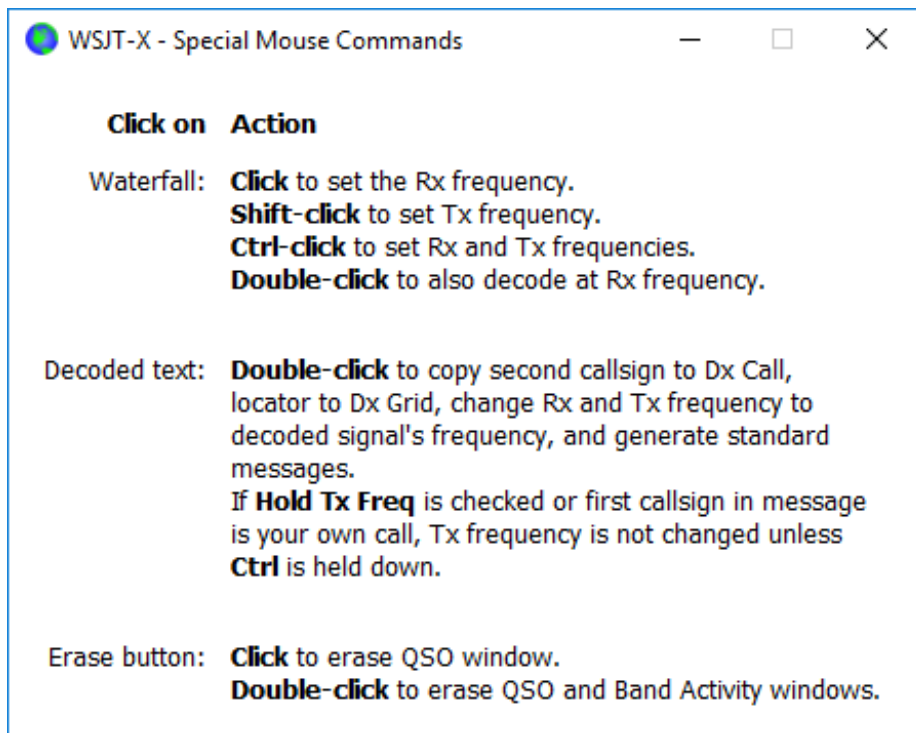
#### 10.1.9. Help Menu

Help	
Release Notes	
Online User Guide	F1
Local User Guide	
Download Samples ...	
<hr/>	
Keyboard shortcuts	F3
Special mouse commands	F5
List of Type 1 prefixes and suffixes	
<hr/>	
Copyright notice	Shift+F1
<hr/>	
About WSJT-X	Ctrl+F1

## Keyboard Shortcuts (F3)

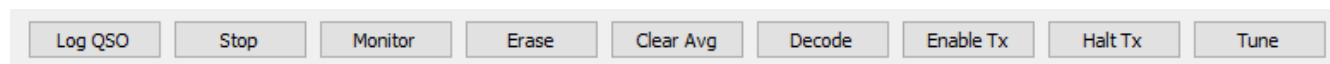
WSJT-X - Keyboard Shortcuts	
<b>F1</b>	Online User's Guide
<b>Shift+F1</b>	Copyright Notice
<b>Ctrl+F1</b>	About WSJT-X
<b>F2</b>	Open settings window
<b>F3</b>	Display keyboard shortcuts
<b>F4</b>	Clear DX Call, DX Grid, Tx messages 1-4
<b>Alt+F4</b>	Exit program
<b>F5</b>	Display special mouse commands
<b>F6</b>	Open next file in directory
<b>Shift+F6</b>	Decode all remaining files in directory
<b>F7</b>	Display Message Averaging window
<b>F11</b>	Move Rx frequency down 1 Hz
<b>Ctrl+F11</b>	Move Rx and Tx frequencies down 1 Hz
<b>Shift+F11</b>	Move Tx frequency down 60 Hz
<b>F12</b>	Move Rx frequency up 1 Hz
<b>Ctrl+F12</b>	Move Rx and Tx frequencies up 1 Hz
<b>Shift+F12</b>	Move Tx frequency up 60 Hz
<b>Alt+1-6</b>	Set now transmission to this number on Tab 1
<b>Ctrl+1-6</b>	Set next transmission to this number on Tab 1
<b>Alt+D</b>	Decode again at QSO frequency
<b>Shift+D</b>	Full decode (both windows)
<b>Ctrl+E</b>	Turn on TX even/1st
<b>Shift+E</b>	Turn off TX even/1st
<b>Alt+E</b>	Erase
<b>Ctrl+F</b>	Edit the free text message box
<b>Alt+G</b>	Generate standard messages
<b>Alt+H</b>	Halt Tx
<b>Ctrl+L</b>	Lookup callsign in database, generate standard messages
<b>Alt+M</b>	Monitor
<b>Alt+N</b>	Enable Tx
<b>Ctrl+O</b>	Open a .wav file
<b>Alt+Q</b>	Log QSO
<b>Alt+S</b>	Stop monitoring
<b>Alt+T</b>	Tune
<b>Alt+V</b>	Save the most recently completed *.wav file

## Special Mouse Commands (F5)



## 10.2. Button Row

The following buttons appear just under the decoded text windows on the main screen:



- **Log QSO** raises a dialog window pre-filled with known information about a QSO you have nearly completed. You can edit or add to this information before clicking **OK** to log the QSO. If you check **Prompt me to log QSO** on the **Settings** → **Reporting** tab, the program will raise the confirmation screen automatically when you send a message containing 73. **Start Date** and **Start Time** are set when you click to send the **Tx 2** or **Tx 3** message, and backed up by one or two sequence lengths, respectively. (Note that the actual start time may have been earlier if repeats of early transmissions were required.) End date and time are set when the **Log QSO** screen is invoked.



WSJT-X v1.7.1-devel by K1JT - Log QSO

Click OK to confirm the following QSO:

Call	Start	End
ZF1EJ	02/08/2017 18:07:17	02/08/2017 18:07:17

Mode	Band	Rpt Sent	Rpt Rcvd	Grid	Name
FT8	6m	-13	-17	EK99	

Tx power: 10 W ☒ Retain

Comments:  ☐ Retain

OK Cancel

- **Stop** will terminate normal data acquisition in case you want to freeze the waterfall or open and explore a previously recorded audio file.
- **Monitor** toggles normal receive operation on or off. This button is highlighted in green when the *WSJT-X* is receiving. If you are using CAT control, toggling **Monitor** OFF relinquishes control of the rig; if **Monitor returns to last used frequency** is selected on the **Settings | General** tab, toggling **Monitor** back ON will return to the original frequency.
- **Erase** clears the right-hand decoded text window. Double-clicking **Erase** clears both text windows.

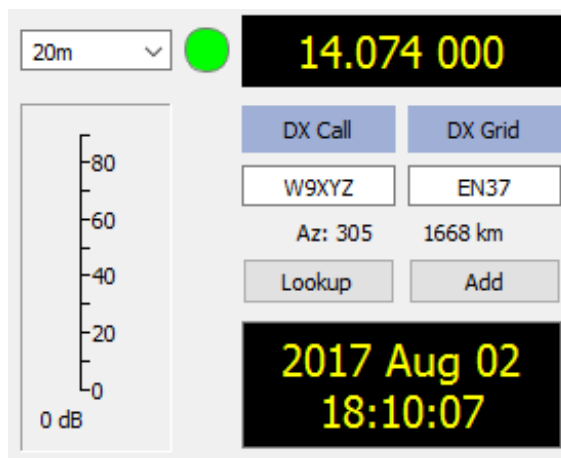


Right-clicking on either text window brings up a context menu with several options (including **Erase**) which operate on that window alone.

- **Clear Avg** is present only in modes that support message averaging. It provides a way to erase the accumulating information, thus preparing to start a new average.
- **Decode** tells the program to repeat the decoding procedure at the Rx frequency (green marker on waterfall scale), using the most recently completed sequence of received data.
- **Enable Tx** toggles automatic T/R sequencing mode on or off and highlights the button in red when ON. A transmission will start at the beginning of the selected (odd or even) sequence, or immediately if appropriate. Toggling the button to OFF during a transmission allows the current transmission to finish.
- **Halt Tx** terminates a transmission immediately and disables automatic T/R sequencing.
- **Tune** toggles the program into Tx mode and generates an unmodulated carrier at the specified Tx frequency (red marker on waterfall scale). This process is useful for adjusting an antenna tuner or tuning an amplifier. The button is highlighted in red while **Tune** is active. Toggle the button a second time or click **Halt Tx** to terminate the **Tune** process. Note that activating **Tune** interrupts a receive sequence and will prevent decoding during that sequence.

### 10.3. Left

Controls related to frequency selection, received audio level, the station being called, and date and time are found at lower left of the main window:



- A drop-down list of frequencies and bands at upper left lets you select the operating band and sets dial frequency to a value taken from the **Frequencies** tab on the **Settings** window. If CAT control is active the radio's dial frequency will be set accordingly; if not, you must tune the radio manually.
- Alternatively, you can enter a frequency (in MHz) or band name in recognized ADIF format, for example 630m, 20m, or 70cm. The band-name format works only if a working frequency has been set for that band and mode, in which case the first such match is selected.
- You can also enter a frequency increment in kHz above the currently displayed integer MHz. For example, if the displayed frequency is 10,368.100, enter `165k` (don't forget the `k` !) to QSY to 10,368.165.
- A small colored circle appears in green if the CAT control is activated and functional. The green circle contains the character **S** if the rig is detected to be in **Split** mode. The circle becomes red if you have requested CAT control but communication with the radio has been lost.



Many Icom rigs cannot be queried for split status, current VFO or split transmit frequency. When using *WSJT-X* with such radios you should not change the current VFO, split status or dial frequency using controls on the radio.

- If **DX Grid** contains a valid Maidenhead locator, the corresponding great-circle azimuth and distance from your location are displayed.
- The program can maintain 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 call. This feature is mainly useful for situations in which the number of active stations is modest and reasonably stable, such as EME (Earth-Moon-Earth) communication. The callsign file name is `CALL3.TXT`.

### 10.4. Center

At the center of the main window are a number of controls used when making QSOs. Controls not relevant to a particular mode or submode may be "grayed out" (disabled) or removed from the display.

- Check **Tx even** to transmit in even-numbered UTC minutes or sequences, starting at 0. Uncheck this box to transmit in the odd sequences. The correct selection is made automatically when you double-click on a decoded text line, as described in the Basic Operating Tutorial.
- The Tx and Rx audio frequencies can be set automatically by double-clicking on decoded text or a signal in the waterfall. They can also be adjusted using the spinner controls.
- You can force Tx frequency to the current Rx frequency by clicking the **Tx←Rx** button, and vice-versa for **Rx←Tx**. The on-the-air frequency of your lowest JT9 or JT65 tone is the sum of dial frequency and audio Tx frequency.
- Check the box **Lock Tx=Rx** to make the frequencies always track one another.



In general we do not recommend using **Lock Tx=Rx** since it encourages poor radio etiquette when running a frequency. With this box checked, your own Tx frequency will move around following your callers.

- For modes lacking a multi-decode feature, or when **Enable VHF/UHF/Microwave features** has been checked on the **Settings** → **General** tab, the **F Tol** control sets a frequency tolerance range over which decoding will be attempted, centered on the Rx frequency.
- The **Report** control lets you change a signal report that has been inserted automatically. Typical reports for the various modes fall in the range −30 to +20 dB. Remember that JT65 reports saturate at an upper limit of −1 dB.



Consider reducing power if your QSO partner reports your signal above −5 dB in one of the *WSJT-X* slow modes. These are supposed to be weak signal modes!

- In some circumstances, especially on VHF and higher bands, you can select a supported submode of the active mode by using the **Submode** control. The **Sync** control sets a minimum threshold for establishing time and frequency synchronization with a received signal.
- Spinner control **T/R xx s** sets sequence lengths for transmission and reception in ISCAT, MSK144, and the fast JT9 modes.
- With **Split operation** activated on the **Settings** → **Radio** tab, in MSK144 and the fast JT9 submodes you can activate the spinner control **Tx CQ nnn** by checking the box to its right. The program will then generate something like CQ nnn K1ABC FN42 for your CQ message, where nnn is the kHz portion of your current operating frequency. Your CQ message **Tx6** will then be transmitted at the calling frequency selected in the **Tx CQ nnn** spinner control. All other messages will be transmitted at your current operating frequency. On reception, when you double-click on a message like CQ nnn K1ABC FN42 your rig will QSY to the specified frequency so you can call the station at his specified response frequency.
- Checkboxes at bottom center of the main window control special features for particular operating modes:
  - **Sh** enables shorthand messages in JT4, JT65, and MSK144 modes
  - **Fast** enables fast JT9 submodes
  - **Auto Seq** enables auto-sequencing of Tx messages
  - **Call 1st** enables automatic response to the first decoded responder to your CQ
  - **Tx6** toggles between two types of shorthand messages in JT4 mode

## 10.5. Tx Messages

Two arrangements of controls are provided for generating and selecting Tx messages. Controls familiar to users of program *WSJT* appear on **Tab 1**, providing six fields for message entry. Pre-formatted messages for the standard minimal QSO are generated when you click **Generate Std Msgs** or double-click on an appropriate line in one of the decoded text windows.

	Next	Now
KF4RWA K1JT FN20	<input checked="" type="radio"/>	Tx 1
KF4RWA K1JT -15	<input type="radio"/>	Tx 2
KF4RWA K1JT R-15	<input type="radio"/>	Tx 3
KF4RWA K1JT RRR	<input type="radio"/>	Tx 4
KF4RWA K1JT 73	<input type="radio"/>	Tx 5
CQ K1JT FN20	<input type="radio"/>	Tx 6

- 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 during a transmission, click on a rectangular button under the **Now** label. Changing a Tx message in mid-stream will slightly reduce the chance of a correct decode, but it is usually OK if done in the first 10-20% of a transmission.
- All six Tx message fields are editable. You can modify an automatically generated message or enter a desired message, keeping in mind the limits on message content. See Protocol Specifications for details.
- Click on the pull-down arrow for message #5 to select one of the pre-stored messages entered on the **Settings | Tx Macros** tab. Pressing **Enter** on a modified message #5 automatically adds that message to the stored macros.
- In some circumstances it may be desirable to make your QSOs as short as possible. To configure the program to start contacts with message #2, disable message #1 by double-clicking on its round radio-button or rectangular **Tx 1** button. Similarly, to send RR73 rather than RRR for message #4, double-click on one of its buttons.

The second arrangement of controls for generating and selecting Tx messages appears on **Tab 2** of the Message Control Panel:

With this setup you normally follow a top-to-bottom sequence of transmissions from the left column if you are calling CQ, or the right column if answering a CQ.

- Clicking a button puts the appropriate message in the **Gen Msg** box. If you are already transmitting, the Tx message is changed immediately.
- You can enter and transmit anything (up to 13 characters, including spaces) in the **Free Msg** box.
- Click on the pull-down arrow in the **Free Msg** box to select a pre-stored macro. Pressing **Enter** on a modified message here automatically adds that message to the table of stored macros.



During a transmission the actual message being sent always appears in the first box of the status bar (bottom left of the main screen).

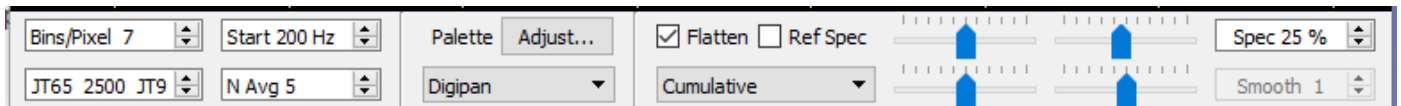
## 10.6. Status Bar

A **Status Bar** at the bottom edge of the main window provides useful information about operating conditions.

Labels on the **Status Bar** display such information as the program's current operating state, configuration name, operating mode, and the content of your most recent transmitted message. The first label (operating state) can be Receiving, Tx (for Transmitting), Tune, or the name of file opened from the **File** menu; this label is highlighted in green for Receiving, yellow for Tx, red for Tune, and light blue for a file name. When transmitting, the Tx message is displayed exactly as it will be decoded by receiving stations. The second label (as shown above) will be absent if you are using the **Default** setting on the **Configurations** menu. A progress bar shows the elapsed fraction of a Tx or Rx sequence. Finally, if the Watchdog (WD) timer was enabled on the **settings | General** tab, a label in the lower right-hand corner displays the number of minutes remaining before timeout.

## 10.7. Wide Graph

The following controls appear at the bottom of the Wide Graph window. Decoding occurs only in the displayed frequency range; otherwise, with the exceptions of **Start NNN Hz** and of **JT65 nnnn JT9** when operating in JT9+JT65 mode, controls on the Wide Graph window have no effect on the decoding process.

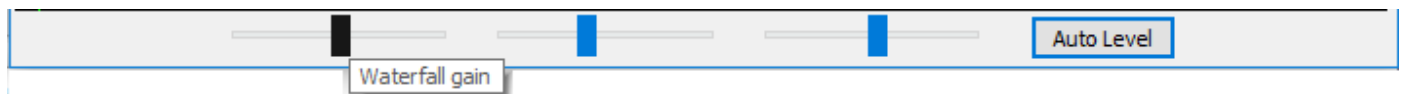


- **Bins/Pixel** controls the displayed frequency resolution. Set this value to 1 for the highest possible resolution, or to higher numbers to compress the spectral display. Normal operation with a convenient window size works well at 2 to 8 bins per pixel.
- **JT65 nnnn JT9** sets the dividing point (blue marker) for wide-band decoding of JT65 and JT9 signals in **JT9+JT65** mode. The decoder looks for JT65 signals everywhere, but JT9 signals only above this frequency. This setting is stored separately for each band.
- **Start nnn Hz** sets the low-frequency starting point of the waterfall frequency scale.
- **N Avg** is the number of successive spectra to be averaged before updating the display. Values around 5 are suitable for normal JT9 and JT65 operation. Adjust **N Avg** to make the waterfall move faster or slower, as desired.
- A dropdown list below the **Palette** label lets you select from a wide range of waterfall color palettes.
- Click **Adjust** to activate a window that allows you to create a user-defined palette.
- Check **Flatten** if you want *WSJT-X* to compensate for a sloping or uneven response across the received passband. For this feature to work properly, you should restrict the range of displayed frequencies so that only the active part of the spectrum is shown.
- Select **Current** or **Cumulative** for the spectrum displayed in the bottom one-third of the Wide Graph window. **Current** is the average spectrum over the most recent **N Avg** FFT calculations. **Cumulative** is the average spectrum since the start of the present UTC minute. **Linear Avg** is useful in JT4 mode, especially when short-form messages are used.

- Four sliders control reference levels and scaling for waterfall colors and the spectrum plot. Values around midscale are usually about right, depending on the input signal level, the chosen palette, and your own preferences. Hover the mouse over a control to display a tip reminding you of its function.
- **Smoothing** is active only when **Linear Average** has been selected. Smoothing the displayed spectrum over more than one bin can enhance your ability to detect weak EME signals with Doppler spread more than a few Hz.

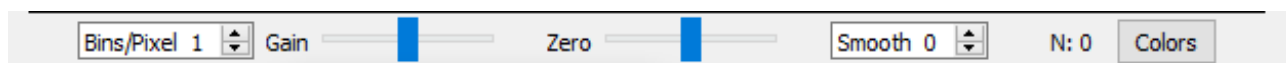
## 10.8. Fast Graph

The waterfall palette used for the Fast Graph is the same as the one selected on the Wide Graph. Three sliders at the bottom of the Fast Graph window can be used to optimize gain and zero-offset for the displayed information. Hover the mouse over a control to display a tip reminding you of its function. Clicking the **Auto Level** button will produce reasonable settings as a starting point.



## 10.9. Echo Graph

The following controls appear at the bottom of the Echo Graph:



- **Bins/Pixel** controls the displayed frequency resolution. Set this value to 1 for the highest possible resolution, or to higher numbers to compress the spectral display.
- **Gain** and **Zero** sliders control scaling and offset of plotted spectra.
- **Smooth** values greater than 0 apply running averages to the plotted spectra, thereby smoothing the curves over multiple bins.
- Label **N** shows the number of echo pulses averaged.
- Click the **Colors** button to cycle through 6 possible choices of color and line width for the plots.

## 10.10. Miscellaneous

Most windows can be resized as desired. If you are short of screen space you can make the Main Window and Wide Graph smaller by hiding some controls and labels. To enable this feature type **Ctrl+M** with focus on the appropriate window. (For the Main Window you can select **Hide menus and labels** on the **View** menu.) Type **Ctrl+M** again to make the controls visible once more.

## 11. Logging

A basic logging facility in *WSJT-X* saves QSO information to files named `wsjtx.log` (in comma-separated text format) and `wsjtx_log.adi` (in standard ADIF format). These files can be imported directly into other programs, for example spreadsheets and popular logging programs. As described in the Installation and Platform Dependencies sections, different operating systems may place your local log files in different locations. You can always navigate to them directly by selecting **Open log directory** from the **File** menu.

More elaborate logging capabilities are supported by third party applications like [JT-Alert](http://hamapps.com/) (<http://hamapps.com/>), which can log QSOs automatically to other applications including [Ham Radio Deluxe](http://www.hrdsoftwarellc.com/) (<http://www.hrdsoftwarellc.com/>), [DX Lab Suite](http://www.dxlabsuite.com/) (<http://www.dxlabsuite.com/>), and [Log4OM](http://www.log4om.com) (<http://www.log4om.com>).

The program option **Show DXCC entity and worked before status** (selectable on the **Settings | General** tab) is intended mostly for use on non-Windows platforms, where [JT-Alert](http://hamapps.com/) (<http://hamapps.com/>) is not available. When this option is checked *WSJT-X* appends some additional information to all CQ messages displayed in the *Band Activity* window. The name of the DXCC entity is shown, abbreviated if necessary. Your “worked before” status for this callsign (according to log file `wsjtx_log.adi`) is flagged with a single character and a change of background color, as follows:

- ! Default color bright purple: New DXCC entity
- ~ Light pink: You have already worked this DXCC entity but not this station
- Green: You have previously worked the calling station

In this respect the program does not distinguish between modes, but it does differentiate between bands.

*WSJT-X* includes a built-in `cty.dat` file containing DXCC prefix information. Updated files can be downloaded from the [Amateur Radio Country Files](http://www.country-files.com/cty/) (<http://www.country-files.com/cty/>) web site when required. If an updated `cty.dat` is present in the logs folder and readable, it will be used in preference to the built-in one.

The log file `wsjtx_log.adi` is updated whenever you log a QSO from *WSJT-X*. (Keep in mind that if you erase this file you will lose all “worked before” information.) You can append or overwrite the `wsjtx_log.adi` file by exporting your QSO history as an ADIF file from another logging program. Turning **Show DXCC entity and worked before status** off and then on again will cause *WSJT-X* to re-read the log file. Very large log files may cause *WSJT-X* to slow down when searching for calls.



# 12. Decoder Notes

## 12.1. AP Decoding

The *WSJT-X* decoders for QRA64 and FT8 include optional procedures that use naturally accumulating information during a minimal QSO. This *a priori* (AP) information increases sensitivity of the decoder by up to 4 dB, at the cost of a slightly higher rate of false decodes.

For example: when you decide to answer a CQ, you already know your own callsign and that of your potential QSO partner. The software therefore “knows” what to expect for 57 of the 72 message bits (28 bits for each of two callsigns, 1 bit for message type) in the next received message. The decoder’s task can thus be reduced to determining the remaining 15 bits of the message and ensuring that the resulting solution is reliable.

AP decoding starts by setting AP bits to the hypothesized values, as if they had been received correctly. We then determine whether the remaining message and parity bits are consistent with the hypothesized AP bits, with a specified level of confidence. Successful AP decodes are labeled with an end-of-line indicator of the form aP , where P is one of the single-digit AP decoding types listed in Table 1. For example, a2 indicates that the successful decode used MyCall as hypothetically known information.

Table 1. AP information types

P	Message components
1	CQ   ?   ?
2	MyCall   ?   ?
3	MyCall DxCall   ?
4	MyCall DxCall RRR
5	MyCall DxCall 73
6	MyCall DxCall RR73

If a codeword is found that is judged to have high (but not overwhelmingly high) probability of being correct, a ? character is appended when the decoded message is displayed. To avoid misleading spots of occasional false decodes, messages so marked are not forwarded to [PSK Reporter](http://pskreporter.info/pskmap.html) (<http://pskreporter.info/pskmap.html>).

Table 2 lists the six possible QSO states that are tracked by the *WSJT-X* auto-sequencer, along with the type of AP decoding that would be attempted in each state.

Table 2. AP decoding types for each QSO state

State	AP type
-------	---------

CALLING	1, 2
REPLYING	2, 3
REPORT	2, 3
ROGER_REPORT	3, 4, 5, 6
ROGERS	3, 4, 5, 6
SIGNOFF	3, 1, 2

## 12.2. Decoded Lines

Displayed information accompanying decoded messages generally includes UTC, signal-to-noise ratio in dB, time offset DT in seconds, and audio frequency in Hz. Some modes include additional information such as frequency offset from nominal (DF), frequency drift (Drift or F1), or distance (km or mi).

There may also be some cryptic characters with special meanings summarized in the following Table:

*Table 3. Notations used on decoded text lines*

Mode	Mode character	Sync character	End of line information
FT8	~		? aP
JT4	\$	*, #	f, fN, dNC
JT9	@		
JT65	#		
JT65 VHF	#	*, #	f, fN, dNC
QRA64	:	*	R
ISCAT		*	M N C T
MSK144	&		N H E

### Sync character

- \* - Normal sync
- # - Alternate sync

### End of line information

- ? - Decoded with lower confidence
- a - Decoded with aid of some a priori (AP) information
- C - Confidence indicator [ISCAT and Deep Search; (0-9,\*)]
- d - Deep Search algorithm
- E - Size of MSK eye diagram opening - if negative, the eye is closed
- f - Franke-Taylor or Fano algorithm
- H - Number of bit errors corrected
- M - Message length (characters)
- N - Number of Rx intervals or frames averaged
- P - Number indicating type of AP information (Table 1, above)
- R - Return code from QRA64 decoder
- T - Length of analyzed region (s)

## 13. Measurement Tools

### 13.1. Frequency Calibration

Many *WSJT-X* capabilities depend on signal-detection bandwidths no more than a few Hz. Frequency accuracy and stability are therefore unusually important. We provide tools to enable accurate frequency calibration of your radio, as well as precise frequency measurement of on-the-air signals. The calibration procedure works by automatically cycling your CAT-controlled radio through a series of preset frequencies of carrier-based signals at reliably known frequencies, measuring the error in dial frequency for each signal.

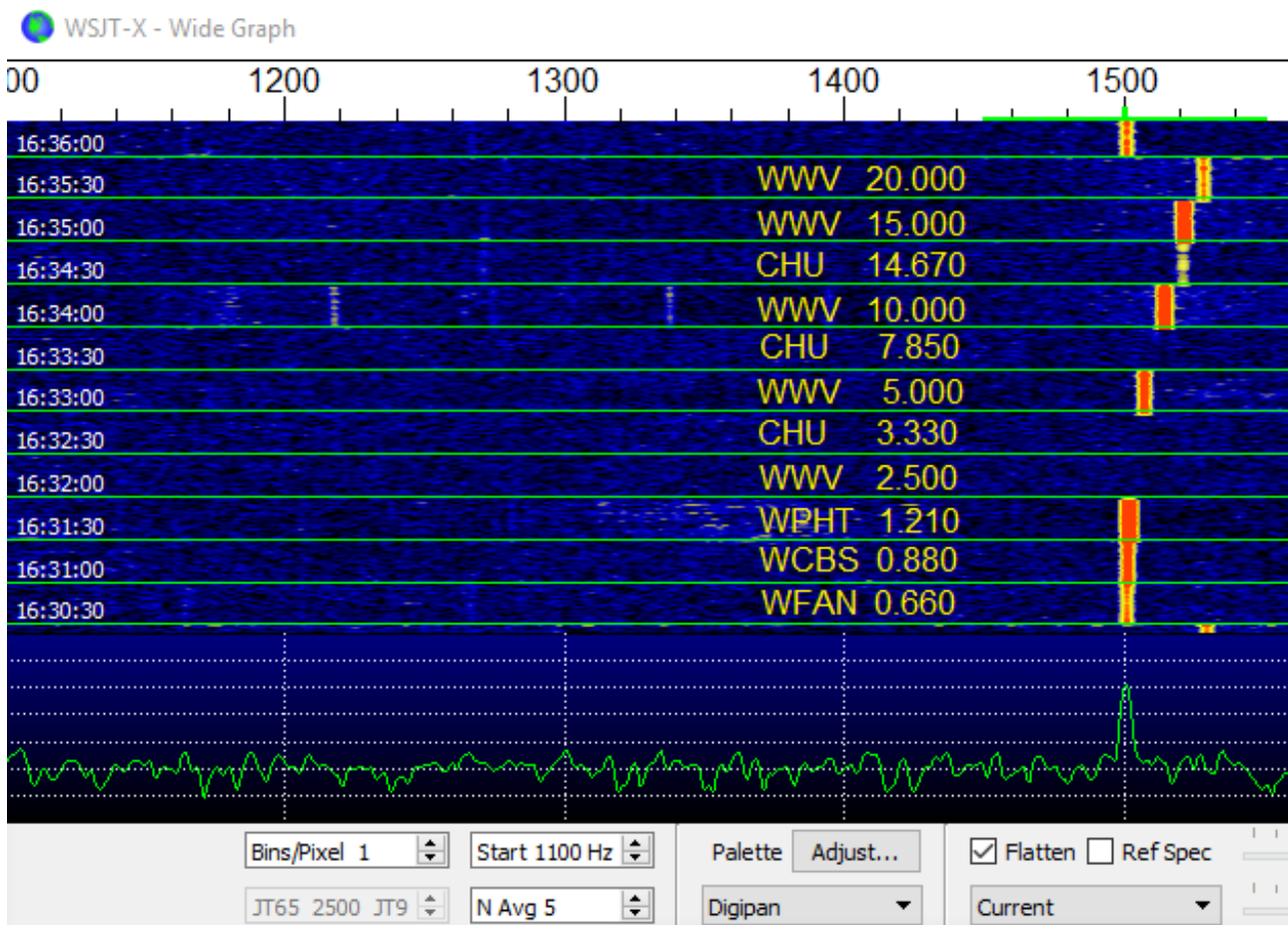
You will probably find it convenient to define and use a special Configuration dedicated to frequency calibration. Then complete the following steps, as appropriate for your system.

- Switch to FreqCal mode
- In the *Working Frequencies* box on the **Settings** → **Frequencies** tab, delete any default frequencies for **FreqCal** mode that are not relevant for your location. You may want to replace some of them with reliably known frequencies receivable at your location.



We find major-city AM broadcast stations generally serve well as frequency calibrators at the low frequency end of the spectrum. In North America we also use the standard time-and-frequency broadcasts of WWV at 2.500, 5.000, 10.000, 15.000, and 20.000 MHz, and CHU at 3.330, 7.850, and 14.670 MHz. Similar shortwave signals are available in other parts of the world.

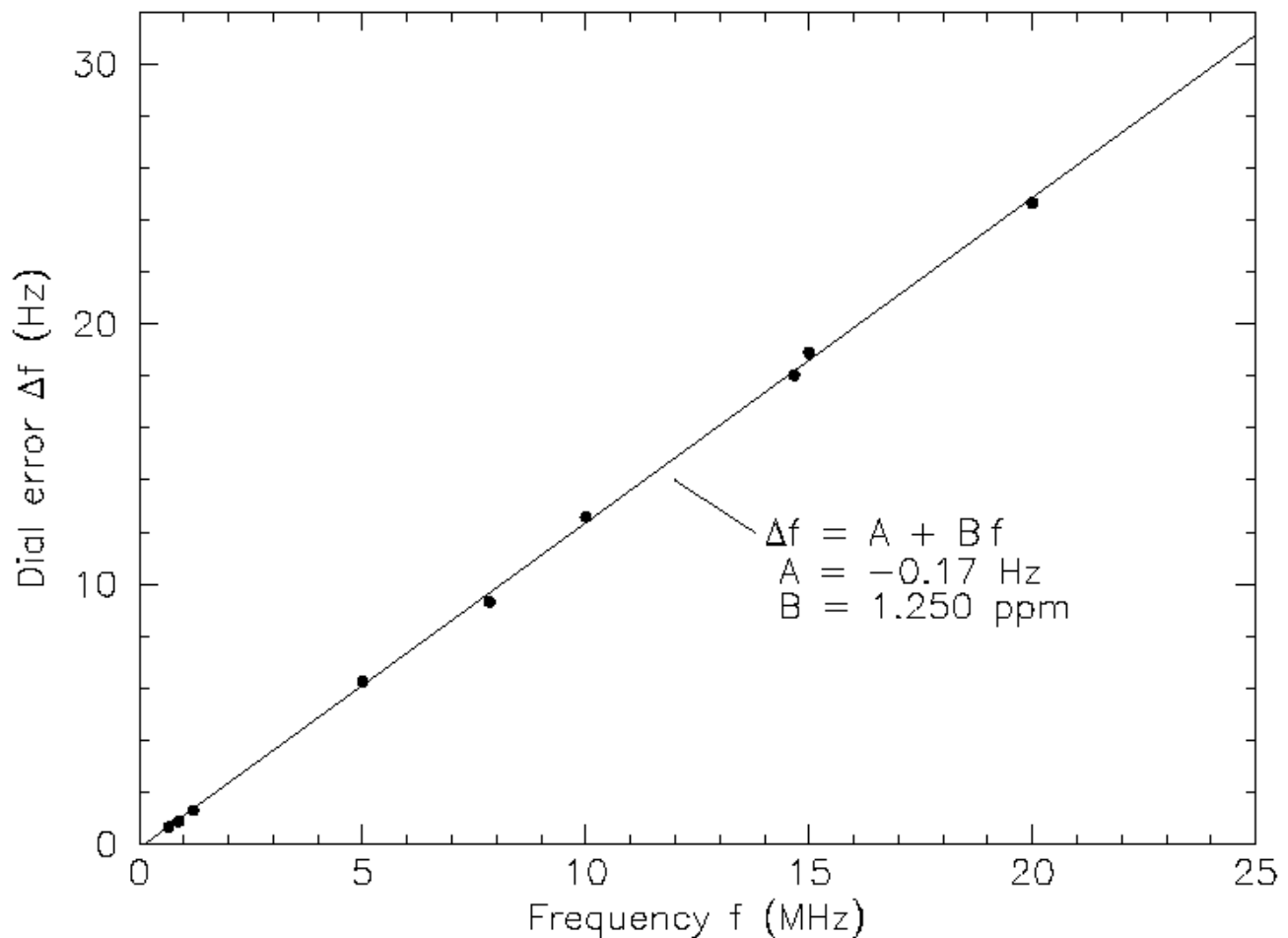
- In most cases you will want to start by deleting any existing file `fmt.all` in the directory where your log files are kept.
- To cycle automatically through your chosen list of calibration frequencies, check **Execute frequency calibration cycle** on the **Tools** menu. *WSJT-X* will spend 30 seconds at each frequency. Initially no measurement data is saved to the `fmt.all` file although it is displayed on screen, this allows you to check you current calibration parameters.
- During the calibration procedure, the radio's USB dial frequency is offset 1500 Hz below each **FreqCal** entry in the default frequencies list. As shown in the screen shot below, detected signal carriers therefore appear at about 1500 Hz in the *WSJT-X* waterfall.
- To start a measurement session check the **Measure** option and let the calibration cycle run for at least one complete sequence. Note that, while measuring, any existing calibration parameters are automatically disabled so you may have to increase the **FTol** range if your rig is off frequency by more than a few Hertz in order to capture valid measurements.



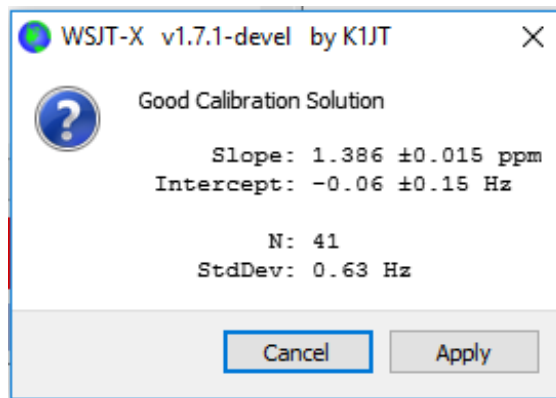
With modern synthesized radios, small measured offsets from 1500 Hz will exhibit a straight-line dependence on frequency. You can approximate the calibration of your radio by simply dividing the measured frequency offset (in Hz) at the highest reliable frequency by the nominal frequency itself (in MHz). For example, the 20 MHz measurement for WWV shown above produced a measured tone offset of 24.6 Hz, displayed in the *WSJT-X* decoded text window. The resulting calibration constant is  $24.6/20=1.23$  parts per million. This number may be entered as **Slope** on the **settings** → **Frequencies** tab.

A more precise calibration can be effected by fitting the intercept and slope of a straight line to the whole sequence of calibration measurements, as shown for these measurements in the graph plotted below. Software tools for completing this task are included with the *WSJT-X* installation, and detailed instructions for their use are available at [https://physics.princeton.edu/pulsar/k1jt/FMT\\_User.pdf](https://physics.princeton.edu/pulsar/k1jt/FMT_User.pdf).

Using these tools and no specialized hardware beyond your CAT-interfaced radio, you can calibrate the radio to better than 1 Hz and compete very effectively in the ARRL's periodic Frequency Measuring Tests.



After running **Execute frequency calibration cycle** at least once with good results, check and edit the file `fmt.a11` in the log directory and delete any spurious or outlier measurements. The line-fitting procedure can then be carried out automatically by clicking **Solve for calibration parameters** on the **Tools** menu. The results will be displayed as in the following screen shot. Estimated uncertainties are included for slope and intercept;  $N$  is the number of averaged frequency measurements included in the fit, and `StdDev` is the root mean square deviation of averaged measurements from the fitted straight line. If the solution seems valid you will be offered an **Apply** button to push that will automatically set the calibration parameters in **Settings** → **Frequencies** → **Frequency Calibration**.



For a quick visual check of the resulting calibration, stay in **FreqCal** mode with the **Measure** option cleared. *WSJT-X* will show the adjusted results directly on the waterfall and the displayed records.

## 13.2. Reference Spectrum

*WSJT-X* provides a tool that can be used to determine the detailed shape of your receiver's passband. Disconnect your antenna or tune to a quiet frequency with no signals. With *WSJT-X* running in one of the slow modes, select **Measure reference spectrum** from the **Tools** menu. Wait for about a minute and then hit the **Stop** button. A file named `refspec.dat` will appear in your log directory.

[ ... more to come ... ]

## 13.3. Phase Equalization

**Measure phase response** under the **Tools** menu is for advanced MSK144 users. Phase equalization is used to compensate for group-delay variation across your receiver passband. Careful application of this facility can reduce intersymbol interference, resulting in improved decoding sensitivity. If you use a software-defined receiver with linear-phase filters there is no need to apply phase equalization.

After a frame of received data has been decoded, **Measure phase response** generates an undistorted audio waveform equal to the one generated by the transmitting station. Its Fourier transform is then used as a frequency-dependent phase reference to compare with the phase of the received frame's Fourier coefficients. Phase differences between the reference spectrum and received spectrum will include contributions from the originating station's transmit filter, the propagation channel, and filters in the receiver. If the received frame originates from a station known to transmit signals having little phase distortion (say, a station known to use a properly adjusted software-defined-transceiver) and if the received signal is relatively free from multipath distortion so that the channel phase is close to linear, the measured phase differences will be representative of the local receiver's phase response.

Complete the following steps to generate a phase equalization curve:

- Record a number of wav files that contain decodable signals from your chosen reference station. Best results will be obtained when the signal-to-noise ratio of the reference signals is 10 dB or greater.

- Enter the callsign of the reference station in the DX Call box.
- Select **Measure phase response** from the **Tools** menu, and open each of the wav files in turn. The mode character on decoded text lines will change from & to ^ while *WSJT-X* is measuring the phase response, and it will change back to & after the measurement is completed. The program needs to average a number of high-SNR frames to accurately estimate the phase, so it may be necessary to process several wav files. The measurement can be aborted at any time by selecting **Measure phase response** again to toggle the phase measurement off.

When the measurement is complete *WSJT-X* will save the measured phase response in the **Log directory**, in a file with suffix ".pcoeff". The filename will contain the callsign of the reference station and a timestamp, for example `K0TPP_170923_112027.pcoeff`.

- Select **Equalization tools ...** under the **Tools** menu and click the **Phase ...** button to view the contents of the **Log directory**. Select the desired pcoeff file. The measured phase values will be plotted as filled circles along with a fitted red curve labeled "Proposed". This is the proposed phase equalization curve. It's a good idea to repeat the phase measurement several times, using different wav files for each measurement, to ensure that your measurements are repeatable.
- Once you are satisfied with a fitted curve, push the **Apply** button to save the proposed response. The red curve will be replaced with a light green curve labeled "Current" to indicate that the phase equalization curve is now being applied to the received data. Another curve labeled "Group Delay" will appear. The "Group Delay" curve shows the group delay variation across the passband, in ms. Click the **Discard** button to remove the captured data, leaving only the applied phase equalization curve and corresponding group delay curve.
- To revert to no phase equalization, push the **Restore Defaults** button followed by the **Apply** button.

The three numbers printed at the end of each MSK144 decode line can be used to assess the improvement provided by equalization. These numbers are: **N** = Number of frames averaged, **H** = Number of hard bit errors corrected, **E** = Size of MSK eye diagram opening.

Here is a decode of K0TPP obtained while **Measure phase response** was measuring the phase response:

```
103900 17 6.5 1493 ^ WA8CLT K0TPP +07      1 0 1.2
```

The "^" symbol indicates that a phase measurement is being accumulated but is not yet finished. The three numbers at the end of the line indicate that one frame was used to obtain the decode, there were no hard bit errors, and the eye-opening was 1.2 on a -2 to +2 scale. Here's how the same decode looks after phase equalization:

```
103900 17 6.5 1493 & WA8CLT K0TPP +07      1 0 1.6
```

In this case, equalization has increased the eye opening from 1.2 to 1.6. Larger positive eye openings are associated with reduced likelihood of bit errors and higher likelihood that a frame will be successfully decoded. In this case, the larger eye-opening tells us that phase equalization was successful, but it is important to note that this test does not by itself tell us whether the applied phase equalization curve is going to improve decoding of signals other than those from the reference station, K0TPP.



It's a good idea to carry out before and after comparisons using a large number of saved wav files with signals from many different stations, to help decide whether your equalization curve improves decoding for most signals. When doing such comparisons, keep in mind that equalization may cause *WSJT-X* to successfully decode a frame that was not decoded before equalization was applied. For this reason, be sure that the time "T" of the two decodes are the same before comparing their end-of-line quality numbers.

When comparing before and after decodes having the same "T", keep in mind that a smaller first number means that decoding has improved, even if the second and third numbers appear to be "worse". For example, suppose that the end-of-line quality numbers before equalization are 2 0 0.2 and after equalization 1 5 -0.5 . These numbers show improved decoding because the decode was obtained using only a single frame after equalization whereas a 2-frame average was needed before equalization. This implies that shorter and/or weaker pings could be decodable.

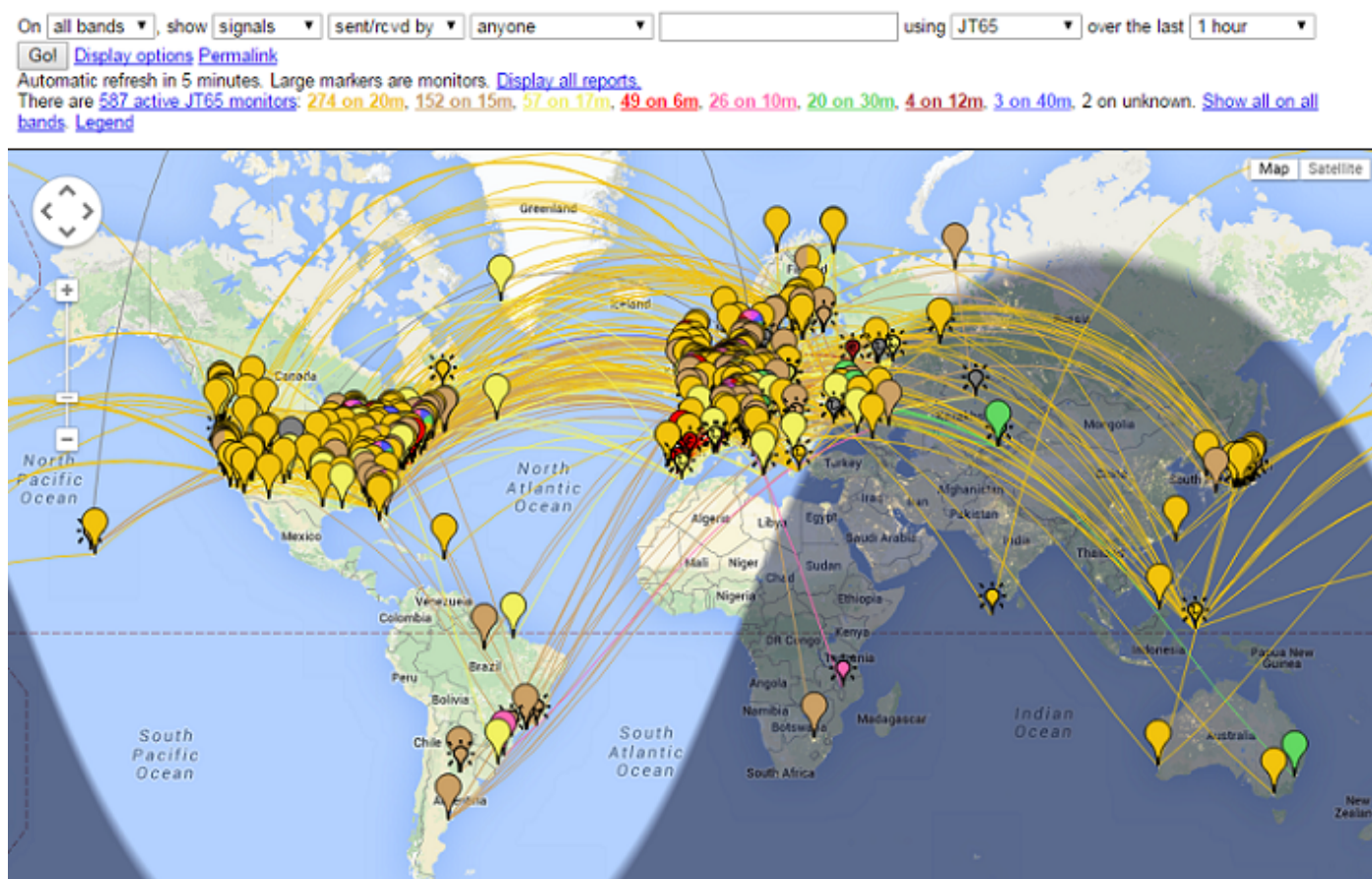


Further details on phase equalization and examples of fitted phase curves and eye diagrams can be found in the article on MSK144 by K9AN and K1JT published in [QEX](http://physics.princeton.edu/pulsar/k1jt/MSK144_Protocol_QEX.pdf) ([http://physics.princeton.edu/pulsar/k1jt/MSK144\\_Protocol\\_QEX.pdf](http://physics.princeton.edu/pulsar/k1jt/MSK144_Protocol_QEX.pdf)).

## 14. Cooperating Programs

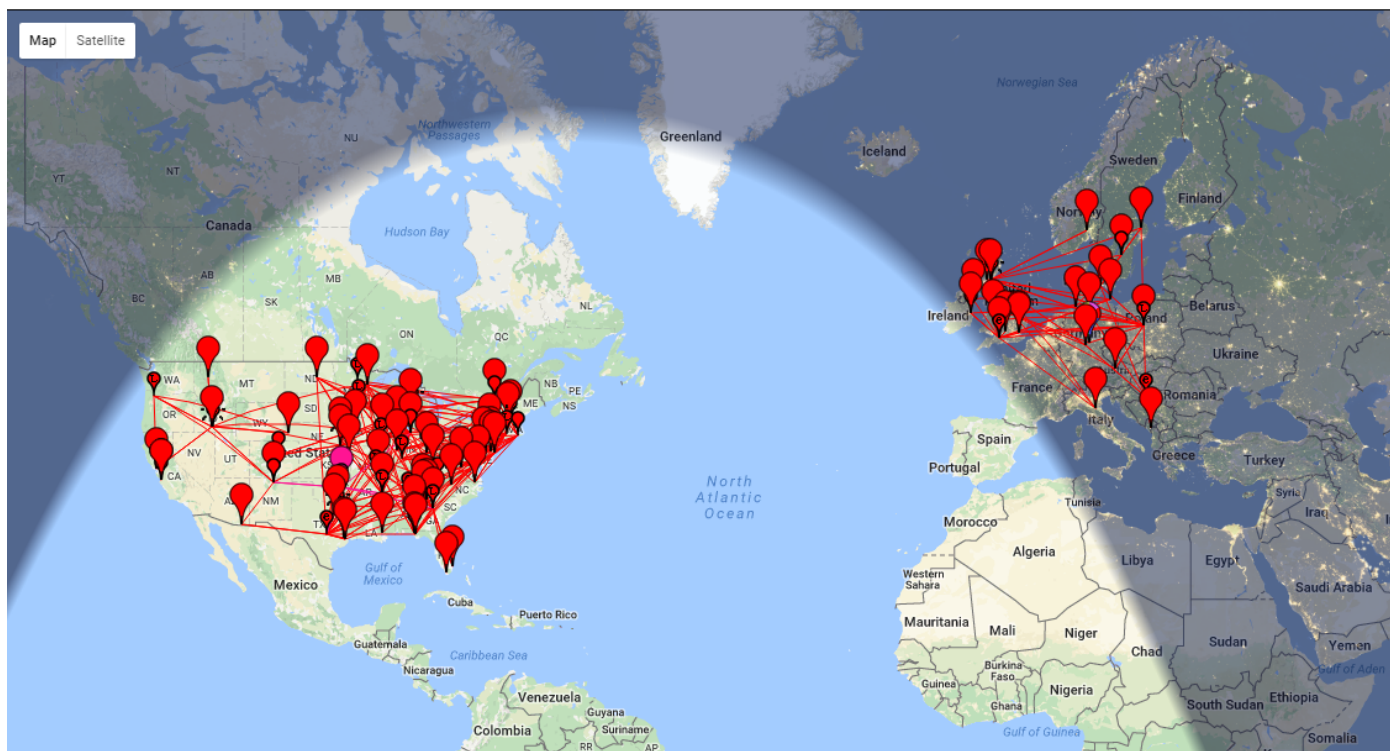
WSJT-X is programmed to cooperate closely with several other useful programs.

- [DX Lab Suite](http://www.dxlabsuite.com/) (<http://www.dxlabsuite.com/>), [Download](http://www.dxatlas.com/OmniRig/Files/OmniRig.zip) (<http://www.dxatlas.com/OmniRig/Files/OmniRig.zip>), and [Ham Radio Deluxe](http://www.hrdsoftwarellc.com/) (<http://www.hrdsoftwarellc.com/>) were described in the section on rig control.
- [PSK Reporter](http://pskreporter.info/pskmap.html) (<http://pskreporter.info/pskmap.html>), by Philip Gladstone, is a web server that gathers reception reports sent by various other programs, including *WSJT-X*. The information is made available in near real time on a world map, and also as statistical summaries of various kinds. A number of options are available to the user; for example, you can request a map showing world-wide JT65 activity on all amateur bands over the past hour. Such a map might look like this, where different colors represent different bands:

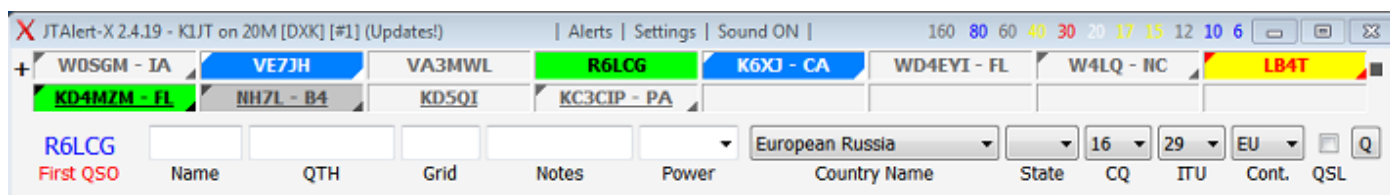


The following screen shot shows the PSK Reporter map configured to show MSK144 reports:

On  show  sent/rcvd by  using  over the last   [Display options](#) [Permalink](#)  
Automatic refresh in 5 minutes. Large markers are monitors. [Display all reports](#).  
There are [72 active MSK144 monitors](#): [71 on 6m](#), [1 on 2m](#). [Show all on all bands](#) [Legend](#)



- [JT-Alert](http://hamapps.com/) (<http://hamapps.com/>), by VK3AMA, is available only for Windows. It provides many operating aids including automatic logging to several third-party logging programs, audio and visual alerts following a number of optional alert conditions (decoding of a new DXCC, new state, etc.), and convenient direct access to web services such as callsign lookup.



- [AlarmeJT](http://f5jmh.free.fr/index.php?page=english) (<http://f5jmh.free.fr/index.php?page=english>), by F5JMH, is available only for Linux. The program keeps its own logbook. It fetches contact information from *WSJT-X* and provides visual alerts for new DXCC entities and grid squares on the current band, as well as other options.
- [JT-Bridge](http://jt-bridge.eller.nu/) (<http://jt-bridge.eller.nu/>), by SM0THU, is available for OS X. It works together with logging applications Aether, MacLoggerDX, RUMlog or RUMlogNG. It checks QSO and QSL status of the call and DXCC entity, as well as many other features.

## 15. Platform Dependencies

A few *WSJT-X* features behave differently in Windows, Linux, or OS X, or may not be relevant to all operating platforms.

### *File locations*

- **Windows**
  - **Settings:** %LOCALAPPDATA%\WSJT-X\WSJT-X.ini
  - **Log directory:** %LOCALAPPDATA%\WSJT-X\
  - **Default save directory:** %LOCALAPPDATA%\WSJT-X\save\
- **Windows, when using "--rig-name=xxx"**
  - **Settings:** %LOCALAPPDATA%\WSJT-X - xxx\WSJT-X - xxx.ini
  - **Log directory:** %LOCALAPPDATA%\WSJT-X - xxx\
  - **Default save directory:** %LOCALAPPDATA%\WSJT-X - xxx\save\
- **Linux**
  - **Settings:** ~/.config/WSJT-X.ini
  - **Log directory:** ~/.local/share/WSJT-X/
  - **Default save directory:** ~/.local/share/WSJT-X/save/
- **Linux, when using "--rig-name=xxx"**
  - **Settings:** ~/.config/WSJT-X - xxx.ini
  - **Log directory:** ~/.local/share/WSJT-X - xxx/
  - **Default save directory:** ~/.local/share/WSJT-X - xxx/save/
- **Macintosh**
  - **Settings:** ~/Library/Preferences/WSJT-X.ini
  - **Log directory:** ~/Library/Application Support/WSJT-X/
  - **Default save directory:** ~/Library/Application Support/WSJT-X/save/
- **Macintosh, when using "--rig-name=xxx"**
  - **Settings:** ~/Library/Preferences/WSJT-X - xxx.ini
  - **Log directory:** ~/Library/Application Support/WSJT-X - xxx/
  - **Default save directory:** ~/Library/Application Support/WSJT-X - xxx/save/

## 16. Frequently Asked Questions

1. *My displayed spectrum is flatter when I do not check the **Flatten** box. What's wrong?*

WSJT-X does not expect a steep filter edge within the displayed passband. Use a wider IF filter or reduce the displayed passband by decreasing **Bins/Pixel**, increasing **Start**, or reducing the width of the **Wide Graph**. You might also choose to re-center the filter passband, if such control is available.

2. *How should I configure WSJT-X to run multiple instances?*

Start WSJT-X from a command-prompt window, assigning each instance a unique identifier as in the following two-instance example. This procedure will isolate the **Settings** file and the writable file location for each instance of WSJT-X.

```
wsjtx --rig-name=TS2000
wsjtx --rig-name=FT847
```

3. *When setting up rig control through OmniRig, something goes wrong when I click **Test CAT**. What can I do about it?*

OmniRig apparently has a bug that appears when you click **Test CAT**. Forget using **Test CAT** and just click **OK**. OmniRig then behaves normally.

4. *I am using WSJT-X with Ham Radio Deluxe. All seems well until I start HRD Logbook or DM780 running in parallel; then CAT control becomes unreliable.*

You may see delays up to 20 seconds or so in frequency changes or other radio commands, due to a bug in HRD. HRD folks are aware of the problem, and are working to resolve it.

5. *I am running WSJT-X under Ubuntu. The program starts, but menu bar is missing from the top of the main window and the hot-keys don't work.*

Ubuntu's new "Unity" desktop puts the menu for the currently active window at the top of the primary display screen. You can restore menu bars to their traditional locations by typing the following in a command-prompt window:

```
sudo apt remove appmenu-qt5
```

Alternatively, you can disable the common menu bar for just WSJT-X by starting the application with the environment variable QT\_QPA\_PLATFORMTHEME set to empty (the space after the '=' character is necessary):

```
QT_QPA_PLATFORMTHEME= wsjtx
```



## 17. Protocol Specifications

### 17.1. Overview

All QSO modes except ISCAT use structured messages that compress user-readable information into fixed-length packets of 72 bits. Each message consists of two 28-bit fields normally used for callsigns and a 15-bit field for a grid locator, report, acknowledgment, or 73. An additional bit flags a message containing arbitrary alphanumeric text, up to 13 characters. Special cases allow other information such as add-on callsign prefixes (e.g., ZA/K1ABC) or suffixes (e.g., K1ABC/P) to be encoded. The basic aim is to compress the most common messages used for minimally valid QSOs into a fixed 72-bit length. Information payloads in FT8 include 3 additional bits (75 bits total), with definitions yet to be defined.

A standard amateur callsign consists of a one- or two-character prefix, at least one of which must be a letter, followed by a digit and a suffix of one to three letters. Within these rules, the number of possible callsigns is equal to  $37 \times 36 \times 10 \times 27 \times 27 \times 27$ , or somewhat over 262 million. (The numbers 27 and 37 arise because in the first and last three positions a character may be absent, or a letter, or perhaps a digit.) Since  $2^{28}$  is more than 268 million, 28 bits are enough to encode any standard callsign uniquely. Similarly, the number of 4-digit Maidenhead grid locators on earth is  $180 \times 180 = 32,400$ , which is less than  $2^{15} = 32,768$ ; so a grid locator requires 15 bits.

Some 6 million of the possible 28-bit values are not needed for callsigns. A few of these slots have been assigned to special message components such as CQ, DE, and QRZ. CQ may be followed by three digits to indicate a desired callback frequency. (If K1ABC transmits on a standard calling frequency, say 50.280, and sends CQ 290 K1ABC FN42, it means that s/he will listen on 50.290 and respond there to any replies.) A numerical signal report of the form -nn or R-nn can be sent in place of a grid locator. (As originally defined, numerical signal reports nn were required to fall between -01 and -30 dB. Recent program versions accommodate reports between -50 and +49 dB.) A country prefix or portable suffix may be attached to one of the callsigns. When this feature is used the additional information is sent in place of the grid locator or by encoding additional information into some of the 6 million available slots mentioned above.

As a convenience for sending directed CQ messages, the compression algorithm supports messages starting with CQ AA through CQ ZZ. These message fragments are encoded internally as if they were the callsigns E9AA through E9ZZ. Upon reception they are converted back to the form CQ AA through CQ ZZ, for display to the user.

The FT8 and MSK144 modes support a special feature allowing convenient transmission and acknowledgment of four-character grid locators, the required exchanges in most North American VHF contests. With this Contest Mode enabled, WSJT-X supports messages of the form W9XYZ K1ABC R FN42 by converting the grid locator to that of its diametrically opposite point on Earth. The receiving program recognizes a locator implying a distance greater than 10,000 km, does the reverse transformation, and inserts the implied "R". Obviously, this mode should not be used on the HF bands or under other circumstances where world-wide propagation is possible.

To be useful on channels with low signal-to-noise ratio, this kind of lossless message compression requires use of a strong forward error correcting (FEC) code. Different codes are used for each mode. Accurate synchronization of time and frequency is required between transmitting and receiving stations. As an aid to the decoders, each protocol includes a "sync vector" of known symbols interspersed with the information-carrying symbols. Generated waveforms for all of the WSJT-X modes have continuous phase and constant envelope.

## 17.2. Slow Modes

### 17.2.1. FT8

Forward error correction (FEC) in FT8 uses a low-density parity check (LDPC) code with 75 information bits, a 12-bit cyclic redundancy check (CRC), and 87 parity bits making a 174-bit codeword. It is thus called an LDPC (174,87) code. Synchronization uses 7×7 Costas arrays at the beginning, middle, and end of each transmission. Modulation is 8-tone frequency-shift keying (8-FSK) at  $12000/1920 = 6.25$  baud. Each transmitted symbol carries three bits, so the total number of channel symbols is  $174/3 + 21 = 79$ . The total occupied bandwidth is  $8 \times 6.25 = 50$  Hz.

### 17.2.2. JT4

FEC in JT4 uses a strong convolutional code with constraint length  $K=32$ , rate  $r=1/2$ , and a zero tail. This choice leads to an encoded message length of  $(72+31) \times 2 = 206$  information-carrying bits. Modulation is 4-tone frequency-shift keying (4-FSK) at  $11025 / 2520 = 4.375$  baud. Each symbol carries one information bit (the most significant bit) and one synchronizing bit. The two 32-bit polynomials used for convolutional encoding have hexadecimal values 0xf2d05351 and 0xe4613c47, and the ordering of encoded bits is scrambled by an interleaver. The pseudo-random sync vector is the following sequence (60 bits per line):

```
00001100011011001010000000110000000000010110110101111101000
100100111110001010001111011001000110101010101111101010110101
011100101101111000011011000111011101110010001101100100011111
10011000011000101101111010
```

### 17.2.3. JT9

FEC in JT9 uses the same strong convolutional code as JT4: 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 nine-tone frequency-shift keying, 9-FSK at  $12000.0/6912 = 1.736$  baud. Eight tones are used for data, one for synchronization. Eight data tones means that three data bits are conveyed by each transmitted information symbol. Sixteen symbol intervals are devoted to synchronization, so a transmission requires a total of  $206 / 3 + 16 = 85$  (rounded up) channel symbols. The sync symbols are those numbered 1, 2, 5, 10, 16, 23, 33, 35, 51, 52, 55, 60, 66, 73, 83, and 85 in the transmitted sequence. Tone spacing of the 9-FSK modulation for JT9A is equal to the keying rate, 1.736 Hz. The total occupied bandwidth is  $9 \times 1.736 = 15.6$  Hz.

### 17.2.4. JT65

A detailed description of the JT65 protocol was published in [QEX](http://physics.princeton.edu/pulsar/K1JT/JT65.pdf) (<http://physics.princeton.edu/pulsar/K1JT/JT65.pdf>) for September-October, 2005. A Reed Solomon (63,12) error-control code converts 72-bit user messages into sequences of 63 six-bit information-carrying symbols. These are interleaved with another 63 symbols of synchronizing information according to the following pseudo-random sequence:

```
100110001111110101000101100100011100111101101111000110101011001
10101010010000001100000011010010110101010011001001000011111111
```

The synchronizing tone is normally sent in each interval having a “1” in the sequence. Modulation is 65-FSK at  $11025/4096 = 2.692$  baud. Frequency spacing between tones is equal to the keying rate for JT65A, and 2 and 4 times larger for JT65B and JT65C. For EME QSOs the signal report OOO is sometimes used instead of numerical signal reports. It is conveyed by reversing sync and data positions in the transmitted sequence. Shorthand messages for RO, RRR, and 73 dispense with the sync vector entirely and use time intervals of  $16384/11025 = 1.486$  s for pairs of alternating tones. The lower frequency is the same as that of the sync tone used in long messages, and the frequency separation is  $110250/4096 = 26.92$  Hz multiplied by n for JT65A, with n = 2, 3, 4 used to convey the messages RO, RRR, and 73.

### 17.2.5. QRA64

QRA64 is intended for EME and other extreme weak-signal applications. Its internal code was designed by IV3NWW. The protocol uses a (63,12) **Q**-ary **R**epeat **A**ccumulate code that is inherently better than the Reed Solomon (63,12) code used in JT65, yielding a 1.3 dB advantage. A new synchronizing scheme is based on three 7 x 7 Costas arrays. This change yields another 1.9 dB advantage.

In most respects the current implementation of QRA64 is operationally similar to JT65. QRA64 does not use two-tone shorthand messages, and it makes no use of a callsign database. Rather, additional sensitivity is gained by making use of already known information as a QSO progresses — for example, when reports are being exchanged and you have already decoded both callsigns in a previous transmission. QRA64 presently offers no message averaging capability, though that feature may be added. In early tests, many EME QSOs were made using submodes QRA64A-E on bands from 144 MHz to 24 GHz.

### 17.2.6. Summary

Table 2 provides a brief summary parameters for the slow modes in *WSJT-X*. Parameters K and r specify the constraint length and rate of the convolutional codes; n and k specify the sizes of the (equivalent) block codes; Q is the alphabet size for the information-carrying channel symbols; Sync Energy is the fraction of transmitted energy devoted to synchronizing symbols; and S/N Threshold is the signal-to-noise ratio (in a 2500 Hz reference bandwidth) above which the probability of decoding is 50% or higher.

*Table 4. Parameters of Slow Modes*

Mode	FEC Type	(n,k)	Q	Modulation type	Keying rate (Baud)	Bandwidth (Hz)	Sync Energy	Tx Duration (s)	S/N Threshold (dB)
<b>FT8</b>	LDPC, r=1/2	(174,87)	8	8-FSK	6.25	50.0	0.27	12.6	-21
<b>JT4A</b>	K=32, r=1/2	(206,72)	2	4-FSK	4.375	17.5	0.50	47.1	-23
<b>JT9A</b>	K=32, r=1/2	(206,72)	8	9-FSK	1.736	15.6	0.19	49.0	-27
<b>JT65A</b>	Reed Solomon	(63,12)	64	65-FSK	2.692	177.6	0.50	46.8	-25



<b>QRA64A</b>	Q-ary Repeat Accumulate	(63,12)	64	64-FSK	1.736	111.1	0.25	48.4	-26
<b>WSPR</b>	K=32, r=1/2	(162,50)	2	4-FSK	1.465	5.9	0.50	110.6	-28

Submodes of JT4, JT9, JT65, and QRA64 offer wider tone spacings for circumstances that may require them, such as significant Doppler spread. Table 3 summarizes the tone spacings, bandwidths, and approximate threshold sensitivities of the various submodes when spreading is comparable to tone spacing.

*Table 5. Parameters of Slow Submodes*

Mode	Tone Spacing	BW (Hz)	S/N (dB)
<b>FT8</b>	6.25	50.0	-21
<b>JT4A</b>	4.375	17.5	-23
<b>JT4B</b>	8.75	30.6	-22
<b>JT4C</b>	17.5	56.9	-21
<b>JT4D</b>	39.375	122.5	-20
<b>JT4E</b>	78.75	240.6	-19
<b>JT4F</b>	157.5	476.9	-18
<b>JT4G</b>	315.0	949.4	-17
<b>JT9A</b>	1.736	15.6	-27
<b>JT9B</b>	3.472	29.5	-26
<b>JT9C</b>	6.944	57.3	-25
<b>JT9D</b>	13.889	112.8	-24
<b>JT9E</b>	27.778	224.0	-23
<b>JT9F</b>	55.556	446.2	-22
<b>JT9G</b>	111.111	890.6	-21
<b>JT9H</b>	222.222	1779.5	-20

<b>JT65A</b>	2.692	177.6	-25
<b>JT65B</b>	5.383	352.6	-25
<b>JT65C</b>	10.767	702.5	-25
<b>QRA64A</b>	1.736	111.1	-26
<b>QRA64B</b>	3.472	220.5	-25
<b>QRA64C</b>	6.944	439.2	-24
<b>QRA64D</b>	13.889	876.7	-23
<b>QRA64E</b>	27.778	1751.7	-22

## 17.3. Fast Modes

### 17.3.1. ISCAT

ISCAT messages are free-form, up to 28 characters in length. Modulation is 42-tone frequency-shift keying at  $11025 / 512 = 21.533$  baud (ISCAT-A), or  $11025 / 256 = 43.066$  baud (ISCAT-B). Tone frequencies are spaced by an amount in Hz equal to the baud rate. The available character set is:

```
0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ / . ? @ -
```

Transmissions consist of sequences of 24 symbols: a synchronizing pattern of four symbols at tone numbers 0, 1, 3, and 2, followed by two symbols with tone number corresponding to (message length) and (message length + 5), and finally 18 symbols conveying the user's message, sent repeatedly character by character. The message always starts with @, the beginning-of-message symbol, which is not displayed to the user. The sync pattern and message-length indicator have a fixed repetition period, recurring every 24 symbols. Message information occurs periodically within the 18 symbol positions set aside for its use, repeating at its own natural length.

For example, consider the user message CQ WA9XYZ. Including the beginning-of-message symbol @, the message is 10 characters long. Using the character sequence displayed above to indicate tone numbers, the transmitted message will therefore start out as shown in the first line below:

```
0132AF@CQ WA9XYZ@CQ WA9X0132AFYZ@CQ WA9XYZ@CQ W0132AFA9X ...
sync##                sync##                sync##
```

Note that the first six symbols (four for sync, two for message length) repeat every 24 symbols. Within the 18 information-carrying symbols in each 24, the user message @CQ WA9XYZ repeats at its own natural length, 10 characters. The resulting sequence is extended as many times as will fit into a Tx sequence.

### 17.3.2. JT9

The JT9 slow modes all use keying rate  $12000/6912 = 1.736$  baud. By contrast, with the **Fast** setting submodes JT9E-H adjust the keying rate to match the increased tone spacings. Message durations are therefore much shorter, and they are sent repeatedly throughout each Tx sequence. For details see Table 4, below.

### 17.3.3. MSK144

Standard MSK144 messages are structured in the same way as those in the slow modes, with 72 bits of user information. Forward error correction is implemented by first augmenting the 72 message bits with an 8-bit cyclic redundancy check (CRC) calculated from the message bits. The CRC is used to detect and eliminate most false decodes at the receiver. The resulting 80-bit augmented message is mapped to a 128-bit codeword using a (128,80) binary low-density-parity-check (LDPC) code designed by K9AN specifically for this purpose. Two 8-bit synchronizing sequences are added to make a message frame 144 bits long. Modulation is Offset Quadrature Phase-Shift Keying (OQPSK) at 2000 baud. Even-numbered bits are conveyed over the in-phase channel, odd-numbered bits on the quadrature channel. Individual symbols are shaped with half-sine profiles, thereby ensuring a generated waveform with constant envelope, equivalent to a Minimum Shift Keying (MSK) waveform. Frame duration is 72 ms, so the effective character transmission rate for standard messages is up to 250 cps.

MSK144 also supports short-form messages that can be used after QSO partners have exchanged both callsigns. Short messages consist of 4 bits encoding R+report, RRR, or 73, together with a 12-bit hash code based on the ordered pair of “to” and “from” callsigns. Another specially designed LDPC (32,16) code provides error correction, and an 8-bit synchronizing vector is appended to make up a 40-bit frame. Short-message duration is thus 20 ms, and short messages can be decoded from very short meteor pings.

The 72 ms or 20 ms frames of MSK144 messages are repeated without gaps for the full duration of a transmission cycle. For most purposes, a cycle duration of 15 s is suitable and recommended for MSK144.

The modulated MSK144 signal occupies the full bandwidth of a SSB transmitter, so transmissions are always centered at audio frequency 1500 Hz. For best results, transmitter and receiver filters should be adjusted to provide the flattest possible response over the range 300Hz to 2700Hz. The maximum permissible frequency offset between you and your QSO partner  $\pm 200$  Hz.

### 17.3.4. Summary

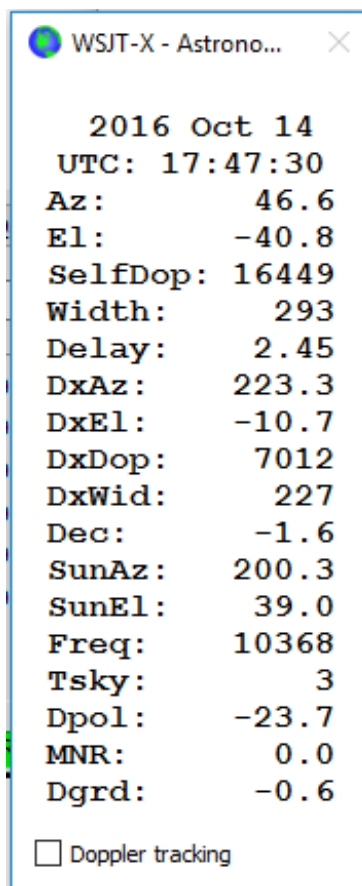
*Table 6. Parameters of Fast Modes*

Mode	FEC Type	(n,k)	Q	Modulation Type	Keying rate (Baud)	Bandwidth (Hz)	Sync Energy	Tx Duration (s)
ISCAT-A	-	-	42	42-FSK	21.5	905	0.17	1.176
ISCAT-B	-	-	42	42-FSK	43.1	1809	0.17	0.588
JT9E		(206,72)	8	9-FSK	25.0	225	0.19	3.400

	K=32, r=1/2							
<b>JT9F</b>	K=32, r=1/2	(206,72)	8	9-FSK	50.0	450	0.19	1.700
<b>JT9G</b>	K=32, r=1/2	(206,72)	8	9-FSK	100.0	900	0.19	0.850
<b>JT9H</b>	K=32, r=1/2	(206,72)	8	9-FSK	200.0	1800	0.19	0.425
<b>MSK144</b>	LDPC	(128,80)	2	OQPSK	2000	2400	0.11	0.072
<b>MSK144 Sh</b>	LDPC	(32,16)	2	OQPSK	2000	2400	0.20	0.020

## 18. Astronomical Data

A text box entitled Astronomical Data provides information needed for tracking the sun or moon, compensating for EME Doppler shift, and estimating EME Doppler spread and path degradation. Toggle the **Astronomical data** on the **View** menu to display or hide this window.



Available information includes the current UTC **Date** and time; **Az** and **El**, azimuth and elevation of the moon at your own location, in degrees; **SelfDop**, **Width**, and **Delay**, the Doppler shift, full limb-to-limb Doppler spread in Hz, and delay of your own EME echoes in seconds; and **DxAz** and **DxEl**, **DxDop**, and **DxWid**, corresponding parameters for a station located at the **DX Grid** entered on the main window. These numbers are followed by **Dec**, the declination of the moon; **SunAz** and **SunEl**, the azimuth and elevation of the Sun; **Freq**, your stated operating frequency in MHz; **Tsky**, the estimated sky background temperature in the direction of the moon, scaled to the operating frequency; **Dpol**, the spatial polarization offset in degrees; **MNR**, the maximum non-reciprocity of the EME path in dB, owing to a combination of Faraday rotation and spatial polarization; and finally **Dgrd**, an estimate of the signal degradation in dB, relative to the best possible time with the moon at perigee in a cold part of the sky.

On the higher microwave bands, where Faraday rotation is minimal and linear polarization is often used, spatial offset will reduce signal levels. Some stations have implemented mechanical polarisation adjustment to overcome this loss, and the amount of rotation needed is predicted in real time by the value of **Dpol**. Positive **Dpol** means that the antenna

should be rotated in a clockwise direction looking from behind the antenna towards the moon. For a dish antenna, the feed should similarly be rotated clockwise looking into the mouth of the feed. A negative value for Dpol means anticlockwise rotation.

The state of the art for establishing three-dimensional locations of the sun, moon, and planets at a specified time is embodied in a numerical model of the solar system maintained at the Jet Propulsion Laboratory. The model has been numerically integrated to produce tabular data that can be interpolated with very high accuracy. For example, the celestial coordinates of the moon or a planet can be determined at a specified time to within about 0.0000003 degrees. The JPL ephemeris tables and interpolation routines have been incorporated into *WSJT-X*. Further details on accuracy, especially concerning calculated EME Doppler shifts, are described in [QEX](http://physics.princeton.edu/pulsar/K1JT/LunarEchoes_QEX.pdf) ([http://physics.princeton.edu/pulsar/K1JT/LunarEchoes\\_QEX.pdf](http://physics.princeton.edu/pulsar/K1JT/LunarEchoes_QEX.pdf)) for November-December, 2016.

The sky background temperatures reported by *WSJT-X* are derived from the all-sky 408 MHz map of Haslam et al. (Astronomy and Astrophysics Supplement Series, 47, 1, 1982), scaled by frequency to the -2.6 power. This map has angular resolution of about 1 degree, and of course most amateur EME antennas have much broader beamwidths than this. Your antenna will therefore smooth out the hot spots considerably, and the observed extremes of sky temperature will be less. Unless you understand your sidelobes and ground reflections extremely well, it is unlikely that more accurate sky temperatures would be of much practical use.

## 19. Utility Programs

The *WSJT-X* packages include program `rigctl-wsjtx[.exe]`, which can be used to send CAT sequences to a rig from the command line, or from a batch file or shell script; and program `rigctld-wsjtx[.exe]`, which allows other compatible applications to share a CAT connection to a rig. These program versions include the latest Hamlib rig drivers — the same ones used by *WSJT-X* itself.

Additional utility programs `jt4code`, `jt9code`, and `jt65code` let you explore the conversion of user-level messages into channel symbols or “tone numbers,” and back again. These programs can be useful to someone designing a beacon generator, for understanding the permissible structure of transmitted messages, and for studying behavior of the error-control codes.

Channel-symbol values for JT4 run from 0 to 3. The total number of symbols in a transmitted message is 206. To run `jt4code`, enter the program name followed by a JT4 message enclosed in quotes. In Windows the command and program output might look like this:

```
C:\WSJTX\bin> jt4code "G0XYZ K1ABC FN42"
  Message          Decoded          Err? Type
-----
1.  G0XYZ K1ABC FN42      G0XYZ K1ABC FN42      1: Std Msg
```

```
Channel symbols
2 0 0 1 3 2 0 2 3 1 0 3 3 2 2 1 2 1 0 0 0 2 0 0 2 1 1 2 0 0
2 0 2 0 2 0 2 0 2 3 0 3 1 0 3 1 0 3 0 1 1 1 1 1 0 1 0 0 2 3
2 2 3 0 2 1 3 3 3 3 2 0 2 1 2 3 0 0 2 3 1 1 1 0 3 1 2 0 3 2
0 2 3 3 0 1 2 1 2 1 0 1 0 1 1 1 1 3 0 3 0 3 2 3 3 0 3 0 1 0
3 3 3 0 0 3 2 1 3 2 3 1 3 3 2 2 0 2 3 3 2 1 1 0 2 2 3 3 1 2
3 1 1 2 1 1 1 0 2 1 2 0 2 3 1 2 3 1 2 2 1 2 0 0 3 3 1 1 1 1
2 0 3 3 0 2 2 2 3 3 0 0 0 1 2 3 3 2 1 1 1 3 2 3 0 3
```

Channel-symbol values for JT9 run from 0 to 8, with 0 representing the sync tone. The total number of symbols in a transmitted message is 85. Enter the program name followed by a JT9 message enclosed in quotes:

```
C:\WSJTX\bin> jt9code "G0XYZ K1ABC FN42"
  Message          Decoded          Err? Type
-----
1.  G0XYZ K1ABC FN42      G0XYZ K1ABC FN42      1: Std Msg
```

```
Channel symbols
0 0 7 3 0 3 2 5 4 0 1 7 7 7 8 0 4 8 8 2 2 1 0 1 1 3 5 4 5 6
8 7 0 6 0 1 8 3 3 7 8 1 1 2 4 5 8 1 5 2 0 0 8 6 0 5 8 5 1 0
5 8 7 7 2 0 4 6 6 6 7 6 0 1 8 8 5 7 2 5 1 5 0 4 0
```

For the corresponding program `jt65code` only the information-carrying channel symbols are shown, and the symbol values range from 0 to 63. Sync symbols lie two tone intervals below data tone 0, and the sequential locations of sync symbols are described in the JT65 Protocol section of this Guide.

A typical execution of `jt65code` is shown below. The program displays the packed message of 72 bits, shown here as 12 six-bit symbol values, followed by the channel symbols:

```
C:\WSJTX\bin> jt65code "G0XYZ K1ABC FN42"
      Message          Decoded          Err? Type
-----
1.  G0XYZ K1ABC FN42      G0XYZ K1ABC FN42      1:   Std Msg
```

Packed message, 6-bit symbols    61 36 45 30    3 55    3    2 14    5 33 40

Information-carrying channel symbols  
56 40    8 40 51 47 50 34 44 53 22 53 28 31 13 60 46    2 14 58 43  
41 58 35    8 35    3 24    1 21 41 43    0 25 54    9 41 54    7 25 21    9  
62 59    7 43 31 21 57 13 59 41 17 49 19 54 21 39 33 42 18    2 60

For an illustration of the power of the strong error-control coding in JT9 and JT65, try looking at the channel symbols after changing a single character in the message. For example, change the grid locator from FN42 to FN43 in the JT65 message:

```
C:\WSJTX\bin> jt65code "G0XYZ K1ABC FN43"
      Message          Decoded          Err? Type
-----
1.  G0XYZ K1ABC FN43      G0XYZ K1ABC FN43      1:   Std Msg
```

Packed message, 6-bit symbols    61 36 45 30    3 55    3    2 14    5 33 41

Information-carrying channel symbols  
25 35 47    8 13    9 61 40 44    9 51    6    8 40 38 34    8    2 21 23 30  
51 32 56 39 35    3 50 48 30    8    5 40 18 54    9 24 30 26 61 23 11  
3 59    7    7 39    1 25 24    4 50 17 49 52 19 34    7    4 34 61    2 61

You will discover that every possible JT65 message differs from every other possible JT65 message in at least 52 of the 63 information-carrying channel symbols.

Here's an example using the QRA64 mode:



```
C:\WSJTX\bin qra64code "KA1ABC WB9XYZ EN37"
```

Message	Decoded	Err?	Type
1 KA1ABC WB9XYZ EN37	KA1ABC WB9XYZ EN37	1:	Std Msg

```
Packed message, 6-bit symbols 34 16 49 32 51 26 31 40 41 22 0 41
```

```
Information-carrying channel symbols
```

```
34 16 49 32 51 26 31 40 41 22 0 41 16 46 14 24 58 45 22 45 38 54 7 23 2 49 32 50 20 33
55 51 7 31 31 46 41 25 55 14 62 33 29 24 2 49 4 38 15 21 1 41 56 56 16 44 17 30 46 36
23 23 41
```

```
Channel symbols including sync
```

```
20 50 60 0 40 10 30 34 16 49 32 51 26 31 40 41 22 0 41 16 46 14 24 58 45 22 45 38 54 7
23 2 49 32 50 20 33 55 51 20 50 60 0 40 10 30 7 31 31 46 41 25 55 14 62 33 29 24 2 49
4 38 15 21 1 41 56 56 16 44 17 30 46 36 23 23 41 20 50 60 0 40 10 30
```

Execution of any of these utility programs with "-t" as the only command-line argument produces examples of all supported message types. For example, using `jt65code -t`:

```
C:\WSJTX\bin> jt65code -t
```

Message	Decoded	Err?	Type
1. CQ WB9XYZ EN34	CQ WB9XYZ EN34	1:	Std Msg
2. CQ DX WB9XYZ EN34	CQ DX WB9XYZ EN34	1:	Std Msg
3. QRZ WB9XYZ EN34	QRZ WB9XYZ EN34	1:	Std Msg
4. KA1ABC WB9XYZ EN34	KA1ABC WB9XYZ EN34	1:	Std Msg
5. KA1ABC WB9XYZ RO	KA1ABC WB9XYZ RO	1:	Std Msg
6. KA1ABC WB9XYZ -21	KA1ABC WB9XYZ -21	1:	Std Msg
7. KA1ABC WB9XYZ R-19	KA1ABC WB9XYZ R-19	1:	Std Msg
8. KA1ABC WB9XYZ RRR	KA1ABC WB9XYZ RRR	1:	Std Msg
9. KA1ABC WB9XYZ 73	KA1ABC WB9XYZ 73	1:	Std Msg
10. KA1ABC WB9XYZ	KA1ABC WB9XYZ	1:	Std Msg
11. CQ 000 WB9XYZ EN34	CQ 000 WB9XYZ EN34	1:	Std Msg
12. CQ 999 WB9XYZ EN34	CQ 999 WB9XYZ EN34	1:	Std Msg
13. CQ EU WB9XYZ EN34	CQ EU WB9XYZ EN34	1:	Std Msg
14. CQ WY WB9XYZ EN34	CQ WY WB9XYZ EN34	1:	Std Msg
15. ZL/KA1ABC WB9XYZ	ZL/KA1ABC WB9XYZ	2:	Type 1 pfx
16. KA1ABC ZL/WB9XYZ	KA1ABC ZL/WB9XYZ	2:	Type 1 pfx
17. KA1ABC/4 WB9XYZ	KA1ABC/4 WB9XYZ	3:	Type 1 sfx
18. KA1ABC WB9XYZ/4	KA1ABC WB9XYZ/4	3:	Type 1 sfx
19. CQ ZL4/KA1ABC	CQ ZL4/KA1ABC	4:	Type 2 pfx
20. DE ZL4/KA1ABC	DE ZL4/KA1ABC	4:	Type 2 pfx
21. QRZ ZL4/KA1ABC	QRZ ZL4/KA1ABC	4:	Type 2 pfx
22. CQ WB9XYZ/VE4	CQ WB9XYZ/VE4	5:	Type 2 sfx
23. HELLO WORLD	HELLO WORLD	6:	Free text
24. ZL4/KA1ABC 73	ZL4/KA1ABC 73	6:	Free text
25. KA1ABC XL/WB9XYZ	KA1ABC XL/WB9	* 6:	Free text
26. KA1ABC WB9XYZ/W4	KA1ABC WB9XYZ	* 6:	Free text
27. 123456789ABCDEFGH	123456789ABCD	* 6:	Free text
28. KA1ABC WB9XYZ EN34 000	KA1ABC WB9XYZ EN34 000	1:	Std Msg
29. KA1ABC WB9XYZ 000	KA1ABC WB9XYZ 000	1:	Std Msg
30. RO	RO	-1:	Shorthand
31. RRR	RRR	-1:	Shorthand
32. 73	73	-1:	Shorthand

MSK144 uses a binary channel code, so transmitted symbols have the value 0 or 1. Even numbered symbols (index starting at 0) are transmitted on the I (in-phase) channel, odd numbered symbols on the Q (quadrature) channel. A typical execution of `msk144code` is shown below.

```
C:\WSJTX\bin> msk144code "K1ABC W9XYZ EN37"
```

Message	Decoded	Err?	Type
1. K1ABC W9XYZ EN37	K1ABC W9XYZ EN37	1:	Std Msg

#### Channel symbols

```
110000100011001101010101001000111111001001001100110010011100001001000000
010110001011101111001010111011001100110101011000111101100010111100100011
```

```
C:\WSJTX\bin> msk144code "<KA1ABC WB9XYZ> R-03"
```

Message	Decoded	Err? Type
-----		
1. <KA1ABC WB9XYZ> R-03	<KA1ABC WB9XYZ> R-03	7: Hashed calls

Channel symbols

1000011100001000111011111010011011111010

## 20. Support

### 20.1. Help with Setup

The best source of help in setting up your station or configuring *WSJT-X* is the [WSJT Group](https://groups.yahoo.com/neo/groups/wsjtgroup/info) (<https://groups.yahoo.com/neo/groups/wsjtgroup/info>) at email address [wsjtgroup@yahoogroups.com](mailto:wsjtgroup@yahoogroups.com). The chances are good that someone with similar interests and equipment has already solved your problem and will be happy to help. To post messages here you will need to join the group.

### 20.2. Bug Reports

One of your responsibilities as a *WSJT-X* user is to help the volunteer programmers to make the program better. Bugs may be reported to [WSJT Group](https://groups.yahoo.com/neo/groups/wsjtgroup/info) (<https://groups.yahoo.com/neo/groups/wsjtgroup/info>) (email address [wsjtgroup@yahoogroups.com](mailto:wsjtgroup@yahoogroups.com)) or the WSJT Developers list ([wsjt-devel@lists.sourceforge.net](mailto:wsjt-devel@lists.sourceforge.net)). Again, you will need to join the group or subscribe to the list. You can register for the list [here](https://lists.sourceforge.net/lists/listinfo/wsjt-devel) (<https://lists.sourceforge.net/lists/listinfo/wsjt-devel>).

To be useful, bug reports should include at least the following information:

- Program version
- Operating system
- Concise description of the problem
- Exact sequence of steps required to reproduce the problem

### 20.3. Feature Requests

Suggestions from users often result in new program features. Good ideas are always welcome: if there's a feature you would like to see in *WSJT-X*, spell it out in as much detail as seems useful and send it to us at one of the email addresses given a few lines above. Be sure to explain why you think the feature is desirable, and what sort of other users might find it so.

## 21. Acknowledgements

The *WSJT* project was started in 2001. Since 2005 it has been an Open Source project, and it now includes programs *WSJT*, *MAP65*, *WSPR*, *WSJT-X*, and *WSPR-X*. All code is licensed under the GNU Public License (GPL). Many users of these programs, too numerous to mention here individually, have contributed suggestions and advice that have greatly aided the development of *WSJT* and its sister programs.

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**The algorithms, source code, look-and-feel of *WSJT-X* and related programs, and protocol specifications for the modes FSK441, FT8, JT4, JT6M, JT9, JT65, JTMS, QRA64, ISCAT, and MSK144 are Copyright © 2001-2017 by one or more of the following authors: Joseph Taylor, K1JT; Bill Somerville, G4WJS; Steven Franke, K9AN; Nico Palermo, IV3NWV; Greg Beam, KI7MT; Michael Black, W9MDB; Edson Pereira, PY2SDR; Philip Karn, KA9Q; and other members of the WSJT Development Group.**

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