

WSJT-X User Guide

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Version 2.7.0-Rc4

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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 “**W**ea**S**ig**J** communication by **K1JT**,” while the suffix “**-X**” indicates that *WSJT-X* started as an extended branch of an earlier program, *WSJT*, first released in 2001. Bill Somerville, G4WJS, Steve Franke, K9AN, and Nico Palermo, IV3NWV, have been major contributors to development of *WSJT-X* since 2013, 2015, and 2016, respectively. Bill Somerville died suddenly and unexpectedly in December 2021; Uwe Risse, DG2YCB, joined the core development team soon afterward, and Brian Moran, N9ADG, in 2022.

WSJT-X Version 2.7 offers eleven different protocols or modes: **FST4**, **FT4**, **FT8**, **JT4**, **JT9**, **JT65**, **Q65**, **MSK144**, **WSPR**, **FST4W**, and **Echo**. The first seven are designed for making reliable QSOs under weak-signal conditions. They use nearly identical message structure and source encoding. JT65 was designed for EME (“moonbounce”) on VHF and higher bands and is mostly used for that purpose today. Q65 is particularly effective for tropospheric scatter, rain scatter, ionospheric scatter, TEP, and EME on VHF and higher bands, as well as other types of fast-fading signals. JT9 was designed for the HF and lower bands. Its submode JT9A is 1 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. The “slow” modes use timed sequences of alternating transmission and reception. JT4, JT9, and JT65 use one-minute sequences, 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 four times faster (15-second T/R sequences) and less sensitive by a few dB. FT4 is faster still (7.5 s T/R sequences) and especially well-suited for radio contesting. FST4 is designed especially for the LF and MF bands. Both FST4 and Q65 offer a wide variety of timed sequence lengths, and Q65 a range of tone spacings for different propagation conditions. 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, scatter, and other propagation types) at signal levels 10 to 15 dB below those required for CW.

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”. MSK144 uses the same structured messages as the slow modes and optionally an abbreviated format with hashed callsigns.

Note that some of the modes classified as slow can have T/R sequence lengths as short as the fast modes. “Slow” in this sense implies message frames being sent only once per transmission. The fast modes in *WSJT-X* send their message frames repeatedly, as many times as will fit into the Tx sequence length.

WSPR (pronounced “whisper”) stands for **W**ea**S**ig**P**ropagation **R**eporter. 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 with two-minute sequences they can be decoded at signal-to-noise ratios as low as -31 dB in a 2500 Hz bandwidth. **FST4W** is designed for similar purposes, but especially for use on LF and MF bands. It includes optional sequence lengths as long as 30 minutes and reaches sensitivity thresholds as low as -45 dB. Users with internet access can automatically upload WSPR and FST4W reception reports to a central database called WSPRnet (<https://wspnet.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 and to make other measurements useful for optimizing your EME station’s performance.

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.

Version Numbers: *WSJT-X* release numbers have major, minor, and patch numbers separated by periods: for example, *WSJT-X* Version 2.1.0. Temporary *beta release* candidates are sometimes made in advance of a new general-availability release, in order to obtain user feedback. For example, version 2.1.0-rc1, 2.1.0-rc2, etc., would be beta releases leading up to the final release of v2.1.0. Release candidates should be used *only* during a short testing period. They carry an implied obligation to provide feedback to the program development group. Candidate releases should not be used on the air after a full release with the same number is made.

A companion program *MAP65*, written by K1JT, is designed for EME communication using the JT65 and Q65 protocols. When used with RF hardware providing coherent signal channels for two orthogonal polarizations, the program provides automatic polarization-matched reception for every JT65 or Q65 signal in a 90 kHz passband. On the Windows platform, *MAP65* is installed automatically along with *WSJT-X*.

1.1. New in Version 2.7

WSJT-X 2.7 introduces a new program called **QMAP**, a new Special Operating Activity **Q65 Pileup**, an option to **Update Hamlib** at the click of a button, and a number of other enhancements and bug fixes.

- QMAP and Q65 Pileup mode are of particular interest to those engaged in Earth-Moon-Earth (EME) communication, but other applications may be found for them as well. QMAP is currently available for Windows only; it is derived from MAP65, an older program used since 2007 for EME. QMAP provides single-polarization receive-only capabilities for any one of the 60-second submodes of Q65. It allows you to monitor all traffic in a 90 kHz sub-band while conducting EME QSOs in the usual way with *WSJT-X*. Q65 Pileup mode helps DX operators using Q65 in pileup circumstances with many simultaneous callers and very weak signals, such as those experienced by 6-meter EME DXpeditions. Further details on QMAP and Q65 Pileup mode are available in a Quick-Start guide posted here: https://wsjt.sourceforge.io/Quick_Start_WSJT-X_2.7_QMAP.pdf
- A button **Update Hamlib** now appears on the **Settings** → **Radio** tab. On Windows it allows the user to automatically download and install the latest version of the rig-control features in Hamlib. The previously used version is backed up, so you can easily revert the procedure if necessary. Names and dates of the active and backup versions are clearly displayed.
- Spotting to **PSK Reporter** has been made more efficient. Redundant spots are omitted, and all posts are spread more widely in time. If your station locator is changed, for example during portable operations, your new locator will be sent automatically to PSK Reporter.
- **Fox** mode now provides more convenient handling of the two callsign queues, and Fox's Log window displays statistical data on recent QSO rate. Multi-streamed messages transmitted by *MSHV* are now handled properly when *WSJT-X* is in **Hound** mode.
- The *cty.dat* file can now be updated by clicking a button on the **Settings** → **Colors** tab.
- The FT Roundup message protocol now allows the exchange of static 4-digit numbers in place of serial numbers. This extends the usability of the FT RU protocol for other contest types.
- Features for main-window switching between modes have been enhanced so that submode and status of the **Sh** and **Fast** checkboxes are saved and restored by mode. Right-click events were made more intuitive and consistent. Right-clicking the Q65 button enables Q65 Pileup mode, and a left-click brings you back to the normal Q65 mode. Right-click on the JT65 button switches to JT9 mode.
- Message averaging is now allowed only when **VHF features** are enabled. Main window text box labels are changed to read "Single Period Decodes" and "Average Decodes" when averaging is enabled.

Further details on minor changes can be found in the Release Notes, accessible from the *WSJT-X Help* menu.

1.2. Documentation Conventions

We include screen shots that illustrate many of the settings and features of *WSJT-X*. Keep in mind that *WSJT-X* is a multi-platform application: the detailed appearance of windows and user controls may be significantly different in Windows, Linux, or macOS environments. The underlying functionality is the same on all operating systems, however. Where desirable we call special attention to important platform differences.

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. User Interface in Other Languages

The *WSJT-X* user interface (UI) is now available in many languages. When a translated UI is available for the computer's default System Language, it will appear automatically on program startup. The UI language may be overridden if desired by starting *WSJT-X* with a command line option. For example, to start *WSJT-X* with its user interface in Spanish, enter this command at the prompt:

```
wsjtx --language es
```

1.4. How You Can Contribute

WSJT-X is part of an open-source project released under the [GNU General Public License](https://www.gnu.org/licenses/gpl-3.0.txt) (GPLv3). 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. We especially encourage those with translation skills to volunteer their help, either for this *User Guide* or for the program's user interface.

The project's source-code repository can be found at [SourceForge](https://sourceforge.net/p/wsjt/wsjtx/ci/master/tree/), and communication among the developers takes place on the email reflector `wsjt-devel@lists.sourceforge.net`. Bug reports and suggestions for new features, improvements to the *WSJT-X* User Guide, etc., may be sent there as well. You must join the group before posting to the email list.

1.5. License

Before using *WSJT-X*, please read our licensing terms [here](#).

2. System Requirements

- SSB transceiver and antenna
- Computer running Windows 7 or later, macOS 10.13 or later, or Linux
- 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 ± 1 second

3. Installation

Installation packages for released versions on Windows, Linux, and OS X are found on the [WSJT Home Page](https://wsjt.sourceforge.io/index.html) (<https://wsjt.sourceforge.io/index.html>). 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 [wsjt-2.7.0-rc4-win32.exe](https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt-2.7.0-rc4-win32.exe)

(<https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt-2.7.0-rc4-win32.exe>) (Windows 7 or later, 32-bit) or [wsjt-2.7.0-rc4-win64.exe](https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt-2.7.0-rc4-win64.exe) (<https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt-2.7.0-rc4-win64.exe>) (Windows 7 or later, 64-bit) 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* are stored in the chosen installation directory and its subdirectories.
- Logs and other writeable files are normally found in the directory

`C:\Users\<username>\AppData\Local\WSJT-X`.

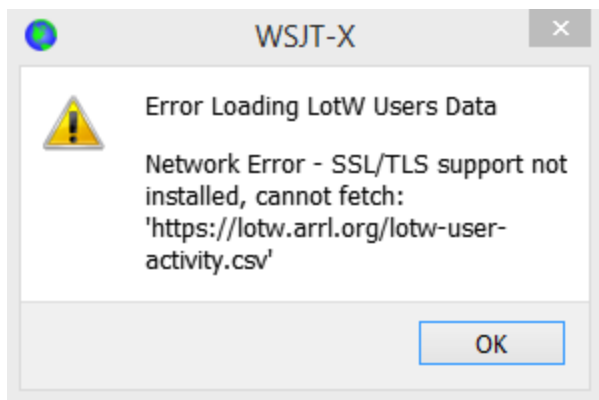


Your computer may be configured so that this directory is “invisible”. It’s there, however, and accessible. An alternative (shortcut) directory name is `“%LocalAppData%\WSJT-X\”`.

- The built-in Windows facility for time synchronization is usually not adequate. We recommend the program *Meinberg NTP Client*: see [Network Time Protocol Setup](https://www.satsignal.eu/ntp/setup.html) (<https://www.satsignal.eu/ntp/setup.html>) for downloading and installation instructions. Recent versions of Windows 10 are now shipped with a more capable Internet time synchronization service that is suitable if configured appropriately. We do not recommend SNTP time setting tools or others that make periodic correction steps, *WSJT-X* requires that the PC clock be monotonically increasing and smoothly continuous.



Having a PC clock that appears to be synchronized to UTC is not sufficient. “Monotonically increasing” means that the clock must not be stepped backwards. “Smoothly continuous” means that time must increase at a nearly constant rate, without steps. Any necessary clock corrections must be applied by adjusting the rate of increase, thereby correcting synchronization errors gradually.



- *WSJT-X* requires installation of the *OpenSSL* libraries. Suitable libraries may already be installed on your system. If they are not, you will see this error shortly after requesting a fetch of the latest LoTW users database. To fix this, install the *OpenSSL*

libraries.

- You can download a suitable *OpenSSL* package for Windows from [Windows OpenSSL Packages](https://slproweb.com/products/Win32OpenSSL.html) (<https://slproweb.com/products/Win32OpenSSL.html>); you need the latest **Windows Light** version. For the 32-bit *WSJT-X* build, use the latest Win32 v1.1.1 version of the *OpenSSL* libraries, for the 64-bit *WSJT-X* use the latest Win64 v1.1.1 version of the *OpenSSL* libraries (Note: it is OK to install both versions on a 64-bit system) which, at the time of writing, were [Win32 OpenSSL Light Package](https://slproweb.com/download/Win32OpenSSL_Light-1_1_1s.msi) (https://slproweb.com/download/Win32OpenSSL_Light-1_1_1s.msi) and [Win64 OpenSSL Light Package](https://slproweb.com/download/Win64OpenSSL_Light-1_1_1s.msi) (https://slproweb.com/download/Win64OpenSSL_Light-1_1_1s.msi) respectively.
- Install the package and accept the default options, including the option to copy the *OpenSSL* DLLs to the Windows system directory. There is no obligation to donate to the *OpenSSL* project. Un-check all the donation options if desired.



If you still get the same network error after installing the *OpenSSL* libraries then you also need to install the [Microsoft VC++ 2013 Redistributable](https://www.microsoft.com/en-ph/download/details.aspx?id=40784) (<https://www.microsoft.com/en-ph/download/details.aspx?id=40784>) component. From the download page select `vc_redist_x86.exe` for use with the 32-bit *WSJT-X* build or `vc_redist_x64.exe` with the 64-bit build, then run it to install.



If you cannot install the *OpenSSL* libraries or do not have an Internet connection on the computer used to run *WSJT-X* 2.7, you can download the *LoTW* file manually. Go to <https://lotw.arrl.org/lotw-user-activity.csv> in a web browser, download the file, then move it to the *WSJT-X* log files directory. This directory can be opened by selecting **File|Open log directory** from the main menu.

- *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 **Properties**, then **Advanced**, and select **16 bit, 48000 Hz (DVD Quality)**. Switch off all audio enhancement features for these devices.
- 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|Programs and Features** option or in **Settings|Apps** on Windows 10.

3.2. Linux

Debian, Ubuntu, and other Debian-based systems including Raspberry Pi OS:



The project team release binary installer packages targeted for one contemporary version of a Linux distribution. Although these may work on newer Linux versions or even different distributions, it is unlikely that they work on older versions. Check the notes provided with the release for details of the targeted Linux distributions and versions. If the binary package is not compatible with your Linux distribution or version, you must build the application from sources.

- 64-bit Intel/AMD: [wsjtx_2.7.0-rc4_amd64.deb](https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt_2.7.0-rc4_amd64.deb) (https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt_2.7.0-rc4_amd64.deb)
 - To install:

```
sudo dpkg -i wsjtx_2.7.0-rc4_amd64.deb
```

- 32-bit ARM hardware FP: [wsjtx_2.7.0-rc4_armhf.deb](https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt_2.7.0-rc4_armhf.deb) (https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/wsjt_2.7.0-rc4_armhf.deb)

- To install:

```
sudo dpkg -i wsjtx_2.7.0-rc4_armhf.deb
```

- 64-bit ARM: [wsjtx_2.7.0-rc4_arm64.deb](https://sourceforge.net/projects/wsjt/files/wsjtx-2.7.0-rc4/wsjtx_2.7.0-rc4_arm64.deb) (https://sourceforge.net/projects/wsjt/files/wsjtx-2.7.0-rc4/wsjtx_2.7.0-rc4_arm64.deb)

- To install:

```
sudo dpkg -i wsjtx_2.7.0-rc4_arm64.deb
```

- Uninstall for any of the above platforms:

```
sudo dpkg -P wsjtx
```

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

```
sudo apt install libgfortran5 libqt5widgets5 libqt5network5 \  
libqt5printsupport5 libqt5multimedia5-plugins libqt5serialport5 \  
libqt5sql5-sqlite libfftw3-single3 libgomp1 libboost-all-dev \  
libusb-1.0-0 libportaudio2
```

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

- 64-bit: [wsjtx-2.7.0-rc4-x86_64.rpm](https://sourceforge.net/projects/wsjt/files/wsjtx-2.7.0-rc4/wsjtx-2.7.0-rc4-x86_64.rpm) (https://sourceforge.net/projects/wsjt/files/wsjtx-2.7.0-rc4/wsjtx-2.7.0-rc4-x86_64.rpm)

- To install:

```
sudo rpm -i wsjtx-2.7.0-rc4-x86_64.rpm
```

- Uninstall:

```
sudo rpm -e wsjtx
```

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

```
sudo dnf install libgfortran fftw-libs-single qt5-qtbase \  
qt5-qtmultimedia qt5-qtserialport qt5-qtsvg \  
qt5-qtserialport libgomp boost libusbx portaudio
```

3.3. OS X and macOS

macOS10.13 and later: Download the file [wsjtx-2.7.0-rc4-Darwin.dmg](#)

(<https://sourceforge.net/projects/wsjt/files/wsjtx-2.7.0-rc4/wsjtx-2.7.0-rc4-Darwin.dmg>) to your desktop, double-click 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 (such as from *WSJT-X* to *WSJT-X_2.2*). 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.



If you are using macOS with an external audio device and find that Tx audio spontaneously switches to the motherboard sound device after a few transmissions, try setting the sample rate to 44100 Hz rather than the otherwise recommended 48000 Hz.

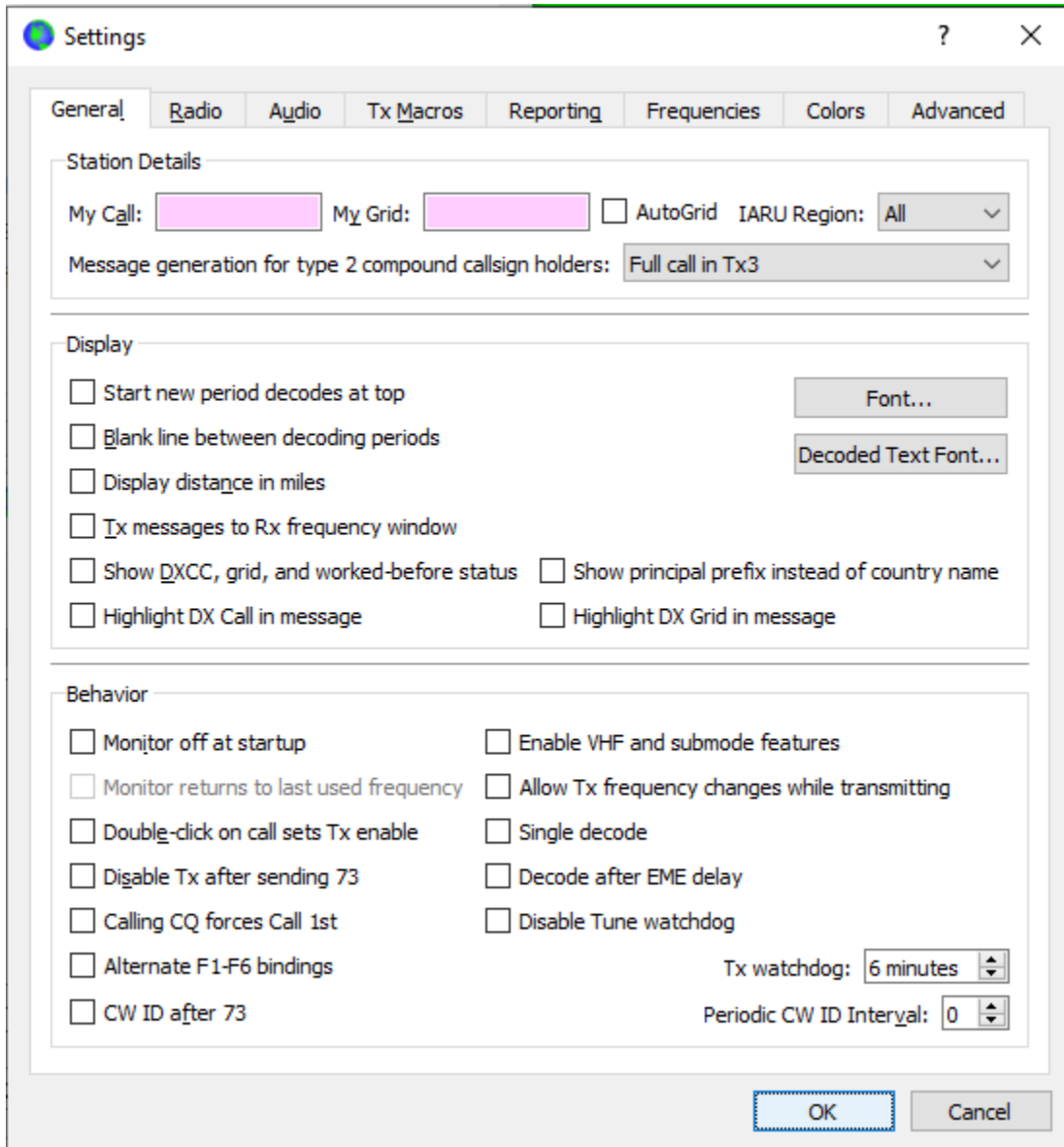
- Use **System Preferences** to select an external time source to keep your system clock synchronized to UTC.
- To uninstall simply drag the *WSJT-X* application from **Applications** to the **Trash Can**.

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 eight tabs selectable near the top of the window.

4.1. General

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.



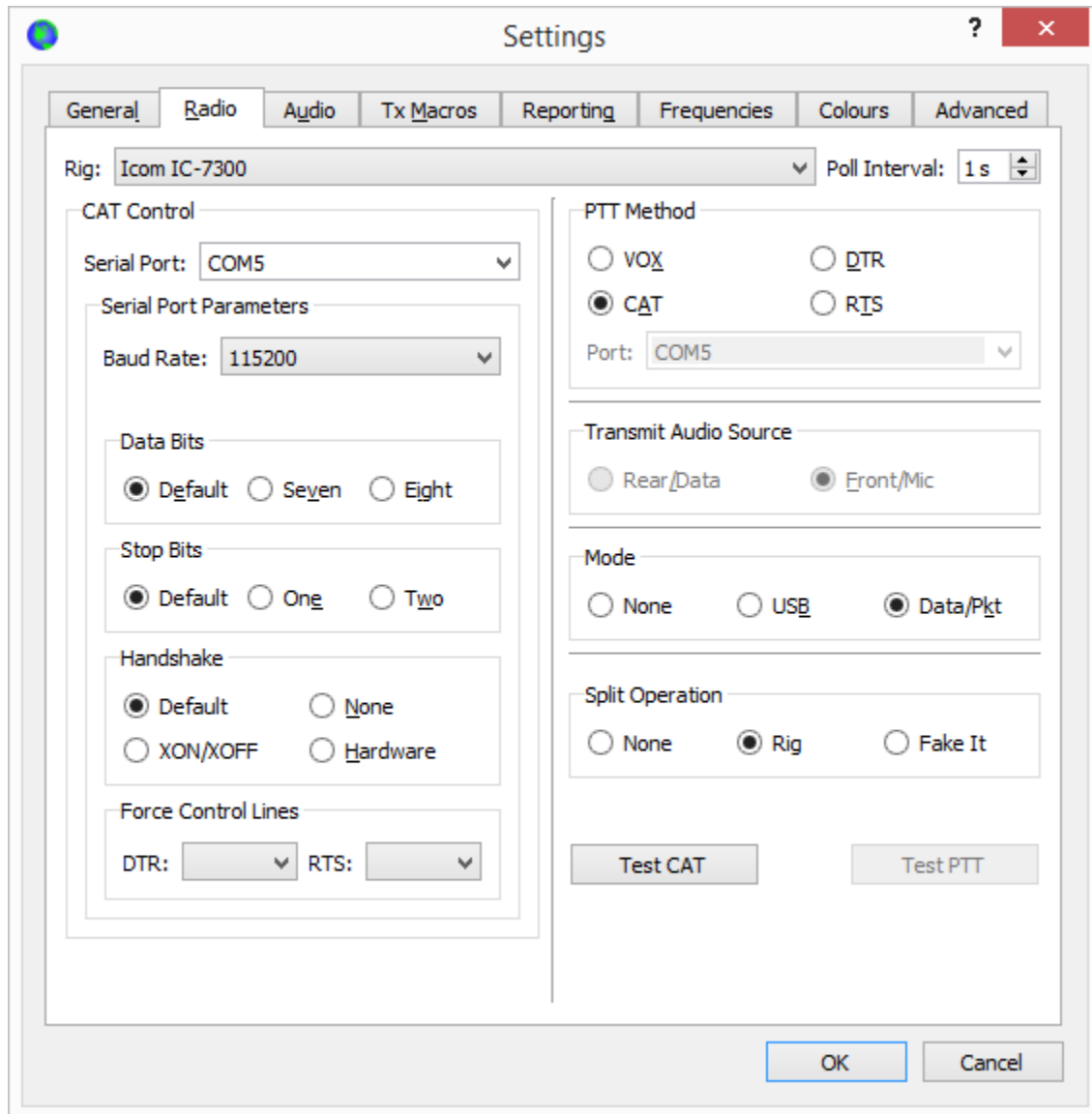
If you are using a callsign with an add-on prefix or suffix, or wish to work a station using such a call, be sure to read the section Nonstandard Callsigns.



Checking **Enable 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**, **Flrig**, **Ham Radio Deluxe**, **Hamlib NET rigctl**, or **Omni-Rig**, 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 **Omni-Rig Rig 1** or **Omni-Rig Rig 2** to connect to an **Omni-Rig** server installed on the same computer. **Omni-Rig** will be started automatically by **WSJT-X**.

- 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** or **Network Server** including the service port number used to communicate with your radio.



A special value of **USB** is available for custom USB devices like those used by some SDR kits. This is not the same as the virtual serial port provided by USB connected transceivers and CAT interfaces, for those use the COM or serial port name that refers to them.

- *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.



CAT interfaces that require handshaking will be non-responsive until the correct **Handshake** setting is applied.

- *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).



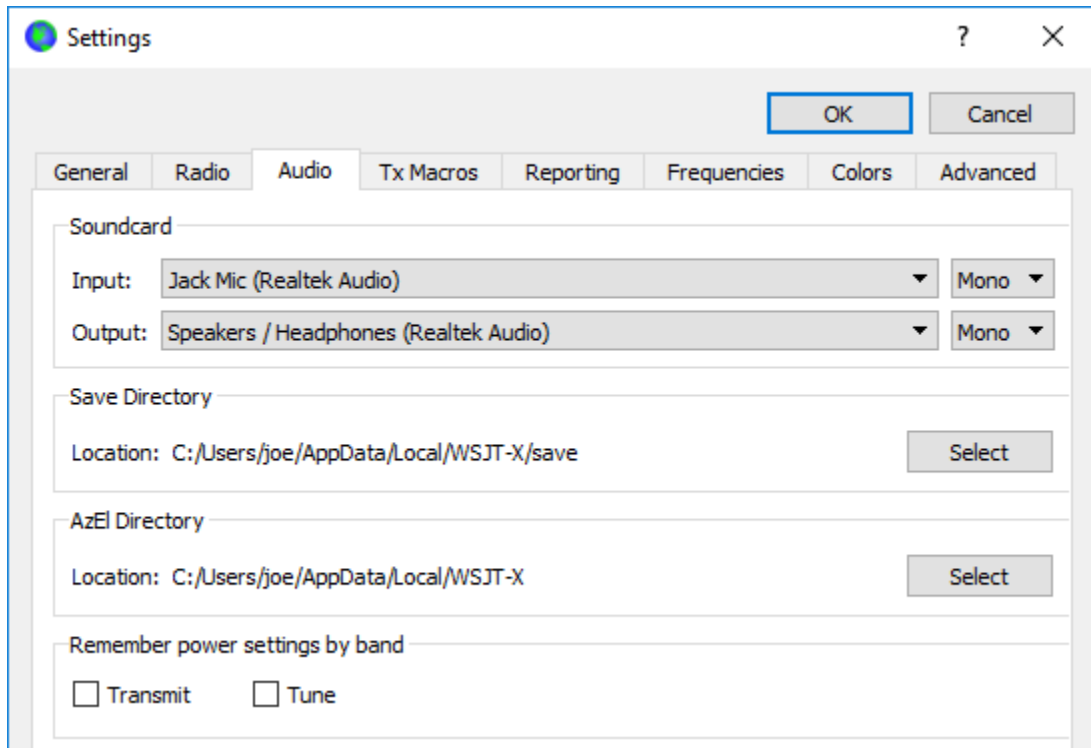
When using a proxy application for rig control, **CAT** is usually the correct option for *PTT Method* assuming the proxy application is capable of keying your transceiver independently.

- *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, the button turns red if the rig has been successfully keyed. (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.

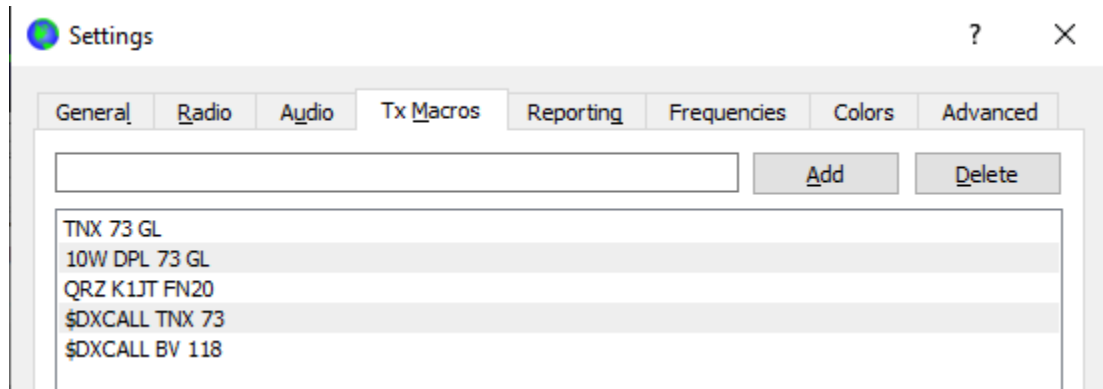


Windows 7 and later may configure audio devices using the Texas Instruments PCM2900 series CODEC for microphone input rather than line input. (This chip is used in many radios with built-in USB CODECs, as well as various other audio interfaces.) If you are using such a device, be sure to set the mic 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 below.



- To add a new message to the list, enter the desired text in the entry field at top, then click **Add**.
- Remember that a transmitted free-text message is limited to 13 characters, including blanks.
- 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. Simply hit [Enter] after the message has been entered.
- If the first word of a message is \$DXCALL (or the shortened form \$DX), that word will be replaced on transmission by the base callsign in the **DxCall** field.

4.5. Reporting

Settings

General | Radio | Audio | Tx Macros | Reporting | Frequencies | Colors | Advanced

Logging

Prompt me to log QSO Op Call:

Log automatically (contesting only)

Convert mode to RTTY

dB reports to comments

Clear DX call and grid after logging

Network Services

Enable PSK Reporter Spotting Use TCP/IP connection

UDP Server

UDP Server: Accept UDP requests

UDP Server port number: Notify on accepted UDP request

Accepted UDP request restores window

Secondary UDP Server (deprecated)

Enable logged contact ADIF broadcast

Server name or IP address:

Server port number:

OK Cancel

- **Logging:** Choose any desired options from this group. Operators in a multi-operator station may wish to enter their home callsign as **Op Call**.
- **Network Services:** Check **Enable PSK Reporter Spotting** to send reception reports to the **PSK Reporter** (<https://pskreporter.info/pskmap.html>) mapping facility.
- **UDP Server:** This group of options controls the network name or address and port number used to exchange information with a third party application that interoperates with *WSJT-X*. Exchanged information includes decoded messages, general program status, QSOs logged, highlighting of callsigns in the *WSJT-X* band activity window, and limited facilities to initiate QSOs in response to CQ or QRZ messages. Full details of the protocol can be found in comments at the top of this file in our source code repository: <https://sourceforge.net/p/wsjt/wsjt/ci/master/tree/Network/NetworkMessage.hpp>

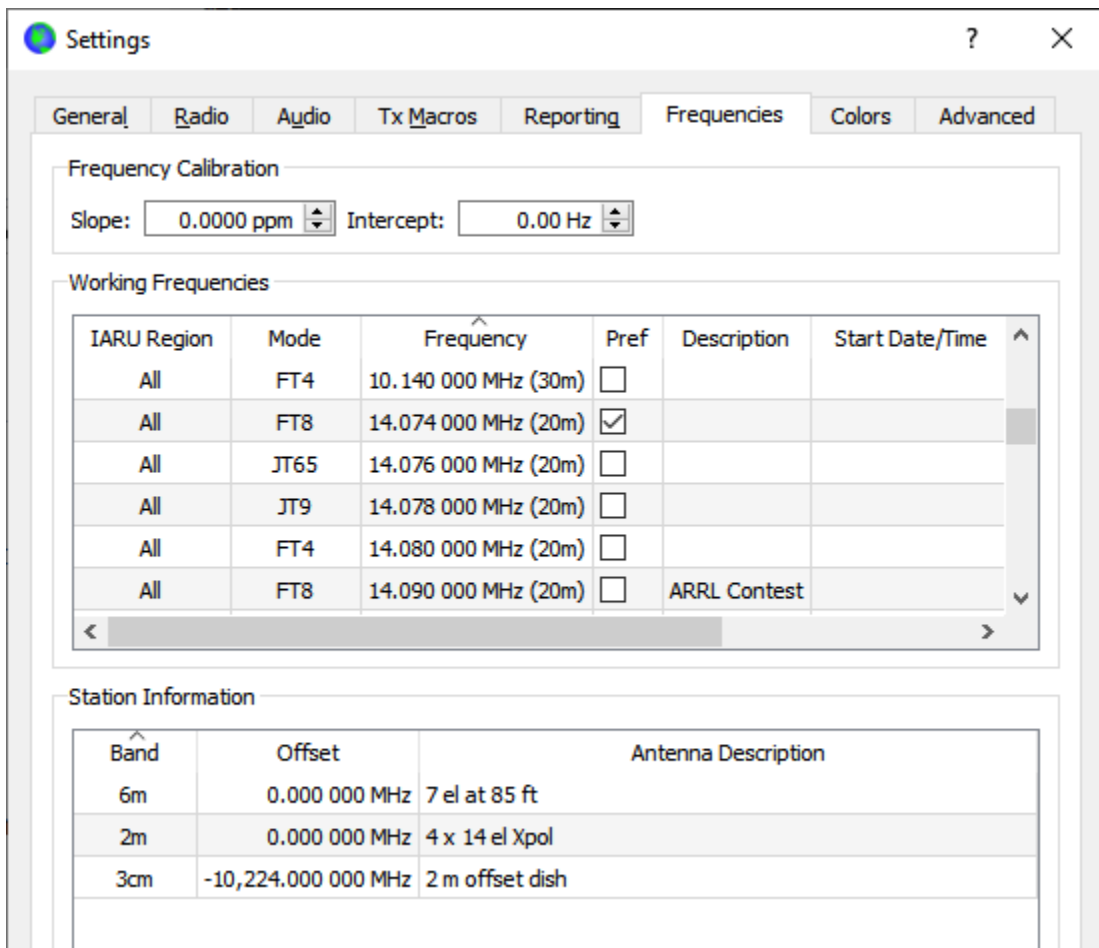


The **Outgoing interfaces** and **Multicast TTL** fields are only present when a multicast group IP address has been entered in the **UDP Server** field.

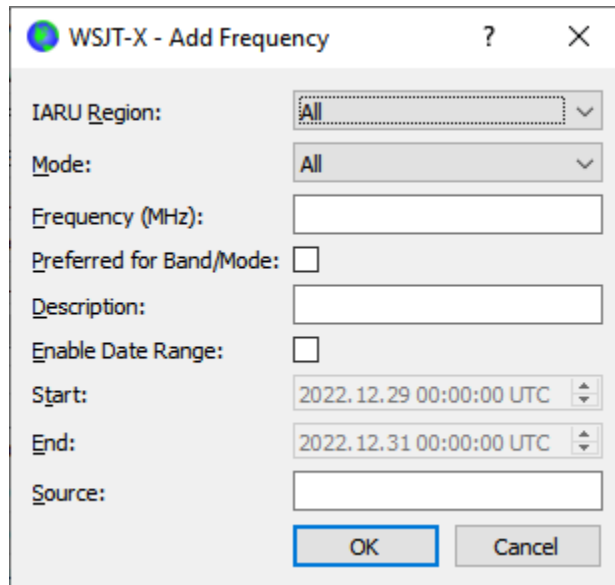
Programs like *JTAlert* use the **UDP Server** feature to obtain information about running *WSJT-X* instances. If you are using *JTAlert* to control *WSJT-X*, be sure to check the **Accept UDP requests** box.

4.6. Frequencies

By default, the **Working Frequencies** table contains a list of frequencies conventionally used for modes FT8, 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. You can mark an entry as Preferred, provide a descriptive label, and indicate starting and ending dates and times for it to be displayed on the band-select control. The program will format your changed entries appropriately.
- To add a new entry, right-click anywhere on the frequency table and select **Insert**. Enter your desired information and click **OK**. The table may include more than one frequency for a given mode and 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 anywhere within the table body and click **Reset** button to return the table to its default configuration.

Other more advanced maintenance operations are available on the right-click context popup 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](https://wsjt.sourceforge.io/FMT_User.pdf) (https://wsjt.sourceforge.io/FMT_User.pdf), enter the measured values for *Intercept A* and *Slope B* in the equation

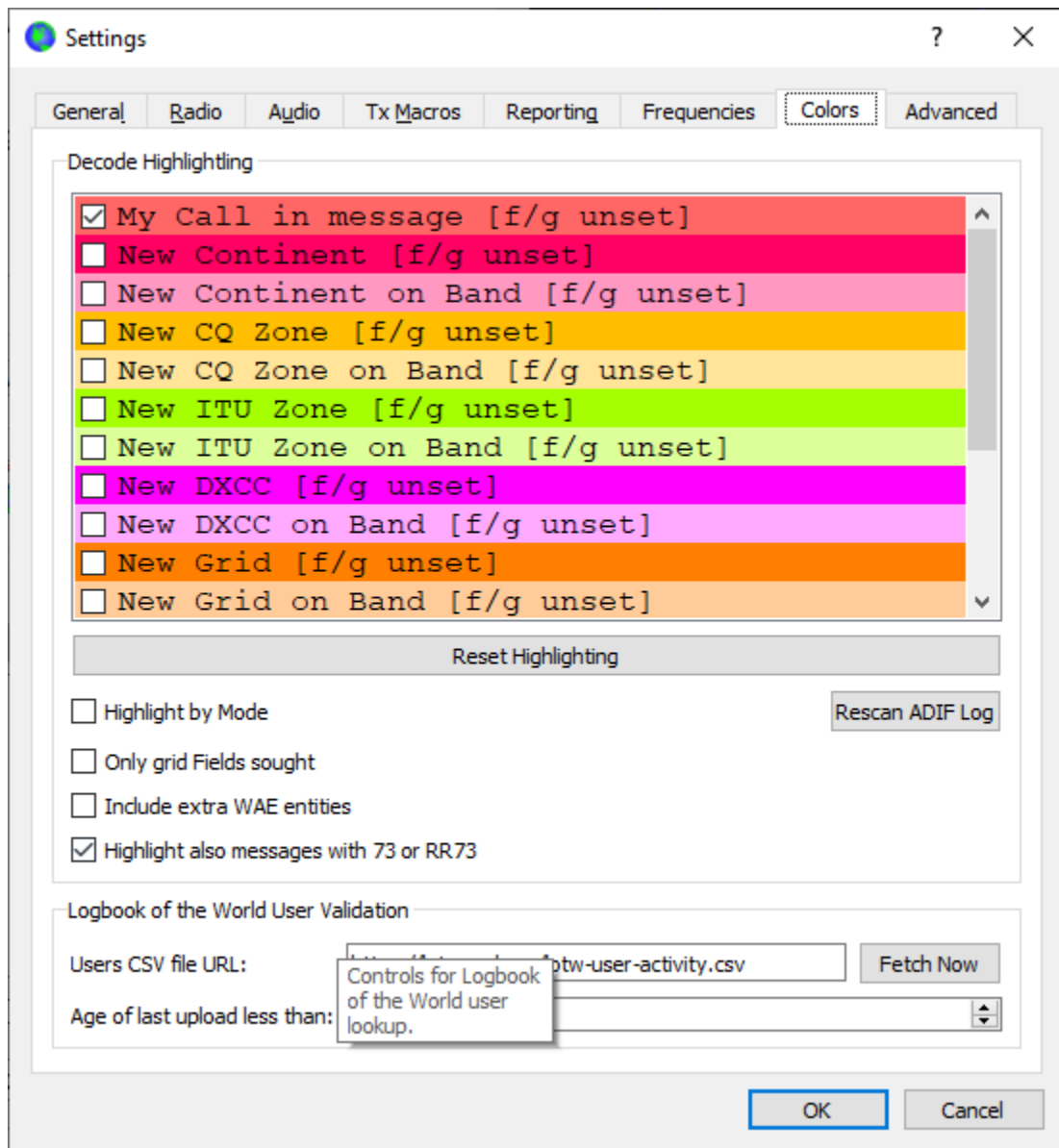
$$\text{Dial error} = A + B \cdot f$$

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](https://pskreporter.info/pskmap.html) (<https://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



Decode Highlighting

- *WSJT-X* uses colors to highlight decoded CQ messages of particular interest. Check the box **Show DXCC, grid, and worked-before status** on the **Settings | General** tab, and any boxes of interest to you on the **Colors** tab. You can drag any line up or down to raise or lower its logical priority. Right-click any line to set a new foreground or background color. Foreground and background colors are applied separately, and careful choices of foreground, background, and priority can provide two indications of worked-before status.
- Press the **Reset Highlighting** button to reset all of the color settings to default values.
- Check **Highlight by Mode** if you wish worked before status to be per mode.
- Check **Only grid Fields sought** if you are only interested in the leading two character grid locator Fields rather than the four character grid locator Squares.
- Check **Include extra WAE entities** if you are interested in the extra entities defined for DARC WAE and CQ Marathon awards.
- Worked before status is calculated from your *WSJT-X* ADIF Logging file, you may replace ADIF log file with one exported from your station logging application, **Rescan ADIF Log** rebuilds the *WSJT-X* worked before indexes using the current ADIF log file.



The *WSJT-X* ADIF file records must contain the "CALL" field. The "BAND", and "MODE", and "GRIDSQUARE" fields are optional depending on your DXing objectives. DXCC entity, continent, CQ, and ITU Zone data for call prefixes and certain well known overrides are derived from the *cty.dat* database which is bundled with *WSJT-X* (See Logging for details).

Logbook of The World User Validation

Stations who are known to have uploaded their logs to the ARRL LoTW QSL matching service can be highlighted. The data used to determine this is available online.

- **Fetch Now** will download a fresh dataset from the **Users CSV file URL**. The LoTW team normally update this data weekly.
- Adjust **Age of last upload less than** to set the period within which a station must have uploaded their log to LoTW to trigger highlighting.

4.8. Advanced

The screenshot shows the 'Settings' dialog box with the 'Advanced' tab selected. The 'JT65 VHF/UHF/Microwave decoding parameters' section includes 'Random erasure patterns' set to 6, 'Aggressive decoding level' set to 0, and a checked 'Two-pass decoding' checkbox. The 'Miscellaneous' section includes 'Degrade S/N of .wav file' set to 0.0 dB, 'Receiver bandwidth' set to 2500 Hz, and 'Tx delay' set to 0.2 s. There are checkboxes for 'Tone spacing' (x 2 and x 4) and 'Waterfall spectra' (Low sidelobes and Most sensitive). The 'Special operating activity' section is checked and includes radio buttons for 'Fox', 'Hound', 'NA VHF', 'ARRL Field Day', 'EU VHF Contest', 'FT Roundup', 'WW Digi Contest', 'ARRL Digi Contest', and 'CQ with individual contest name'. Text boxes for 'FD Exch:' (6A SNJ), 'FT RU Exch:' (NJ), and 'Contest name:' (PACC) are also visible. 'OK' and 'Cancel' buttons are at the bottom right.

JT65 VHF/UHF/Microwave 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 **x 2 Tone spacing** or **x 4 Tone spacing** to generate Tx audio with twice or four times the normal tone spacing. This feature is intended for use with specialized LF/MF transmitters that divide generated frequencies by 2 or 4 as part of the transmission process.

Special Operating Activity

- Check this box and select the type of activity to enable auto-generation of special message formats for contesting and DXpeditions. For **ARRL Field Day**, enter your operating Class and ARRL/RAC section; for **FT Roundup**, enter your state or province. Use "DX" for section or state if you are not in the US or Canada. In the FT Roundup, Stations in Alaska and Hawaii should enter "DX".
- Check **Fox** if you are a DXpedition station operating in FT8 DXpedition Mode. Check **Hound** if you wish to make QSOs with such a Fox. Be sure to read the operating instructions for [FT8 DXpedition Mode](https://wsjt.sourceforge.io/FT8_DXpedition_Mode.pdf) (https://wsjt.sourceforge.io/FT8_DXpedition_Mode.pdf).

4.9. Dark Style

An optional **Dark** style is available. To make it effective you will probably want to redefine your color settings. In Windows or Linux, start the program from a command-prompt window using the following command, or modify the *WSJT-X* desktop shortcut accordingly:

```
wsjtx --stylesheet :/qdarkstyle/style.qss
```

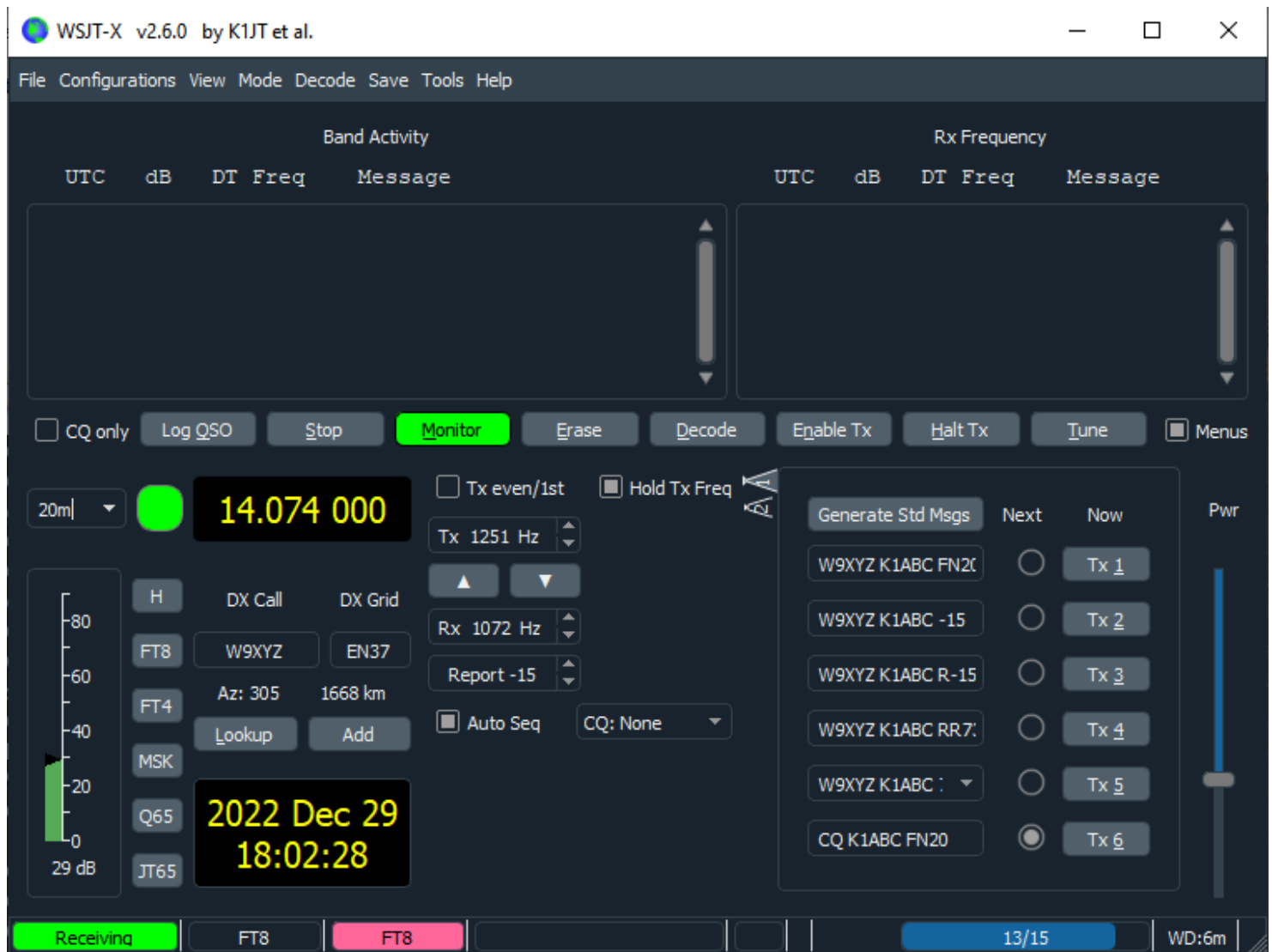
In macOS, enter the following command from a terminal:

```
open /Applications/wsjtx.app --args -stylesheet :/qdarkstyle/style.qss
```

In Linux using the Unity or GNOME GUI the following commands will update the *WSJT-X* start up:

```
sed '/Exec=wsjtx/ s/$/ -stylesheet :\\qdarkstyle\\style.qss/' \
/usr/share/applications/wsjtx.desktop >~/.local/share/applications/wsjtx.desktop
update-desktop-database ~/.local/share/applications/
```

Depending on your operating system, the main *WSJT-X* window will look something like this:



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.



The PC audio mixer normally has two sliders, one for each application attached which should be set to maximum (0dB FS) as it cannot help with distortion from overly high or low input levels from your receiver and another **Master** level which is analogue attenuator on the sound card before the Analogue to Digital Converter (ADC). The **Master** level can be used to adjust the signal level received by *WSJT-X*.

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.
- 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.

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

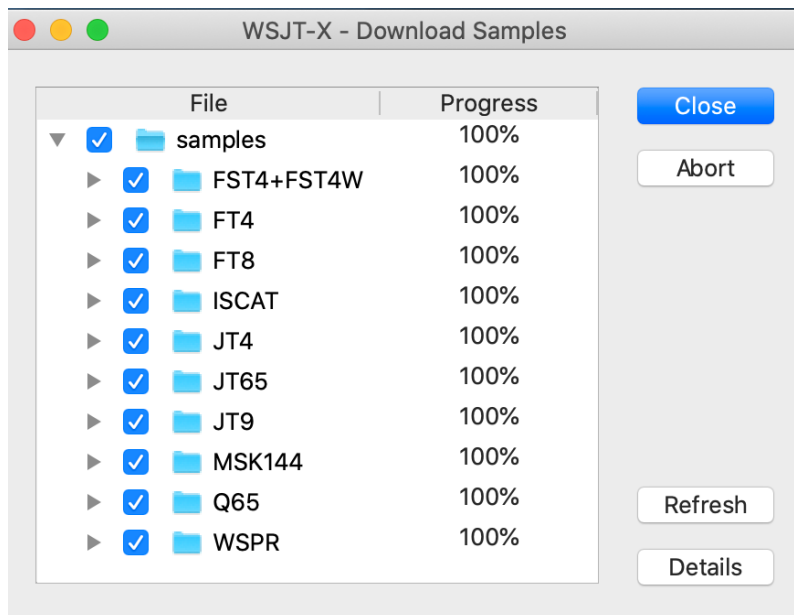
This section introduces the basic user controls and program behavior of *WSJT-X*, with particular emphasis on the FT8 mode. We suggest that new users should go through the full HF-oriented tutorial, preferably while at your radio.

Subsequent sections cover additional details on Making QSOs, WSPR mode and VHF+ Features.

6.1. Download Samples

The following steps will download sample audio Wave files that were originally recorded by *WSJT-X*. These files can be read in and processed by *WSJT-X* to simulate realtime operation.

- 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 FT8 files.



6.2. Wide Graph Settings

The *WSJT-X* Wide Graph window displays the frequency spectrum of the received audio. Usually, the upper portion of the window shows a waterfall plot of the frequency spectrum (a spectrogram) and a line plot of the current or average spectrum. Controls at the bottom of the window are used to set up the displayed audio frequency range, color palette, and scaling of the spectrum displays. A control on the bottom right of the Wide Graph (displayed as **Spec nn%**) lets you control the vertical fraction of the window occupied by the spectrum line plot. It is important to set appropriate lower and upper audio frequency limits for the Wide Graph because these limits define the FT8 decoder's search window. For this tutorial, the limits will be set to cover 100-3300 Hz:

- Set **Start** = 100 Hz.
- Set **Bins/Pixel** = 5. Smaller/larger values make the Wide Graph cover a smaller/larger frequency range.
- 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 3300 Hz.

The **N Avg** setting controls how many spectra are averaged to produce each line in the spectrogram. Smaller values make the

spectrogram update more frequently, resulting in signals being more spread out in the vertical (time) direction. On the other hand, larger values make it easier to detect very weak signals:

- Set **N Avg** = 2.

The **Palette** setting controls the color scheme used for the spectrogram:

- Set **Palette** = Fldigi

When **Flatten** is checked, WSJT-X attempts to correct for slope or curvature in the receiver's passband shape.

- **Flatten** = checked

The line plot can be set to display the current (un-averaged) spectrum or the cumulative (averaged) spectrum:

- Select **Cumulative** for data display
- Set the **Gain** and **Zero** sliders for the waterfall and spectrum to near midscale

The **Spec nn%** setting determines what fraction of the vertical extent of the Wide Graph will be used for the line plot of the spectrum. Setting **Spec** to 0 will eliminate the line plot and a setting of 100 will eliminate the spectrogram and show only the line plot:

- Set **Spec** = 50%

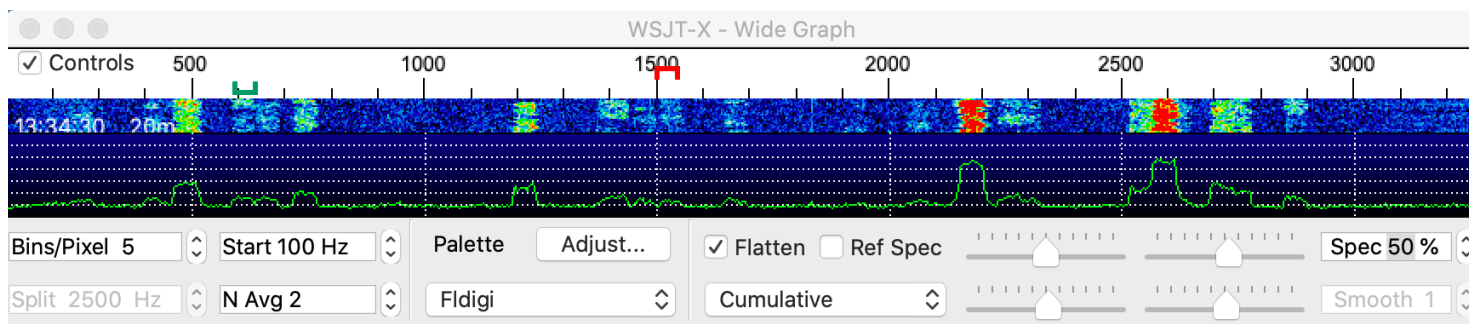
6.3. FT8

Main Window:

- Click the **Stop** button on the main window to halt any data acquisition.
- Select **FT8** from the **Mode** menu and **Deep** from the **Decode** menu.
- Double-click on **Erase** to clear both text windows.

Open a Wave File:

- Select **File | Open log directory** and navigate to ...\save\samples\FT8\210703_133430.wav. The waterfall and Band Activity/Rx Frequency windows should look something like the following screen shots:
- 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. Don't forget to change **My Call** back to your own call when you are done!



WSJT-X v2.5.0-rc4 by K1JT, G4WJS, K9AN, and IV3NWV

Band Activity					Rx Frequency				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
133430	17	0.3	2571	- W1FC F5BZB -08					
133430	15	-0.1	2157	- WM3PEN EA6VQ -09					
133430	-3	-0.8	1197	- CQ F5RXL IN94					
133430	-13	0.3	641	- N1JFU EA6EE R-07					
133430	-9	0.1	723	- A92EE F5PSR -14					
133430	-3	-0.1	2695	- K1BZM EA3GP -09					
133430	-14	0.3	400	- W0RSJ EA3BMU RR73					
133430	-15	0.3	590	- K1JT HA0DU KN07	133430	-15	0.3	590	- K1JT HA0DU KN07
133430	-7	0.4	2733	- W1DIG SV9CVY -14					
133430	-15	0.1	1648	- K1JT EA3AGB -15	133430	-15	0.1	1648	- K1JT EA3AGB -15
133430	-13	0.2	2852	- XE2X HA2NP RR73					
133430	-5	0.2	2522	- K1BZM EA3CJ JN01					
133430	-7	-0.1	2546	- WA2FZW DL5AXX RR73					
133430	-11	0.3	2238	- N1API HA6FQ -23					
133430	-2	0.2	466	- N1PJT HB9CQK -10					
133430	-17	0.7	1513	- N1API F2VX 73					
133430	-16	0.2	2606	- CQ DX DL8YHR JO41					
133430	-17	0.1	2039	- K1JT HA5WA 73	133430	-17	0.1	2039	- K1JT HA5WA 73
133430	-6	0.4	472	- KD2UGC F6GCP R-23					
133430	-15	0.1	2280	- CQ EA2BFM IN83					
133430	-17	0.5	244	- K1BZM DK8NE -10					

Decoding Overview

Decoding takes place at the end of a receive sequence. With **Decode** set to **Deep**, three decoding passes will be done and the **Decode** button on the main window will illuminate three times, once for each pass. The first decoding attempt in each decoding pass is done at the selected Rx frequency, indicated by the U-shaped green marker on the waterfall frequency scale. All decodes appear in the left (**Band Activity**) window. The right (**Rx Frequency**) text window displays any decodes obtained at the current Rx frequency along with any decodes addressed to **My Call** (K1JT in this case). The red marker on the waterfall scale indicates your Tx frequency.

Twenty-one FT8 signals are decoded from the example file. The number of decodes is shown in a box at the bottom of the main window. When this file was recorded HA5WA was finishing a QSO with K1JT, and his 73 message is shown in red because it is addressed to **My Call** (in this case K1JT). By default, lines containing **CQ** are highlighted in green, and lines with **My Call** (K1JT) in red. Notice that K1JT has two callers; HA0DU and EA3AGB.

Decoding Controls

To gain some feeling for controls frequently used when making QSOs, try double-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 one of the decoded **CQ** messages highlighted in green. These actions produce the following results:
 - Callsign and locator of the 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.
 - 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. (On a Mac computer, use the **command** key instead of **Ctrl**).
 - In addition, if **Double-click on call sets Tx enable** is checked on the **Settings | General** tab then **Enable Tx** will be activated so that a transmission will start automatically at the proper time.



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

- Double-click on the decoded message K1JT HA0DU KN07 , 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.
- 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 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.
- 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.



To avoid QRM from competing callers, it is usually best to answer a CQ on a different frequency from that of the CQing station. The same is true when you tail-end another QSO. Choose a Tx frequency that appears to be not in use. You might want to check the box **Hold Tx Freq**.



Keyboard shortcuts **Shift+F11** and **Shift+F12** provide an easy way to move your Tx frequency down or up in 60 Hz steps.



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.



An online [FT8 Operating Guide](https://www.g4ifb.com/FT8_Hinson_tips_for_HF_DXers.pdf) (https://www.g4ifb.com/FT8_Hinson_tips_for_HF_DXers.pdf) by ZL2IFB offers many additional tips on operating procedures.

FT8 DXpedition Mode:

This special operating mode enables DXpeditions to make FT8 QSOs at very high rates. Both stations must use *WSJT-X* Version 1.9 or later. Detailed operating instructions for [FT8 DXpedition Mode](https://wsjt.sourceforge.io/FT8_DXpedition_Mode.pdf) (https://wsjt.sourceforge.io/FT8_DXpedition_Mode.pdf) are available online. Do not try to use DXpedition mode without reading these instructions carefully!



FT8 DXpedition mode is intended for use by rare-entity DXpeditions and other unusual circumstances in which sustained QSO rates well above 100/hour are expected. Do not use the multi-signal capability unless you satisfy this requirement, and do not use DXpedition Mode in the conventional FT8 sub-bands. If you are contemplating operation as Fox using DXpedition Mode, find a suitable dial frequency consistent with regional band plans and publicize it for the operators you hope to work. Remember that on-the-air signal frequencies will be higher than the dial frequency by up to 4 kHz.



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

6.4. FT4

FT4 is designed for contesting, particularly on the HF bands and 6 meters. Compared with FT8 it is 3.5 dB less sensitive and requires 1.6 times the bandwidth, but it offers the potential for twice the QSO rate.

Main Window:

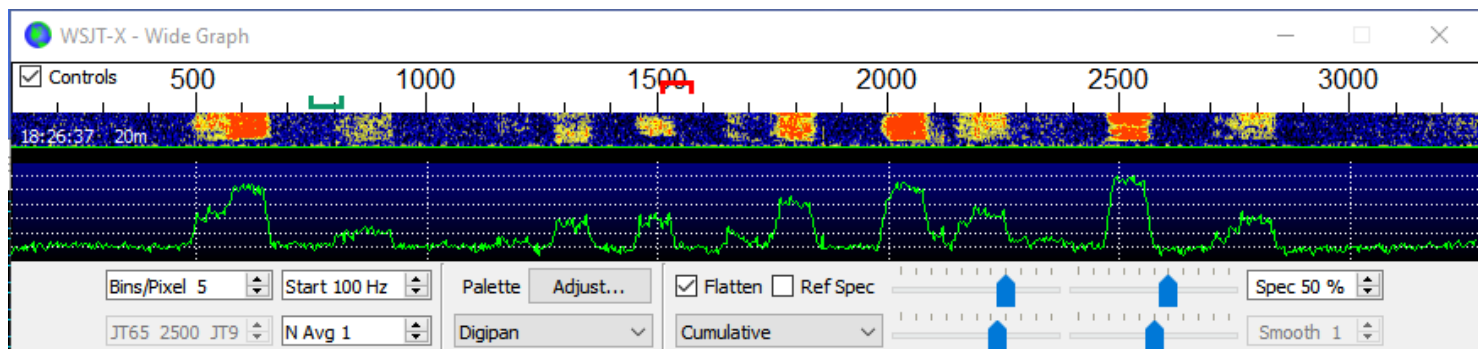
- Select **FT4** on the **Mode** menu.
- Double-click on **Erase** to clear both text windows.

Wide Graph Settings:

- **Bins/Pixel** = 5, **Start** = 100 Hz, **N Avg** = 1
- Adjust the width of the Wide Graph window so that the upper frequency limit is approximately 3300 Hz.

Open a Wave File:

- Select **File | Open** and navigate to ...\\save\\samples\\FT4\\200514_182053.wav. The waterfall and Band Activity window should look something like the following screen shots. This sample file was recorded during a practice contest test session, so most of the decoded messages use the **FT Roundup** message formats.



Band Activity					
UTC	dB	DT	Freq		Message
182053	6	0.1	581	+	VE7SA F5RRS -11
182053	-11	0.0	857	+	<...> SP7MOW R-15
182053	-7	-0.0	1285	+	K9IA HI8RMQ R-11
182053	-6	-0.1	1464	+	CQ F5PBG IN78
182053	-14	0.0	1655	+	CQ DX W3FOX FM19
182053	0	0.0	1768	+	CQ NA F6JON JN05
182053	7	0.5	2013	+	CQ LB8IB JO59
182053	-2	0.6	2189	+	EK1RR SP2WGB JO94
182053	-16	0.0	2314	+	CQ LZ2RR KN12
182053	10	0.1	2492	+	CQ EA3NP JN11
182053	-5	0.2	2768	+	KC3LEE O09A R-09
182053	1	0.4	584	+	K2FD K4DAY -03
182053	-14	-0.0	807	+	PY7KG DL8UNO -08
182053	-14	0.0	1746	+	CQ IZ8EYN JM89
182053	3	-0.0	1999	+	WA6LAU W6OAT +01
182053	-8	0.0	2155	+	NQ6N SM6MDF JO68
182053	-12	-0.1	2712	+	2E0GXQ AA3B +03
182053	-14	0.2	2237	+	CQ N2YBB FN30

- 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 both colored markers and both spinner controls will follow your selections.
- Now double-click on any of the lines of decoded text in the Band Activity window. Any line will show similar 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.

Best S+P Button

The FT4 user interface includes a button labeled **Best S+P**.

Tx even/1st Hold Tx Freq
 Tx 1000 Hz

 Rx 1000 Hz
 Report -15
 Auto Seq CQ: Max Dist

Clicking **Best S+P** during an Rx cycle arms the program to examine all CQ messages decoded at the end of the Rx sequence. The program will select the best potential QSO partner (from a contesting perspective), and treat it as if you had double-clicked on that

line of decoded text. Here "best potential QSO partner" means "New Multiplier" (1st priority) or "New Call on Band" (2nd priority). "New Multiplier" is currently interpreted to mean "New DXCC"; a more broadly defined multiplier category (for the FT Roundup rules) will be implemented in due course. We may provide additional priority rankings, for example "New Grid on Band" (useful for North American VHF contests), sorting by signal strength, etc.

Best S+P is a useful feature only if you have defined what "best" is supposed to mean. This is done by configuring suitable options on the **Settings | Colors** tab. Selection and ordering of color-highlighting options determines what potential QSO partners will be chosen by the "Best S+P" feature. Optimum choices will be different for different contests. In a contest using FT Roundup rules we recommend activating **My Call in message**, **New DXCC**, **New Call on Band**, **CQ in message** and **Transmitted message**, reading from top to bottom.



Keyboard shortcuts **Shift+F11** and **Shift+F12** provide an easy way to move your FT4 Tx frequency down or up in 90 Hz steps.



For easy keyboard control of transmitted messages, check **Alternate F1–F6 bindings** on the Settings | General tab. In contest-style operation you can then hit **F1** to solicit a QSO by sending CQ. Similarly, keys **F2** to **F5** will send the messages in entry fields **Tx2** to **Tx5**. More details on contest-style operation can be found in [The FT4 Protocol for Digital Contesting](https://wsjt.sourceforge.io/FT4_Protocol.pdf) (https://wsjt.sourceforge.io/FT4_Protocol.pdf).

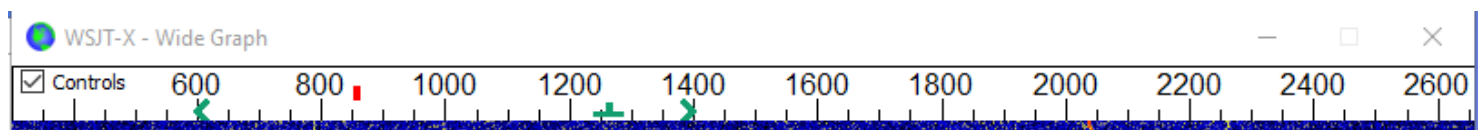


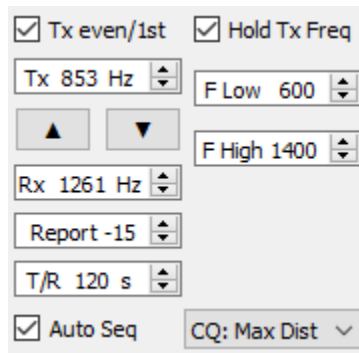
When finished with this Tutorial, don't forget to re-enter your own callsign as **My Call** on the **Settings | General** tab.

6.5. FST4

Do not confuse FST4 with FT4, which has a very different purpose! FST4 is designed primarily for making weak-signal 2-way QSOs on the LF and MF bands. T/R periods from 15 s up to 1800 s are available. Longer T/R periods provide better sensitivity only if Tx and Rx frequency instability and channel Doppler spread are small enough so that received signals remain phase coherent over periods spanning several transmitted symbols. Generally speaking, Rx and Tx frequency changes during the transmission and channel Doppler spread should each be small compared to the symbol keying rate shown for each T/R duration in Table 7 within section Protocol Specifications. For example, the keying rate for the 1800 s T/R period is 0.089 Baud, so successful operation using this T/R length requires Tx and Rx frequency stability better than 0.089 Hz over the duration of the 1800 s transmission in addition to channel Doppler spread smaller than 0.089 Hz.

Operation with FST4 is similar to that with other *WSJT-X* modes: most on-screen controls, auto-sequencing, and other features behave in familiar ways. However, operating conventions on the 2200 and 630 m bands have made some additional user controls desirable. Spin boxes labeled **F Low** and **F High** set lower and upper frequency limits used by the FST4 decoder, and these limits are marked by dark green angle-bracket symbols **< >** on the Wide Graph frequency scale:



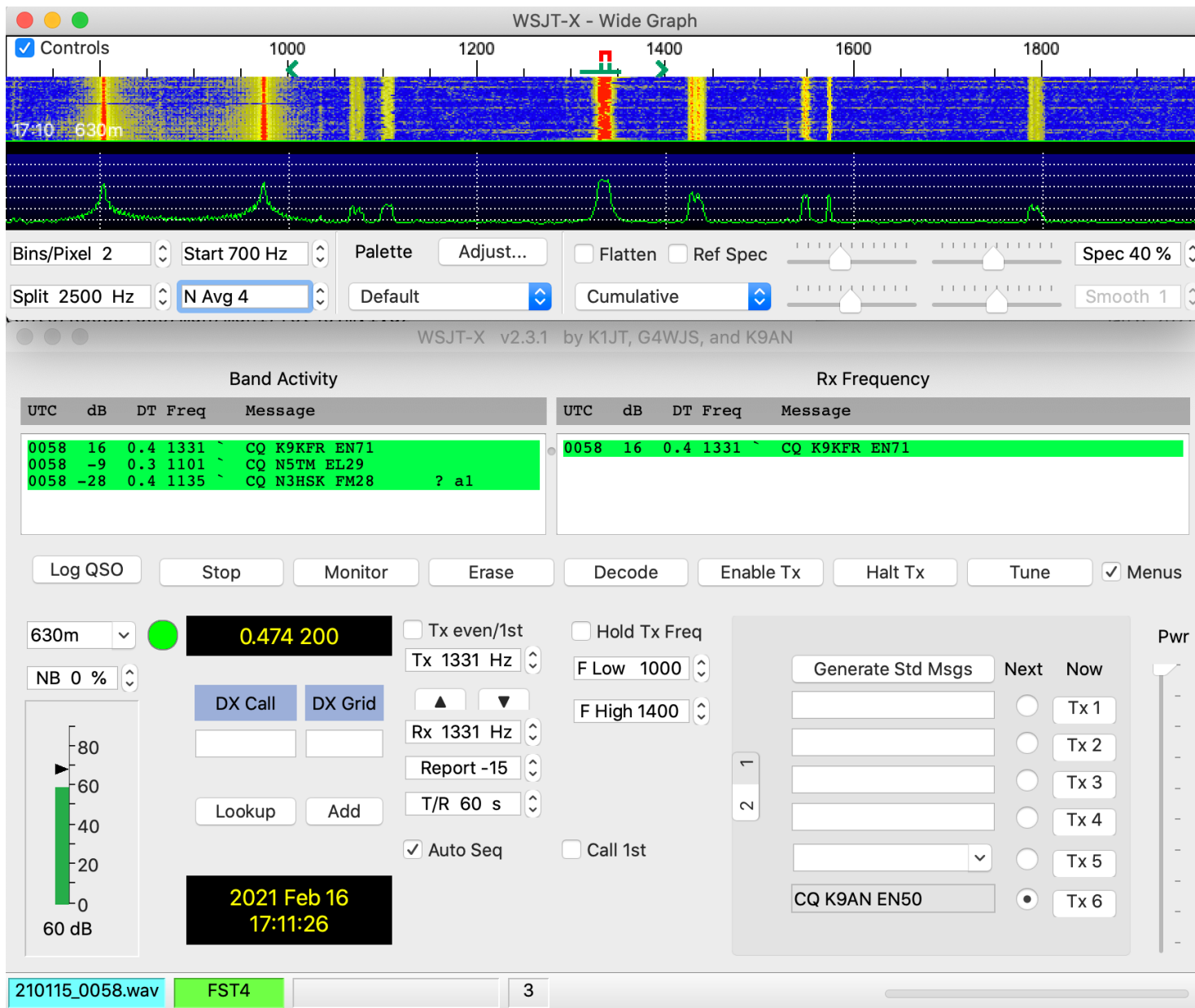


It's best to keep the decoding range fairly small, since QRM and transmissions in other modes or sequence lengths will slow down the decoding process (and of course will be undecodable). By checking **Single decode** on the **File | Settings | General** tab, you can further limit the decoding range to the setting of **F Tol** on either side of **Rx Freq**.

A noise blanker can be enabled by setting the **NB** percentage to a non-zero value. This setting determines how many of the largest-amplitude samples will be blanked (zeroed) before the data is submitted to the decoder. Most users find that settings between 0% (no blanking) and 10% work best. If the noise blanker percentage is set to -1%, then the decoder will try 0, 5, 10, 15, and 20 % in succession. Similarly, a setting of -2% causes the decoder to loop over blanking percentages 0, 2, 4, ... 20 %. To save time, the multiple blanking percentages triggered by negative **NB** settings are tried only for signal candidates located near (within +/- 20 Hz) of the **Rx** frequency setting.

Open a sample Wave File:

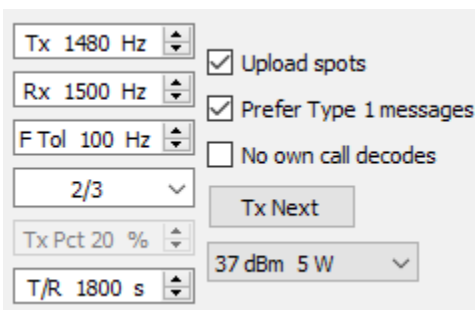
- Select **FST4** on the **Mode** menu. Set **T/R** to 60 s and **Decode | Deep**.
- Set **NB** (noise blanker) to 0%.
- Set up the Wide Graph display with settings appropriate for the FST4-60 mode. For example, try **Bins/Pixel 2** and **N Avg 4**. Set the **Start** frequency and the width of the Wide Graph to include the frequency range that you want to decode. For this example, make sure that **Start** is less than 1000 Hz and that the Wide Graph extends to above 1400 Hz.
- Set **F Low 1000**, **F High 1400**. These settings define the decoder's frequency search range.
- Open a sample Wave file using **File | Open** and select the file ...\\save\\samples\\FST4+FST4W210115_0058.wav. After **WSJT-X** has processed the file you should see something similar to the following screen shot:



6.6. FST4W

FST4W is used in the same way as WSPR, but FST4W has significant advantages for use on the 2200 m and 630 m bands. By default the central **Rx Freq** is 1500 Hz and **F Tol** is 100 Hz, so the active decoding range is 1400 to 1600 Hz. However, for added flexibility you can select different center frequencies and **F Tol** values. We expect that usage conventions will soon be established for FST4W activity on 2200 and 630 m.

A new drop-down control below **F Tol** offers a round-robin mode for scheduling FST4W transmissions:



If three operators agree in advance to select the options **1/3**, **2/3**, and **3/3**, for example, their FST4W transmissions will occur in a fixed sequence with no two stations transmitting simultaneously. Sequence 1 is the first sequence after 00:00 UTC. For WSPR-like scheduling behavior, you should select **Random** with this control.

Open a Wave File:

- Select **FST4W** on the **Mode** menu. Set **T/R** to 1800 s and **Decode | Deep**.
- Set **NB** to 0%.
- Select appropriate wide graph settings. For example, try **Bins/Pixel 1**, **Start 1200 Hz** and **N Avg 150**.
- Open a sample Wave file using **File | Open** and select the file ...\save\samples\FST4+FST4W201230_0300.wav. When it is finished you should see a single decode as shown in the screenshot:



Note that the weak signal associated with the single decode is all but invisible on the widegraph spectrogram.

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. Some operators prefer to send RR73 rather than RRR. This is workable because RR73 is encoded as a valid grid locator, one unlikely ever to be occupied by an amateur station.

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, and -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.

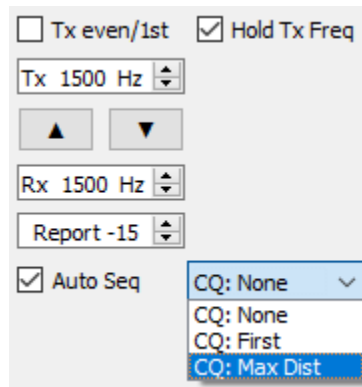
7.2. Free-Text Messages

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 T/R cycles of many *WSJT-X* modes allow only a few seconds to inspect decoded messages and decide how to reply. Often this is not enough time, so for FST4, FT4, FT8, MSK144, and Q65 the program offers a basic auto-sequencing feature.

Check **Auto Seq** on the main window to enable this feature:



When calling CQ you may choose to select **CQ: First** to reply automatically to the first decoded responder, or **CQ: Max Dist** to reply to the most distant responder.



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. Auto-sequencing is an operator aid, not an operator replacement.

7.4. Contest Messages

The FT4, FT8, and MSK144 protocols support special messages optimized for **NA VHF** and **EU VHF** contests. FT4 and FT8 also support messages for **ARRL Field Day**, **FT Roundup**, and the **WW Digi** contest. The decoders recognize and decode these messages at any time. Configure the program to automatically generate the required message types for contest exchanges and carry out suitable auto-sequencing by selecting a supported operating activity on the **Settings | Advanced** tab. Model QSOs then proceed as follows, for each event type:

NA VHF Contest and ARRL International Digital Contest

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

Either callsign (or both) may have /R appended to signify a Rover in a VHF contest. You can use RR73 in place of RRR, and the final 73 is optional.

EU VHF Contest

```
CQ TEST G4ABC I091
G4ABC PA9XYZ J022
<PA9XYZ> <G4ABC> 570123 I091NP
<G4ABC> <PA9XYZ> R 580071 J022DB
PA9XYZ G4ABC RR73
```

Either callsign (or both) may have /P appended.



Messages conveying signal reports, QSO serial numbers, and 6-character locators have been changed in *WSJT-X v2.2* and are **not compatible** with the formats used in earlier program versions. Be sure to upgrade *WSJT-X* if you will use **EU VHF Contest** messages.

ARRL Field Day

```
CQ FD K1ABC FN42
                                K1ABC W9XYZ 6A WI
W9XYZ K1ABC R 2B EMA
                                K1ABC W9XYZ RR73
```

FT Roundup

```
CQ RU K1ABC FN42
                                K1ABC W9XYZ 579 WI
W9XYZ K1ABC R 589 MA
                                K1ABC W9XYZ RR73
```

WW Digi Contest

```
CQ WW K1ABC FN42
                                K1ABC S52XYZ JN76
S52XYZ K1ABC R FN42
                                K1ABC S52XYZ RR73
```

Contest QSOs are generally treated as invalid when they appear in one station's log and not the supposed QSO partner's. To avoid Not-in-Log (NIL) penalties for yourself and others, we recommend the following guidelines for contest logging with FT4, FT8, and MSK144:

- Activate and learn to use the **Alternate F1-F6 bindings** selectable on the **Settings | General** tab.
- Always log a QSO when you have received RRR, RR73, or 73 from a station you are working.
- Log a QSO when you send RR73 or 73 if you are reasonably confident it will be copied. But be sure to watch for any indication that it was not copied, and then take appropriate action. For example, if you receive the Tx3 message (R plus contest exchange) again, and if you have activated the **Alternate F1-F6 bindings**, hit **F4** to re-send your RR73.

7.5. Nonstandard Callsigns

Modes with 77-bit message payloads: FST4, FT4, FT8, MSK144, and Q65

Compound callsigns like PJ4/K1ABC or K1ABC/3 and special event callsigns like YW18FIFA are supported for normal QSOs but not for contest-style messages. Model QSOs look something like this:

```

CQ PJ4/K1ABC
                <PJ4/K1ABC> W9XYZ
W9XYZ <PJ4/K1ABC> +03
                <PJ4/K1ABC> W9XYZ R-08
<W9XYZ> PJ4/K1ABC RRR
                PJ4/K1ABC <W9XYZ> 73

```

The compound or nonstandard callsigns are automatically recognized and handled using special message formats. One such callsign and one standard callsign may appear in most messages, provided that one of them is enclosed in < > angle brackets. If the message includes a grid locator or numerical signal report, the brackets must enclose the compound or nonstandard callsign; otherwise the brackets may be around either call.

Angle brackets imply that the enclosed callsign is not transmitted in full, but rather as a hash code using a smaller number of bits. Receiving stations will display the full nonstandard callsign if it has been received in full in the recent past. Otherwise it will be displayed as < . . . >. These restrictions are honored automatically by the algorithm that generates default messages for minimal QSOs. Except for the special cases involving /P or /R used in VHF contesting, *WSJT-X 2.7* offers no support for two nonstandard callsigns to work each other.



Using a nonstandard callsign has definite costs. It restricts the types of information that can be included in a message. It prevents including your locator in standard messages, which necessarily impairs the usefulness of tools like PSK Reporter.

Modes with 72-bit message payloads: JT4, JT9, and JT65

In the 72-bit modes, compound callsigns are handled in one of two possible ways:

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 callsigns

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 receives 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	
	K1ABC G0XYZ I091
G0XYZ K1ABC -19	
	K1ABC G0XYZ R-22
G0XYZ K1ABC RRR	
	K1ABC/VE1 73
CQ K1ABC FN42	
	DE G0XYZ/W4 FM18
G0XYZ K1ABC -19	
	K1ABC G0XYZ R-22
G0XYZ K1ABC RRR	
	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 **File | 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 ± 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 FT4, 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 supports a number of features designed for use on the VHF and higher bands. These features include:

- **FT4**, for contesting
- **FT8**, for fast QSOs with weak, fading signals
- **JT4**, for EME on the microwave bands
- **JT9 fast modes**, for scatter propagation on VHF bands
- **JT65**, for EME on VHF and higher bands
- **Q65**, for ionospheric scatter, tropospheric scatter, rain scatter, TEP, and EME
- **MSK144**, for meteor scatter
- **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 and submode features** and **Single decode**.
- For EME, check **Decode after EME delay** 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, HPSDR, 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.

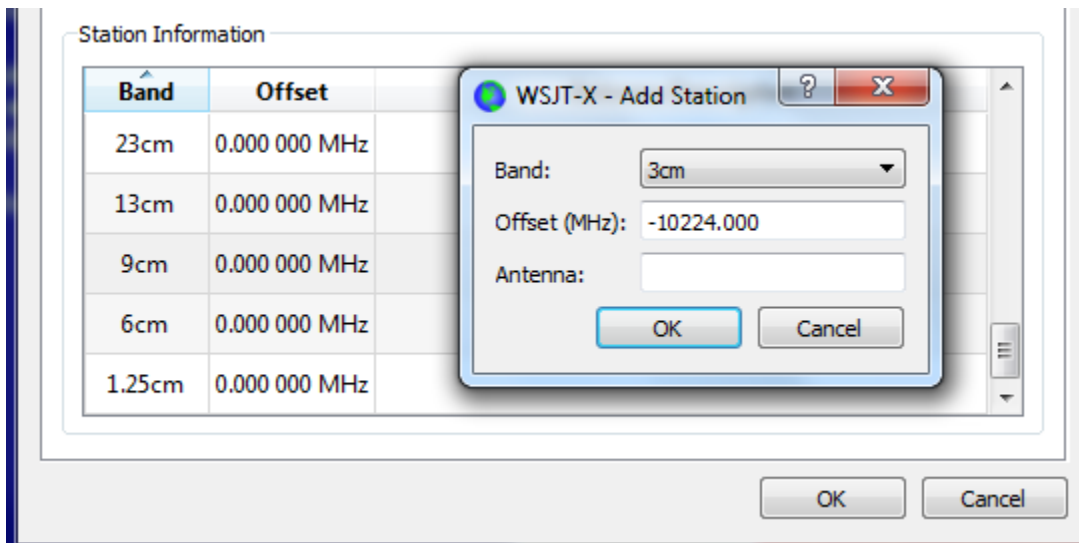


If your radio does not accept commands to change frequency while transmitting, Doppler tracking will be approximated with a single Tx frequency adjustment before a transmission starts, using a value computed for the middle of the Tx period.

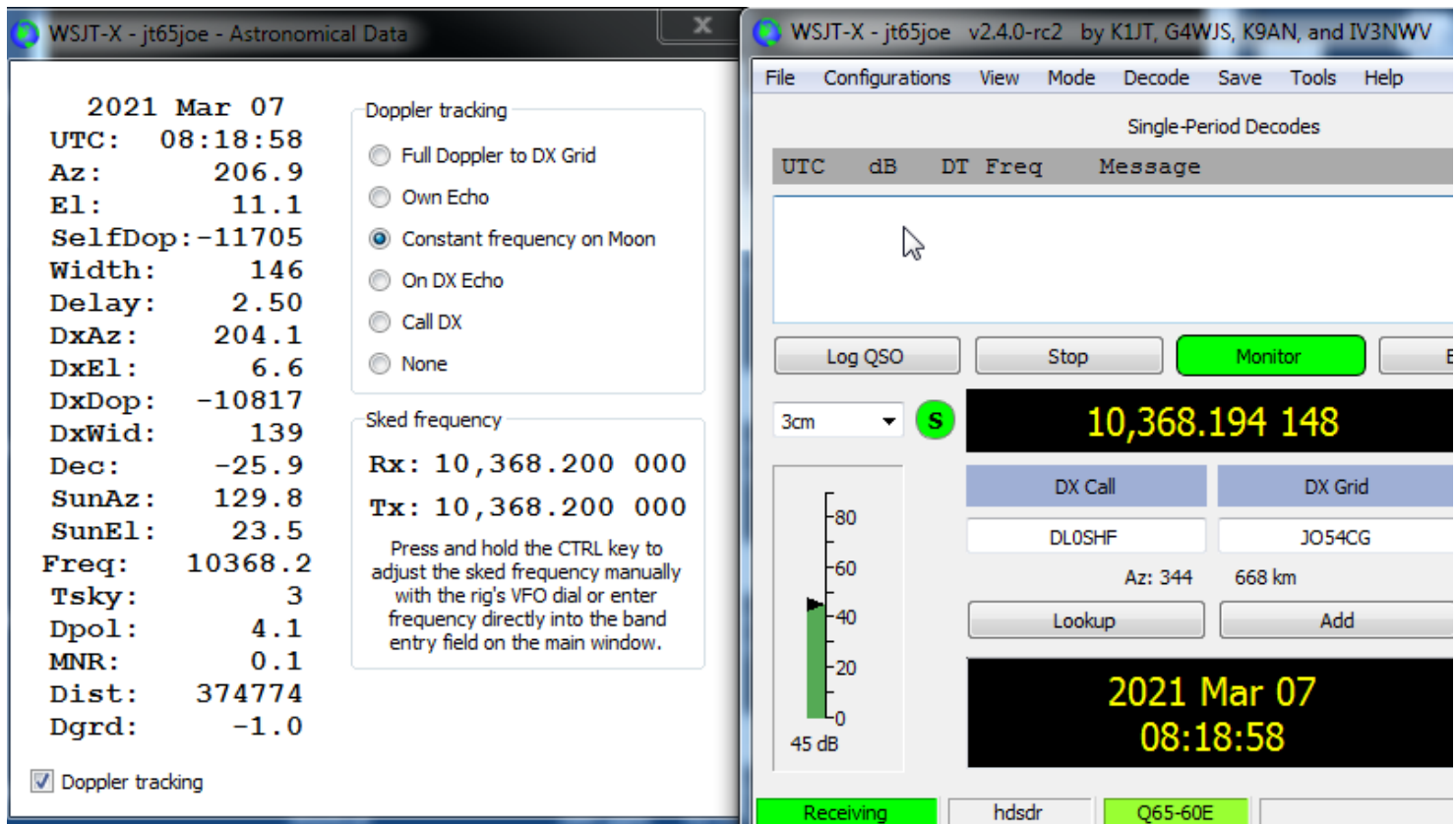
- On the **Radio** tab select **Split Operation** (use either **Rig** or **Fake It**; you may need to experiment with both options to find one that works best with your radio).
- On the right side of the main window select **Tab 1** to present the traditional format for entering and choosing Tx messages.

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**.



Five 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 **Own Echo** to enable EME Doppler tracking of your receive frequency to your own echo frequency. Your Tx frequency will remain fixed and is set to the Sked frequency. This mode can be used when announcing your CQ call on a specific frequency and listening on your own echo frequency. It can also be used for echo testing with Echo mode.
- Select **Constant frequency on Moon** to correct for your own one-way Doppler shift to or from the Moon. If your QSO partner

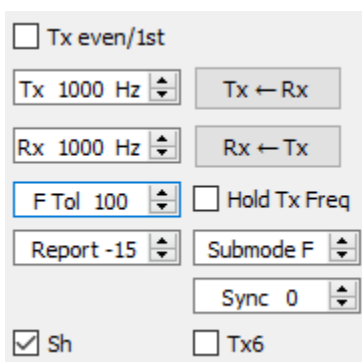
does the same thing, both stations will have the required Doppler compensation. Moreover, anyone else using this option will hear both of you without the need for manual frequency changes.

- Select **On Dx Echo** when your QSO partner announces his/her transmit frequency and that they are listening on their own echo frequency. When clicked, this Doppler method will set your rig frequency on receive to correct for the mutual Doppler shift. On transmit, your rig frequency will be set so that your QSO partner will receive you on the same frequency as they receive their own echo. Sked frequency in this case is set to that announced by your QSO partner.
- Select **Call DX** after tuning the radio manually to find a station, with the Doppler mode initially set to **None**. You may be tuning the band looking for random stations, or to a frequency where a station has been seen on an SDR display. It is usually necessary to hold down the Ctrl key while tuning the radio. From the moment **Call DX** is pressed, your transmit frequency is set so that your echo will fall on the same frequency you (and the DX station) are listening.
- 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.

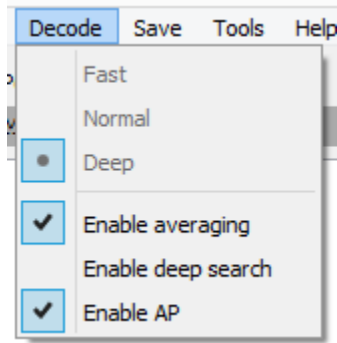
- Select **JT4** from the **Mode** menu. The central part of the main window will look something like this:



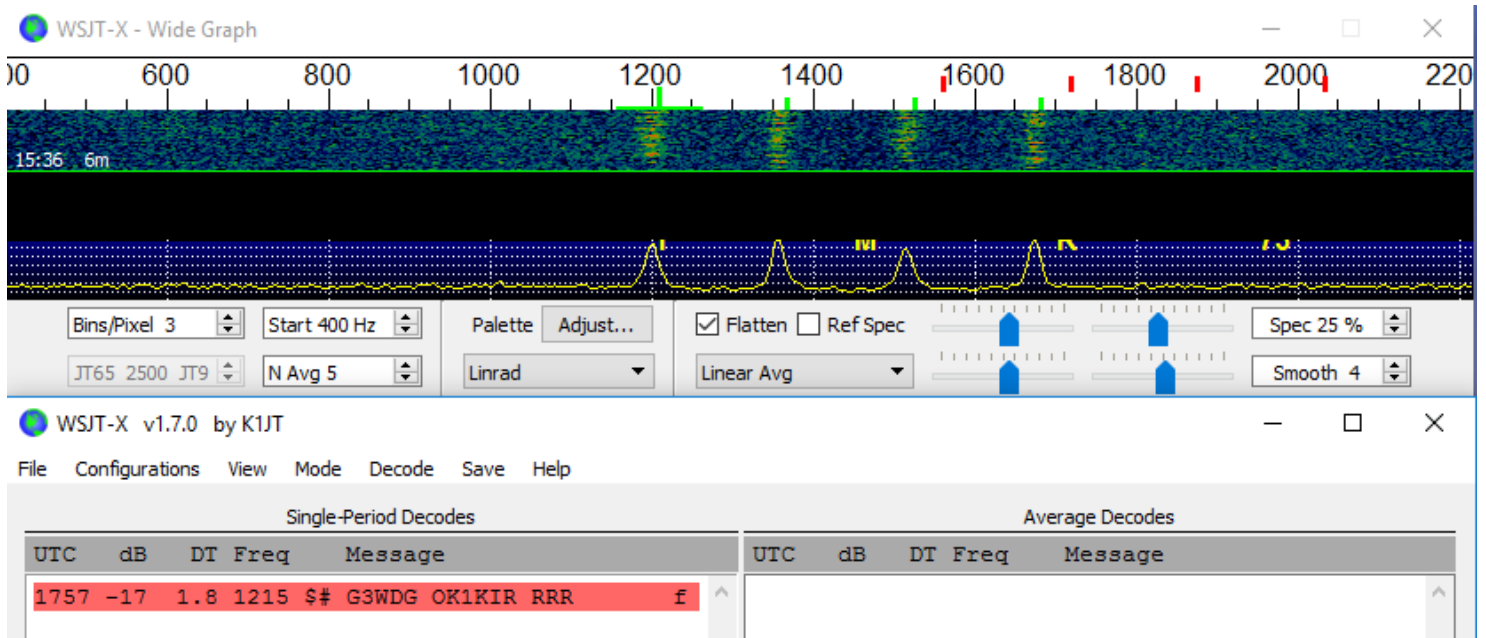
The screenshot shows a control panel for JT4 with the following elements:

- Tx even/1st
- Tx 1000 Hz (dropdown)
- Tx ← Rx (button)
- Rx 1000 Hz (dropdown)
- Rx ← Tx (button)
- F Tol 100 (dropdown)
- Hold Tx Freq
- Report -15 (dropdown)
- Submode F (dropdown)
- Sync 0 (dropdown)
- 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).



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. We recommend that you check **Single decode** on the **Settings** → **General** tab, and do not check **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. Deep** on the **Decode** menu will be automatically selected. You may optionally include **Enable averaging**, **Enable Deep search**, and **Enable AP**.

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.

The screenshot displays the WSJT-X software interface. At the top, a wide graph shows a frequency spectrum from 600 to 2200 kHz. A red horizontal bar highlights a signal between approximately 1500 and 1800 kHz. Below the graph, there are several control panels. The top panel includes settings for 'Bins/Pixel 3', 'Start 400 Hz', 'Palette Adjust...', 'Flatten', 'Ref Spec', 'Spec 25%', 'JT65 2500 JT9', 'N Avg 5', 'Linrad', 'Cumulative', and 'Smooth 4'. The middle panel shows 'Single-Period Decodes' and 'Average Decodes' tables. The bottom panel contains a control area with a frequency display showing '144.120 004', a signal strength indicator at '62 dB', and various control buttons like 'Log QSO', 'Stop', 'Monitor', 'Erase', 'Clear Avg', 'Decode', 'Enable Tx', 'Halt Tx', and 'Tune'. A 'Generate Std Msgs' section is also visible, listing messages like 'EA5SE K1JT FN20', 'EA5SE K1JT FN20 OOO', 'RO', 'RRR', '73', and 'CQ K1JT FN20'. The status bar at the bottom shows 'EA5SE_050819_000800.WAV', 'JT65 VHF', 'JT65 B', and '0/100 WD:5m'.

Single-Period Decodes						Average Decodes					
UTC	dB	DT	Freq	Message		UTC	dB	DT	Freq	Message	
0004	-21	3.7	1226	##	K1JT EA5SE IM98 OOO f	0004	-21	3.7	1226	##	K1JT EA5SE IM98 OOO f
0006	-20	5.9	1222	#	RRR	0006	-20	5.9	1222	#	RRR
0008	-21	-3.0	1220	#	73	0008	-21	-3.0	1220	#	73

8.4. Q65

Q65 is designed for fast-fading signals: tropospheric scatter, rain scatter, ionospheric scatter, trans-equatorial propagation (TEP), EME, and the like. The following screen shot shows a series of ionospheric scatter QSOs using submode Q65-30A on the 6 meter band. The received signals were barely audible most of the time.

WSJT-X - Wide Graph

Controls 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800

14:25:00 6m
14:24:00 6m
14:23:00 6m
14:22:00 6m
14:21:00 6m
14:20:00 6m

DT = 0.19

Bins/Pixel 4 Start 300 Hz Palette Adjust... Flatten Ref Spec Spec 20 %
Split 2500 Hz N Avg 5 Scope Q65_Sync Smooth 5

WSJT-X v2.4.0-rc2 by K1JT, G4WJS, K9AN, and IV3NWW

File Configurations View Mode Decode Save Tools Help

Single-Period Decodes Average Decodes

UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
141200	-10	0.2	1987	K1JT K01FP 73 q0	141900	-29	0.1	1804	K1JT W4IMD 73 q3
141300	-11	0.2	990	K1JT KG5CCI EM36 q0	141930	Tx	1800	1800	W4IMD K1JT 73
141400	-7	0.1	1803	K1JT KG5CCI R-04 q2	142000	-10	0.1	1801	K1JT W4IMD 73 q0
141500	-10	0.1	1803	K1JT W4IMD EM84 q0	142030	Tx	1800	1800	W4IMD K1JT 73
141600	-17	0.2	1803	K1JT KG5CCI 73 q3	142031	Tx	1800	1800	CQ K1JT FN20
141700	-17	0.0	1800	K1JT W4IMD EM84 q3	142100	-15	0.2	1814	K1JT KF2T FM19 q0
141800	-2	0.2	1807	K1JT W4IMD R-16 q3	142130	Tx	1800	1800	KF2T K1JT -15
141900	-29	0.1	1804	K1JT W4IMD 73 q3	142200	-11	0.2	1814	K1JT KF2T R-15 q3
142000	-10	0.1	1801	K1JT W4IMD 73 q0	142230	Tx	1800	1800	KF2T K1JT RRR
142100	-15	0.2	1814	K1JT KF2T FM19 q0	142300	-11	0.2	1814	K1JT KF2T 73 q3
142200	-11	0.2	1814	K1JT KF2T R-15 q3	142330	Tx	1800	1800	KF2T K1JT 73
142300	-11	0.2	1814	K1JT KF2T 73 q3	142400	-1	0.1	1801	K1JT W9DR EM78 q0
142400	-1	0.1	1801	K1JT W9DR EM78 q0	142430	Tx	1800	1800	W9DR K1JT -01
142500	0	0.2	1798	K1JT W9DR R-08 q3	142500	0	0.2	1798	K1JT W9DR R-08 q3
142500	-14	0.2	997	CQ KF2T FM19 q0	142530	Tx	1800	1800	W9DR K1JT RRR

Log QSO Stop Monitor Erase Clear Avg Decode Enable Tx Halt Tx Tune Menus

6m 50.275 000 Tx even/1st Tx 1800 Hz F Tol 50 Rx 1798 Hz Submode A Report -1 T/R 30 s Sh Auto Seq Call 1st Tx6

DX Call W9DR DX Grid EM78 Az: 260 912 km Lookup Add

2021 Mar 05 14:25:31

Generate Std Msgs Next Now Pwr

W9DR K1JT FN20	<input type="radio"/>	Tx 1
W9DR K1JT -01	<input type="radio"/>	Tx 2
W9DR K1JT R-01	<input type="radio"/>	Tx 3
W9DR K1JT RRR	<input checked="" type="radio"/>	Tx 4
W9DR K1JT 73	<input type="radio"/>	Tx 5
CQ K1JT FN20	<input type="radio"/>	Tx 6

Tx: W9DR K1JT RRR Q65 Q65-30A Last Tx: W9DR K1JT -01 0 0 1/30

The Q65 decoder takes advantage of *a priori* (AP) information such as the encoded forms of one's own callsign and the message word CQ . In normal usage, as a QSO progresses AP information increases to include the callsign of the station being worked and perhaps his/her 4-digit grid locator. The decoder takes advantage of whatever AP information is currently available.

For Q65 EME QSOs on the microwave bands, some operators use short-form 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** switches the Tx6 message from 1000Hz to 1250Hz to indicate to the other station that you are ready to receive messages. These short-form messages are not decoded automatically, and auto-sequencing will not respond to them. You must recognize and interpret them yourself.

8.5. 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 W or more, and a single yagi it can usually be done. The following screen shot shows two 15-second reception intervals containing MSK144 signals from three different stations.

The image shows two screenshots of the WSJT-X software interface. The top screenshot, titled "WSJT-X - Fast Graph", displays a waterfall plot of band activity from 0 to 14 MHz. A green line graph below the plot shows signal strength over time, with timestamps 12:08:00 and 19:40:45. The bottom screenshot shows the main control interface for WSJT-X v2.3.0 by K1JT, G4WJS, and K9AN. It includes a menu bar (File, Configurations, View, Mode, Decode, Save, Tools, Help), a "Band Activity" table, a "Tx Messages" table, and various control buttons and displays.

Band Activity				Tx Messages					
UTC	dB	T	Freq	Message	UTC	dB	T	Freq	Message
120500	8	8.7	1488	& K1JT WA4CQG EM72					
120800	5	4.6	1453	& CQ W4IMD EM84					
120800	7	12.2	1496	& CQ KD9VV EN71					

Control Panel Details:

- Mode: 20m
- Frequency: 14.078 000
- DX Call: WA4CQG, DX Grid: EM72
- Time: 2021 Feb 10 19:42:07
- Bandwidth: 33 dB
- Buttons: Log QSO, Stop, Monitor, Erase, Decode, Enable Tx, Halt Tx, Tune, Menus
- Settings: Tx even/1st, F Tol 200, Rx 1500 Hz, Report 0, T/R 15 s, Tx CQ 260, Sh, Auto Seq, SWL
- Message Queue:

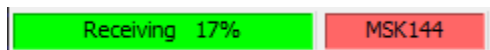
Generate Std Msgs	Next	Now
WA4CQG K1JT FN20	<input type="radio"/>	Tx 1
WA4CQG K1JT +00	<input type="radio"/>	Tx 2
WA4CQG K1JT R+00	<input type="radio"/>	Tx 3
WA4CQG K1JT RRR	<input type="radio"/>	Tx 4
WA4CQG K1JT :	<input type="radio"/>	Tx 5
CQ K1JT FN20	<input checked="" type="radio"/>	Tx 6

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
                                K1ABC W9XYZ EN37
W9XYZ K1ABC +02
                                <K1ABC W9XYZ> R+03
<W9XYZ K1ABC> RRR
                                <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.

8.6. Echo Mode

Echo mode provides tools for two types of measurements: echoes of your transmitted signal from the Moon, and broadband noise power received from the Sun, Moon, and possibly other sources including nearby ground. In each case the system noise temperature (noise power referred to the antenna terminals, expressed in Kelvin degrees) serves as the reference noise level. Such measurements are widely used for optimizing a station's capabilities for Earth-Moon-Earth (EME) communication.

For lunar echoes, *WSJT* generates short fixed-frequency transmissions that alternate with reception intervals at the appropriate Doppler-shifted frequency. Be sure that **Enable VHF and submode features** has been checked on the **Settings | General** tab. With **Split Operation** set to **Rig** or **Fake It** on the **Settings | Radio** tab, check **Doppler tracking** and **Own Echo** on the Astronomical Data window. Point your antenna at the Moon and click **Enable Tx** on the main window to start a sequence of echo

measurements. Each cycle takes 6 seconds. If strong enough, echoes will be visible in the waterfall. Their average spectrum will be displayed in the Echo Graph window, and numerical parameters of the measurements appear in the main window:

The screenshot displays the WSJT-X software interface, which is used for digital voice communication. It is divided into several main sections:

- Waterfall Plot (WSJT-X - Wide Graph):** Shows a frequency spectrum from 1300 to 1800 Hz. A prominent signal is visible at approximately 1500 Hz, highlighted in yellow.
- Echo Graph (WSJT-X - Echo Graph):** Shows a spectrum plot from -150 to 150 Hz, with a sharp peak at 0 Hz, indicating the presence of echoes.
- Data Table:** A table with 10 columns: UTC, Hour, Level, Doppler, Width, N, Q, DF, SNR, and dBerr. It lists 10 measurement cycles.
- Control Panel:** Includes buttons for 'Stop', 'Monitor', 'Erase', 'Clear Avg', 'Avg 100', 'Decode', 'Enable Tx', 'Halt Tx', and 'Tune'. It also features a frequency display showing 1,296.065 000 MHz and a power level indicator.
- Call Sign and Date/Time:** The call sign 'W2ZQ' and grid 'FN20OG' are displayed, along with the date '2022 Oct 06' and time '18:40:23'.
- File List:** At the bottom, a file named '220819_043557.wav' is shown, with 'Echo' selected.

UTC	Hour	Level	Doppler	Width	N	Q	DF	SNR	dBerr
043503	4.584167	53.55	2219	18.0	1	10	-1	-10.2	0.5
043509	4.585834	53.88	2219	18.0	2	10	-1	-9.5	0.5
043515	4.587500	53.70	2219	18.0	3	10	-1	-9.8	0.5
043521	4.589167	53.73	2219	18.0	4	10	-1	-10.3	0.5
043527	4.590833	53.73	2219	18.0	5	10	-2	-10.4	0.5
043533	4.592500	53.91	2219	18.0	6	10	-2	-9.9	0.5
043539	4.594167	53.50	2219	18.0	7	10	-1	-10.1	0.5
043545	4.595833	53.69	2219	18.0	8	10	-1	-9.9	0.5
043551	4.597500	53.62	2219	18.0	9	10	-1	-10.0	0.5
043557	4.599167	53.61	2219	18.0	10	10	-1	-9.9	0.5

At the end of each echo cycle a line of data in the main text window displays the following information:

UTC	Time in hhmss format
Hour	UTC in hours and decimal fraction
Level	Relative received noise power (dB)
Doppler	EME Doppler shift at center of lunar disk
Width	EME Doppler spread over full lunar disk
N	Number of accumulated echo or monitor cycles
Q	Estimated quality of averaged data on a 0 - 10 scale
DF	Offset of spectral peak from 1500 Hz
SNR	Average signal-to-noise ratio (dB/2500 Hz)
dBerr	Estimated uncertainty of SNR

i. more to come ...

8.7. Tips for EME

Until the advent of Q65, digital EME has mostly been done using JT65A on the 50 MHz band, JT65B on 144 and 432 MHz, and JT65C on 1296 MHz. On higher microwave bands typical choices have been JT65C, one of the wider JT4 submodes, or QRA64, depending on the expected amount of Doppler spread. We now recommend a suitable submode of Q65 (which has replaced QRA64) for EME on any VHF or higher band: for example, Q65-60A on 50 and 144 MHz, Q65-60B on 432 MHz, Q65-60C on 1296 MHz, and Q65-60D on 10 GHz.

JT4, JT65, and Q65 offer **Message Averaging** — the summation of subsequent transmissions that convey the same message — to enable decodes at signal-to-noise ratios several dB below the threshold for single transmissions. JT4 and JT65 also allow **Deep Search** decoding, in which the decoder hypothesizes messages containing known or previously decoded callsigns and tests them for reliability using a correlation algorithm. JT65 and Q65 offer *a priori* (AP) decoding, which takes advantage of naturally accumulating information during a QSO.

For CW mode on SHF and microwave EME WSJT-X can be used to do Doppler shift correction if desired:

- Check the **Settings** → **Radio** → **Mode** → **None** option, this stops *WSJT-X* from trying to set the mode of your rig.
- Put you rig into CW mode as normal.
- Before transmitting press **Tune** in *WSJT-X*, no tones will be transmitted as the rig is in CW mode, but importantly *WSJT-X* knows your are transmitting and adjusts the Doppler shift correction as needed for the currently selected Doppler shift correction mode in transmit.
- When you have finish transmitting CW press **Tune** again to revert to receive mode and the correct Doppler shift correction for receiving.



The above assumes you are already set up for *WSJT-X* Doppler shift correction with working CAT control, and **Monitor** enabled etc..

- 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 an executable file or script named `user_hardware`. This is done using `CMD /C user_hardware <band>` on Windows, or `/bin/sh -c user_hardware <band>` on other platforms, where `band` is described below. On Windows the first file with any extension listed on the `PATHEXT` environment variable added to the file name root `user_hardware`, and found in the directories listed on the `PATH` environment variable will be executed. On other platforms, the first executable script, or program, named `user_hardware` found in a directory listed on the `PATH` environment variable will be executed.
- `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 use of the `PATH` (and `PATHEXT` on Windows) environment variables is a new feature. To emulate previous behavior make sure that the location of your `user_hardware` script or program is on the `PATH` environment variable used by *WSJT-X*.

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	MOXDC	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	NV0O	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	GOIDE	IO83	37	5403	
0158	----- Transmitting WSPR -----								30m

Stop Monitor Erase Decode **Enable Tx** Halt Tx Tune

30m ● **10.138 700** Pwr

60+
50
40
30
20
10
0
0.0 dB

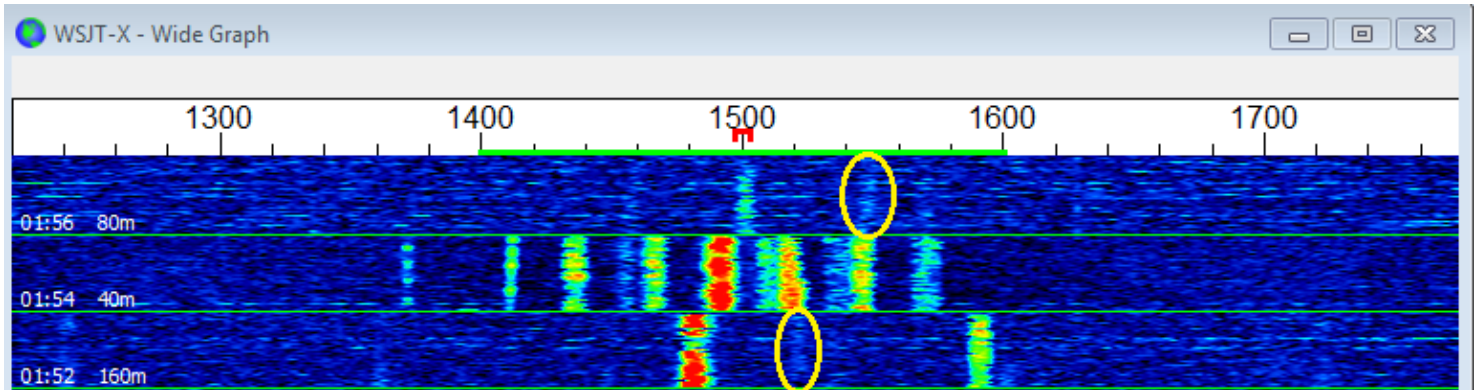
2016 Oct 24
01:59:12

Tx 1500 Hz Tx Pct 20 % Upload spots Prefer type 1 messages
 Band Hopping Tx Next
 Schedule ... 37 dBm 5 W

Tx: K1JT FN20 37 WSPR Last Tx: K1JT FN20 37 Night 72/120

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

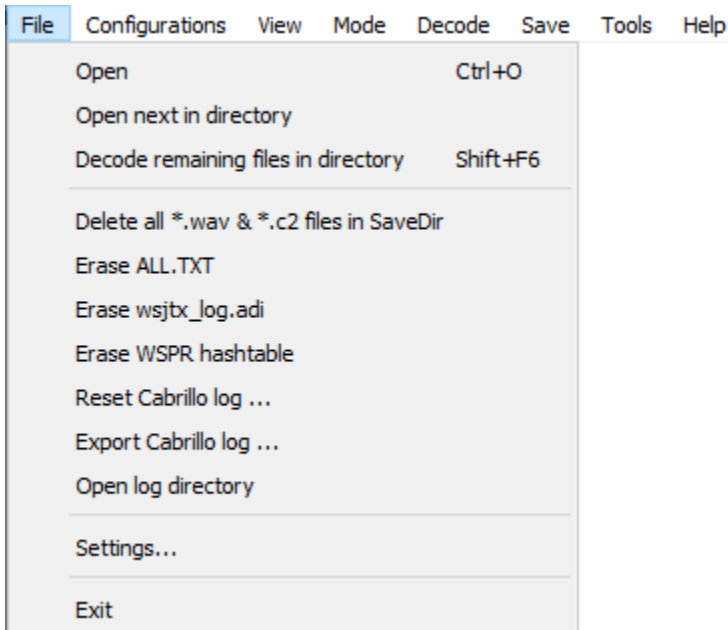
Menus at top of the main window offer many options for configuration and operation. Most of the items are self-explanatory; a few additional details are provided below. Keyboard shortcuts for some frequently used menu items are listed at the right edge of the menu.

10.1.1. *WSJT-X* menu

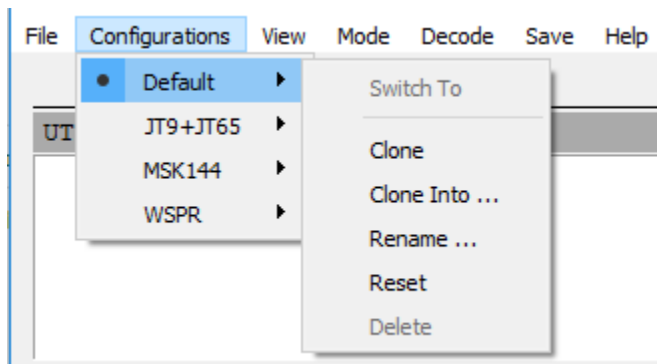


This menu appears on the Macintosh only. **Settings** appears here, labeled as **Preferences**, rather than on the **File** menu. **About WSJT-X** appears here rather than on the **Help** menu.

10.1.2. File menu



10.1.3. Configuration Menu

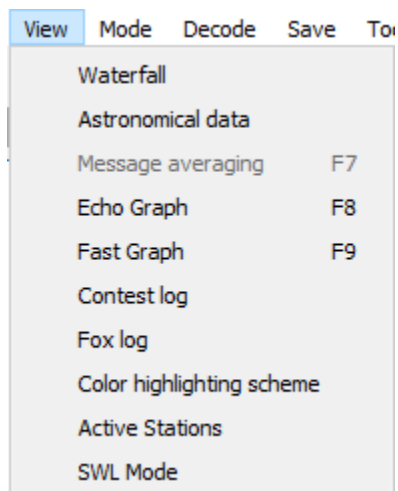


Many users prefer to create and use entries on the **Configurations** menu for switching between modes. Simply **Clone** the **Default** entry, **Rename** it as desired, and then make all desired settings for that configuration. These settings are restored whenever you select that configuration.

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



Active Stations displays a window that can help you to work the most distant stations, in particular for the distance-scored ARRL International Digital Contest. Controls are provided to set the maximum length of the list and the maximum “age” of decodes in Rx sequences. You can request display of only ready-to-be-called stations. For the ARRL International Digital Contest the window displays scoring rate (points in the most recent hour), total score, and the number of band changes in the past hour.

WSJT-X - Active Stations

N	Call	Grid	Az	S/N	Freq	Tx	Age	Pts
1.	A92AA	LL56	47	-02	1837	1	0*	23
2.	TA3IR	KN30	51	-16	1152	1	0*	18
3.	LZ1KU	KN32	50	-10	1413	1	0*	17
4.	SP6LHT	JO80	47	-16	2194	1	0*	15
5.	ON2VHF	JO20	51	-13	933	1	0*	14
6.	EB5AFK	IM98	66	-14	1554	1	0*	14
7.	EA1IEH	IN91	63	-05	511	1	0*	14
8.	EA7HY	IM66	71	-15	828	1	0*	13
9.	2E0IAR	IO92	50	-19	1726	1	0*	13
10.	F6GPT	IN94	59	-16	851	1	0*	13

Max N 10 Max Age 4 Ready only Rate: 0

Band Changes: 0 Score: 6,613

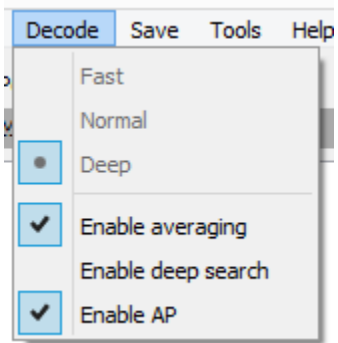
SWL Mode reduces the *WSJT-X* main window to a minimum size with just the menus, decodes windows, and status bar visible. You may find this useful when running multiple instances of the application. Both size and location of the main window are saved and recalled independently for this view.

10.1.5. Mode Menu

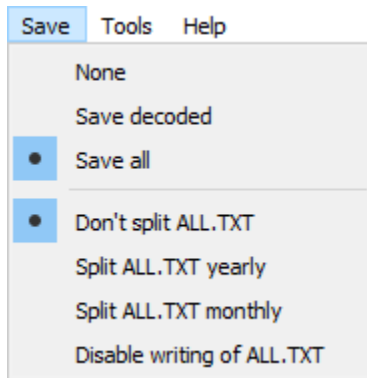
Mode Decode

- FST4
- FT4
- FT8
- JT4
- JT9
- JT65
- Q65
- MSK144
- FST4W
- WSPR
- Echo
- FreqCal

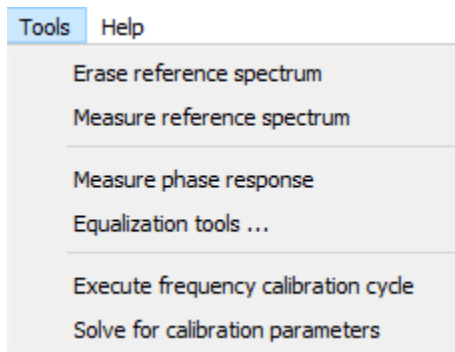
10.1.6. Decode Menu



10.1.7. Save Menu



10.1.8. Tools Menu



10.1.9. Help Menu

Help

Release Notes

Online User Guide

Local User Guide

FT8 DXpedition Mode User Guide

Quick-Start Guide to FST4 and FST4W

Quick-Start Guide to Q65

Quick-Start Guide to WSJT-X 2.5.0 and MAP65 3.0

Download Samples ...

Keyboard shortcuts

Special mouse commands

List of Type 1 prefixes and suffixes

Copyright notice

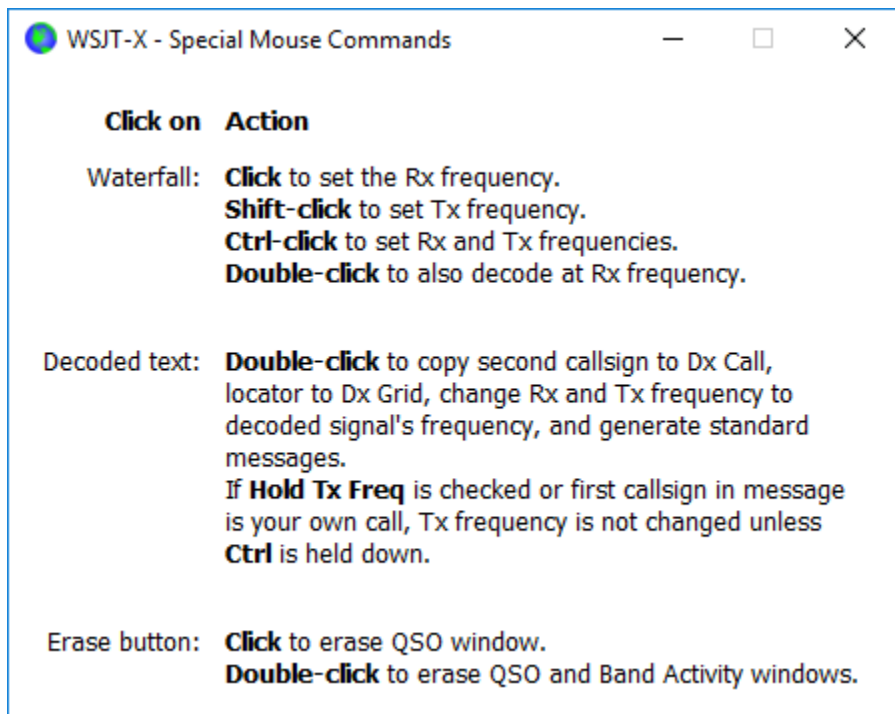
Shift+F1

About WSJT-X

Keyboard Shortcuts (F3)

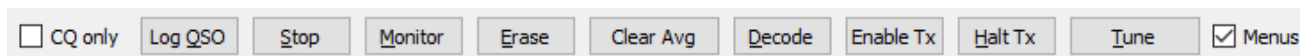
WSJT-X - Keyboard Shortcuts	
Esc	Stop Tx, abort QSO, clear next-call queue
F1	Online User's Guide (Alt: transmit Tx6)
Shift+F1	Copyright Notice
Ctrl+F1	About WSJT-X
F2	Open settings window (Alt: transmit Tx2)
F3	Display keyboard shortcuts (Alt: transmit Tx3)
F4	Clear DX Call, DX Grid, Tx messages 1-4 (Alt: transmit Tx4)
Alt+F4	Exit program
F5	Display special mouse commands (Alt: transmit Tx5)
F6	Open next file in directory (Alt: toggle "Call 1st")
Shift+F6	Decode all remaining files in directory
F7	Display Message Averaging window
F11	Move Rx frequency down 1 Hz
Ctrl+F11	Move identical Rx and Tx frequencies down 1 Hz
Shift+F11	Move Tx frequency down 60 Hz (FT8) or 90 Hz (FT4)
Ctrl+Shift+F11	Move dial frequency down 2000 Hz
F12	Move Rx frequency up 1 Hz
Ctrl+F12	Move identical Rx and Tx frequencies up 1 Hz
Shift+F12	Move Tx frequency up 60 Hz (FT8) or 90 Hz (FT4)
Ctrl+Shift+F12	Move dial frequency up 2000 Hz
Alt+1-6	Set now transmission to this number on Tab 1
Ctrl+1-6	Set next transmission to this number on Tab 1
Alt+B	Toggle "Best S+P" status
Alt+C	Toggle "Call 1st" checkbox
Alt+D	Decode again at QSO frequency
Shift+D	Full decode (both windows)
Ctrl+E	Turn on TX even/1st
Shift+E	Turn off TX even/1st
Alt+E	Erase
Ctrl+F	Edit the free text message box
Alt+G	Generate standard messages
Alt+H	Halt Tx
Ctrl+L	Lookup callsign in database, generate standard messages
Alt+M	Monitor
Alt+N	Enable Tx
Ctrl+O	Open a .wav file
Alt+O	Change operator
Alt+Q	Log QSO
Ctrl+R	Set Tx4 message to RRR (not in FT4)
Alt+R	Set Tx4 message to RR73
Alt+S	Stop monitoring
Alt+T	Toggle Tune status
Alt+Z	Clear hung decoder status

Special Mouse Commands (F5)

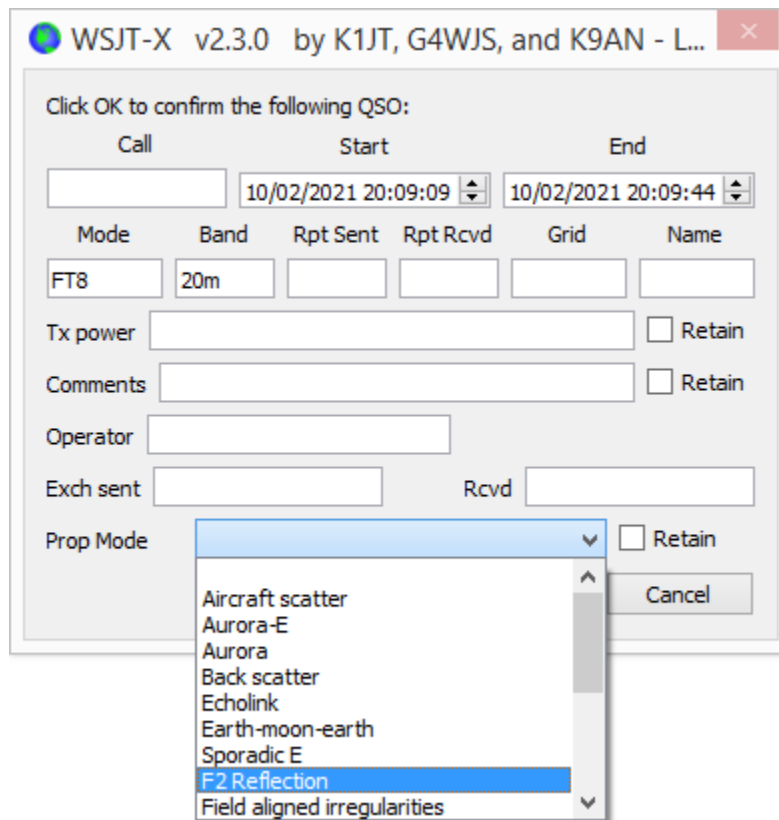


10.2. Button Row

The following controls appear just under the decoded text windows on the main screen. Some of them are visible only in certain modes.



- When **CQ only** is checked, only messages from stations calling CQ are displayed in the left text panel.
- **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 **File** → **Settings** → **Reporting** tab, the program raises 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.



- **Stop** terminates 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 *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 **File** → **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.

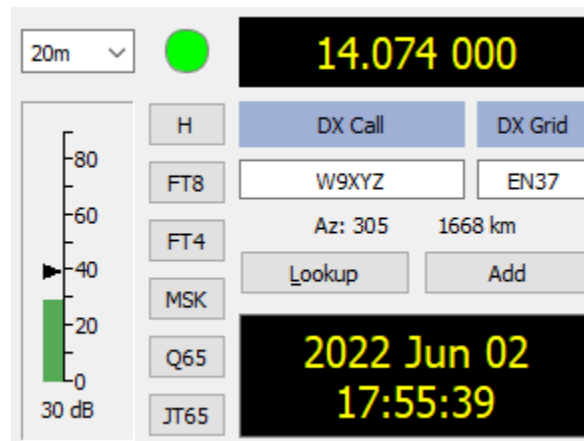


Activating **Tune** interrupts a receive sequence and will prevent decoding during that sequence.

- Uncheck the box **Menus** to make the top-of-window menus disappear, leaving more vertical space for decoded messages.

10.3. Left

Controls related to frequency selection, received audio level, the station being called, and date and time are found in the lower, left-hand section of the main window. Buttons are provided for making quick changes among the modes FT8, FT4, MSK144, Q65, and JT65, and for toggling FT8 Hound mode ON or OFF.



- A drop-down list of frequencies and bands in the upper, left-hand corner lets you select the operating band. It also 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 is 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.

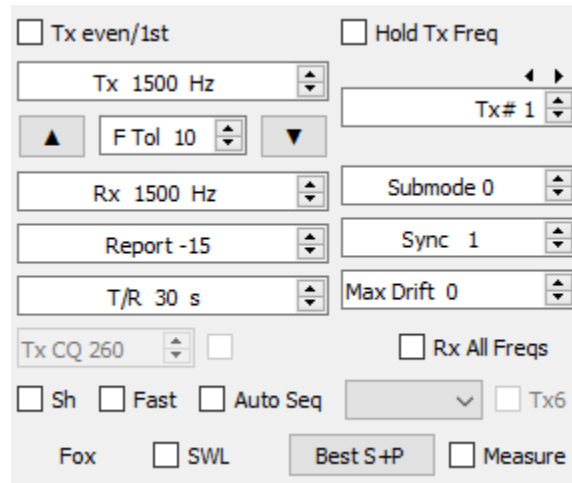


Many Icom rigs cannot be queried for split status, current VFO or split transmit frequency. When using *WSJT-X* with such radios you should not change the current VFO, split status or dial frequency using controls on the radio.

- 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/1st** 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 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 **Hold Tx Freq** to ensure that the specified Tx frequency is not changed automatically when you double-click on decoded text or a signal in the waterfall.
- For modes lacking a multi-decode feature, or when **Enable VHF/UHF/Microwave features** has been checked on the **File** → **Settings** → **General** tab, the **F Tol** control sets a frequency tolerance range over which decoding is attempted, centered on the Rx frequency.
- The **Report** control lets you change an automatically inserted signal report. 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 Q65, MSK144, and the fast JT9 modes.
- With **Split operation** activated on the **File** → **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, in the range 010 to 999. 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, Q65, 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 and Q65 modes

10.5. 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
1	<input checked="" type="radio"/>	Tx 1
2	<input type="radio"/>	Tx 2
	<input type="radio"/>	Tx 3
	<input type="radio"/>	Tx 4
	<input type="radio"/>	Tx 5
	<input type="radio"/>	Tx 6

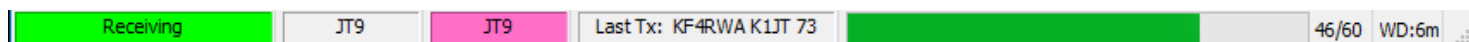
- Select the next message to be transmitted (at the start of your next Tx sequence) by clicking the radio button in the **Next** column.
- To change to a specified Tx message immediately during a transmission, click a rectangular button in the **Now** column. Changing a Tx message in mid-stream slightly reduces 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 the pull-down arrow for message #5 to select one of the stored messages entered on the **Files** → **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 its radio-button in the **Next** column or **Tx 1** button in the **Now** column. Similarly, to send RR73 rather than RRR for message #4, double-click one of its buttons.



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



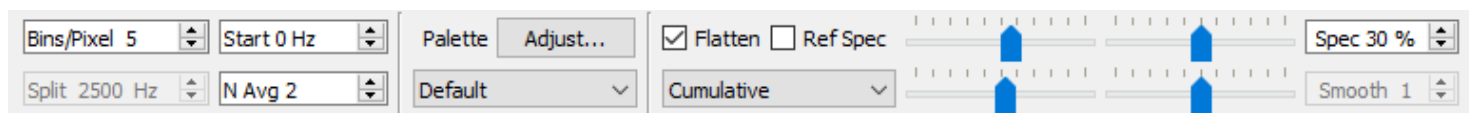
Labels on the **Status Bar** display such information as the program's current operating state, configuration name, operating mode, and the content of your most recent transmitted message. The first label (operating state) can be Receiving, Tx (for Transmitting), Tx: Tune, or the name of the file opened 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 **Files | Settings | General** tab, a label in the lower right-hand corner displays the number of minutes remaining before timeout.



Temporary status messages may occasionally be displayed here for a few seconds when background processing completes.

10.7. Wide Graph

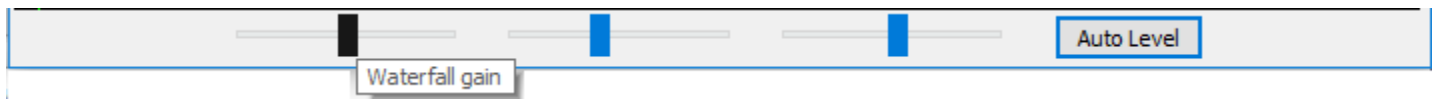
The following controls appear at the bottom of the Wide Graph window. Decoding occurs only in the displayed frequency range; otherwise, controls on the Wide Graph window have no effect on the decoding process.



- **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.
- **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 import or export 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.
- The **Spec nn%** control is used to set the fractional height of the spectrum plotted below the waterfall.
- **Smooth** is active only when **Linear Average** is 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.

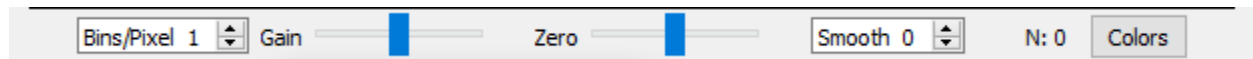
10.8. Fast Graph

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 produces 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 six 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 uncheck the box labeled **Controls** at top left of the **Wide Graph** window, or the box **Menus** to the right of the **Tune** button on the Main Window.

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 (such as 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 JTAlert (<https://hamapps.com/>), which can log QSOs automatically to other applications including Ham Radio Deluxe (<http://www.hrdsoftwarellc.com/>), DX Lab Suite (<https://www.dxlabsuite.com/>), and Log4OM (<https://www.log4om.com>).

The program option **Show DXCC entity and worked before status** (selectable on the **File | Settings | General** tab) is intended mostly for use on non-Windows platforms, where JTAlert (<https://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 indicated by highlighting colors, if that option is selected.

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

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 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 causes *WSJT-X* to re-read the log file. Very large log files may cause *WSJT-X* to slow down when searching for calls. If the ADIF log file has been changed outside of *WSJT-X* you can force *WSJT-X* to reload the file from the **Settings | Colors** tab using the **Rescan ADIF Log** button, see Decode Highlighting.

Additional features are provided for **Contest** and **Fox** logging. (more to come, here ...)

12. Decoder Notes

12.1. AP Decoding

The *WSJT-X* decoders for FST4, FT4, FT8, JT65, and Q65 include 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. AP is optional in FT8 and JT65, but is always enabled for Q65 and for FT4 and FST4 when decode depth is Normal or Deep.

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 might be expected for at least 57 message bits (28 for each of two callsigns, one or more for message type) in the next received message. The decoder’s task is thus 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. Type `a7`, used only in FT8 mode, uses information from the previous Rx sequence.

Table 1. FST4, FT4, and FT8 AP information types

aP	Message components
a1	CQ ? ?
a2	MyCall ? ?
a3	MyCall DxCall ?
a4	MyCall DxCall RRR
a5	MyCall DxCall 73
a6	MyCall DxCall RR73
a7	(Call_1 or CQ) Call_2 ?

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](https://pskreporter.info/pskmap.html) (<https://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 in FT4 or FT8. The FST4 table (not shown) is the same except that it omits the decoding attempts for AP types 4 and 5 to save time.

Table 2. FT4 and FT8 AP decoding types for each QSO state

State	AP type
CALLING STN	2, 3
REPORT	2, 3
ROGER_REPORT	3, 4, 5, 6
ROGERS	3, 4, 5, 6
SIGNOFF	3, 1, 2
CALLING CQ	1, 2

Decoding with *a priori* information behaves slightly differently in JT65. Some details are provided in Tables 3 and 4.

Table 3. JT65 AP information types

aP	Message components
a1	CQ ? ?
a2	MyCall ? ?
a3	MyCall DxCall ?
a4	MyCall DxCall RRR
a5	MyCall DxCall 73
a6	MyCall DxCall DxGrid
a7	CQ DxCall DxGrid

Table 4. JT65 AP decoding types for each QSO state

State	AP type
CALLING STN	2, 3, 6, 7
REPORT	2, 3
ROGER_REPORT	3, 4, 5
ROGERS	3, 4, 5
SIGNOFF	2, 3, 4, 5

State	AP type
CALLING CQ	1, 2, 6

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 5. Notations used on decoded text lines

Mode	Mode character	Sync character	End of line information
FST4	`		? aP
FT4	+		? aP
FT8	~		? aP
JT4	\$	*, #	f, fN, dCN
JT9	@		
JT65	#		
JT65 VHF	#	*, #	f, fN, dCN
Q65	:		qP
MSK144	&		

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 [Deep Search; (0-9,*)]
- d - Deep Search algorithm
- f - Franke-Taylor or Fano algorithm
- N - Number of Rx intervals or frames averaged
- P - Number indicating type of AP information (Table 1 or Table 6)

Table 6. Q65 end-of-line codes

qP	Message components
q0	? ? ?
q1	CQ ? ?
q2	MyCall ? ?
q3	MyCall DxCall ?
q4	MyCall DxCall [<blank> RRR RR73 73]
q5	MyCall DxCall ? (Max Drift = 50)

13. Measurement Tools

13.1. Frequency Calibration

Many *WSJT-X* capabilities depend on signal-detection bandwidths of 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.

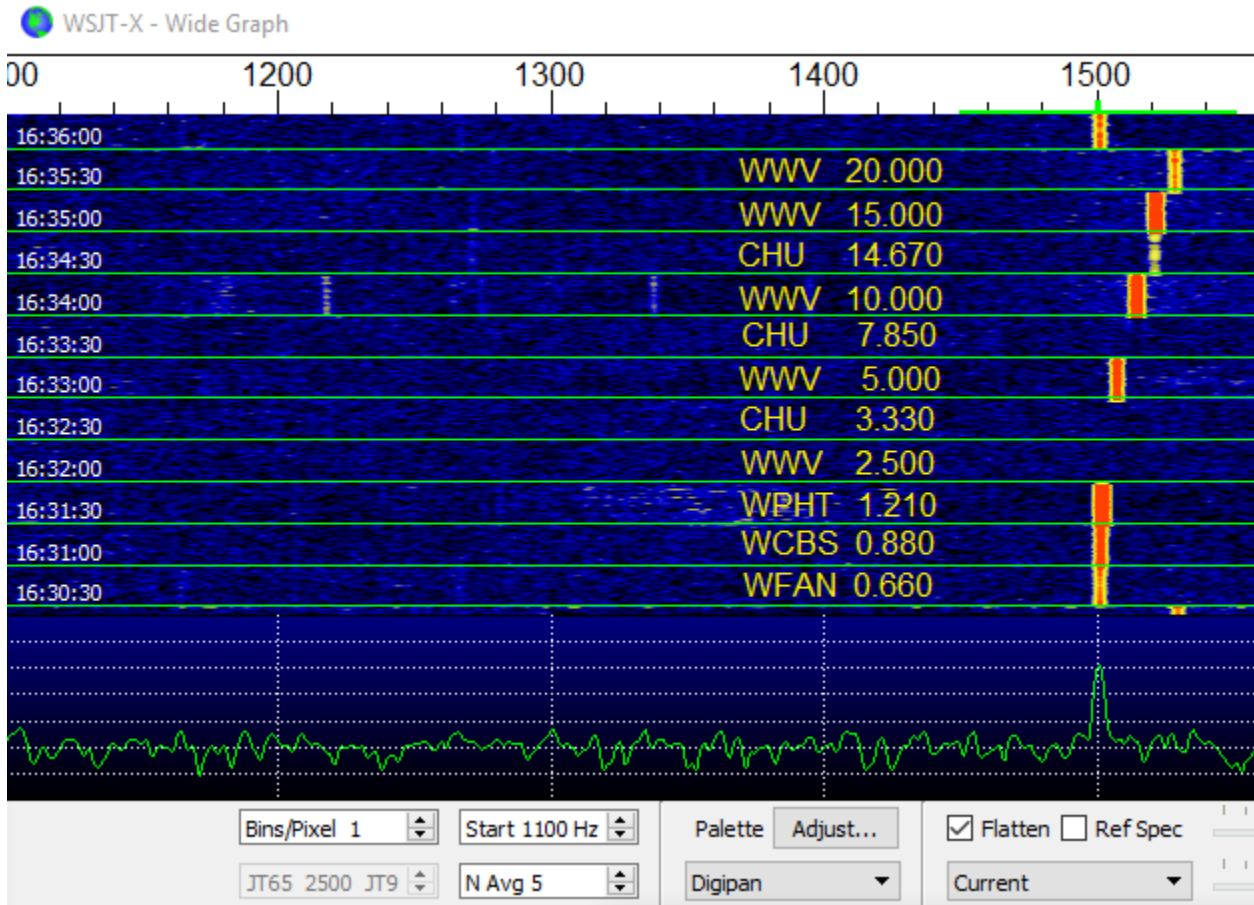
You will probably find it convenient to define and use a special Configuration dedicated to frequency calibration. Then complete the following steps, as appropriate, for your system.

- Switch to FreqCal mode
- In the *Working Frequencies* box on the **File | 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.

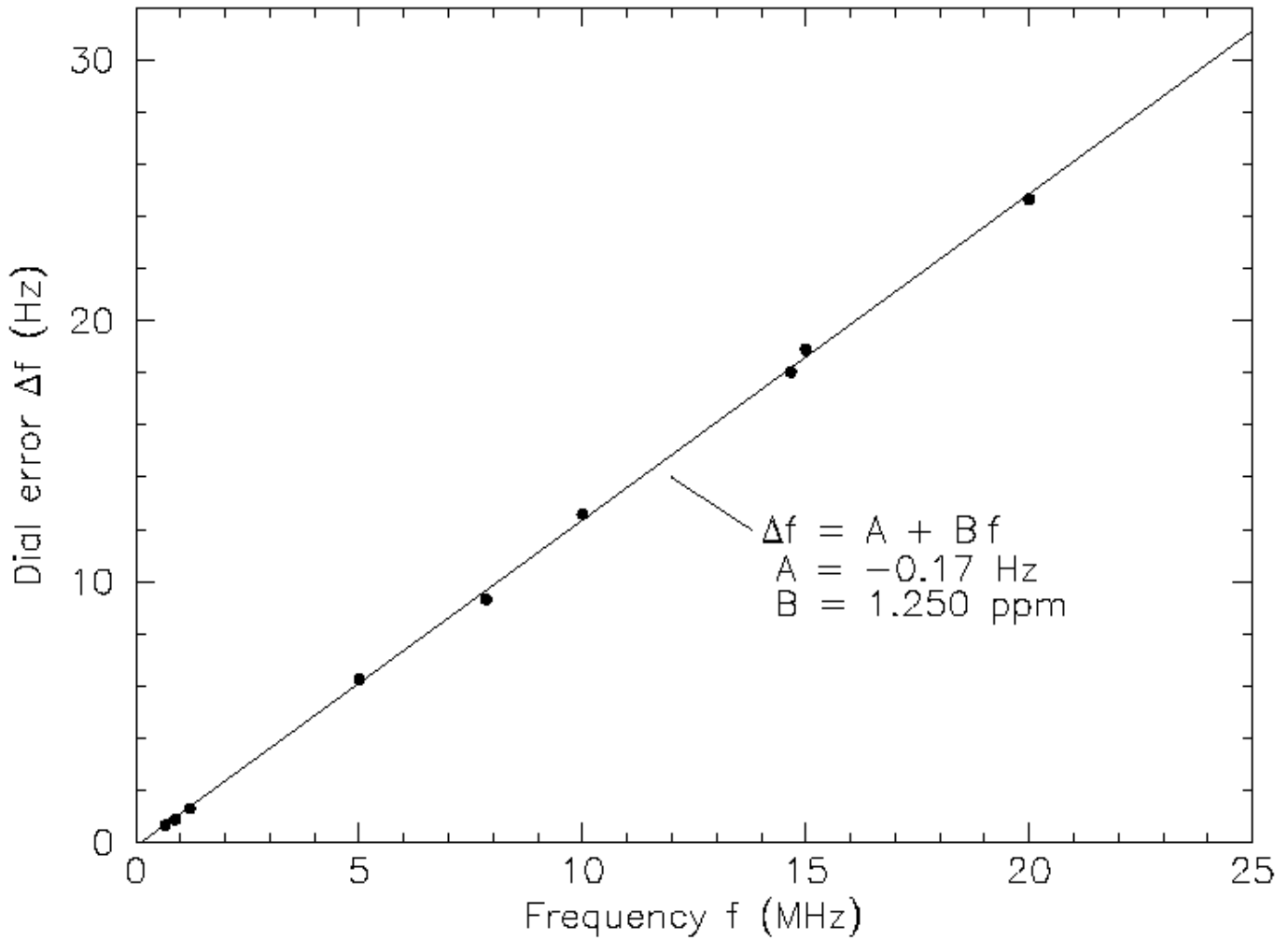
- In most cases, start by deleting any existing file `fmt.a11` in the directory where your log files are kept.
- To cycle automatically through your chosen list of calibration frequencies, check **Execute frequency calibration cycle** on the **Tools** menu. *WSJT-X* will spend 30 seconds at each frequency. Initially no measurement data is saved to the `fmt.a11` file although it is displayed on screen; this allows you to check your 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.



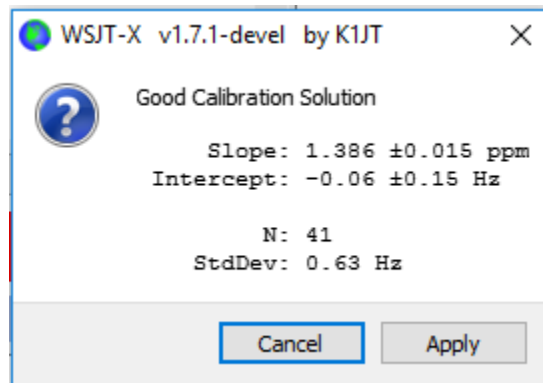
With modern synthesized radios, small measured offsets from 1500 Hz will exhibit a straight-line dependence on frequency. You can approximate the calibration of your radio by simply dividing the measured frequency offset (in Hz) at the highest reliable frequency by the nominal frequency itself (in MHz). 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 **File | 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://wsjt.sourceforge.io/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.all` 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 are 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 are offered an **Apply** button to push that automatically sets the calibration parameters in **File | Settings | Frequencies | Frequency Calibration**.



For a quick visual check of the resulting calibration, stay in **FreqCal** mode with the **Measure** option cleared. *WSJT-X* shows 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 click **Stop**. A file named `refspec.dat` appears in your log directory. When you check **Ref Spec** on the **Wide Graph**, the recorded reference spectrum will then be used to flatten your overall effective passband.

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 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 (such as 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 are 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 changes from `&` to `^` while *WSJT-X* is measuring the phase response, and it changes 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* saves the measured phase response in the **Log directory**, in a file with suffix `.pcoeff`. The filename contains 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, click the **Apply** button to save the proposed response. The red curve is 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" appears. The "Group Delay" curve shows the group delay variation across the passband, in ms. Click the **Discard Measured** button to remove the captured data from the plot, leaving only the applied phase equalization curve and corresponding group delay curve.

- To revert to no phase equalization, click 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, and 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.



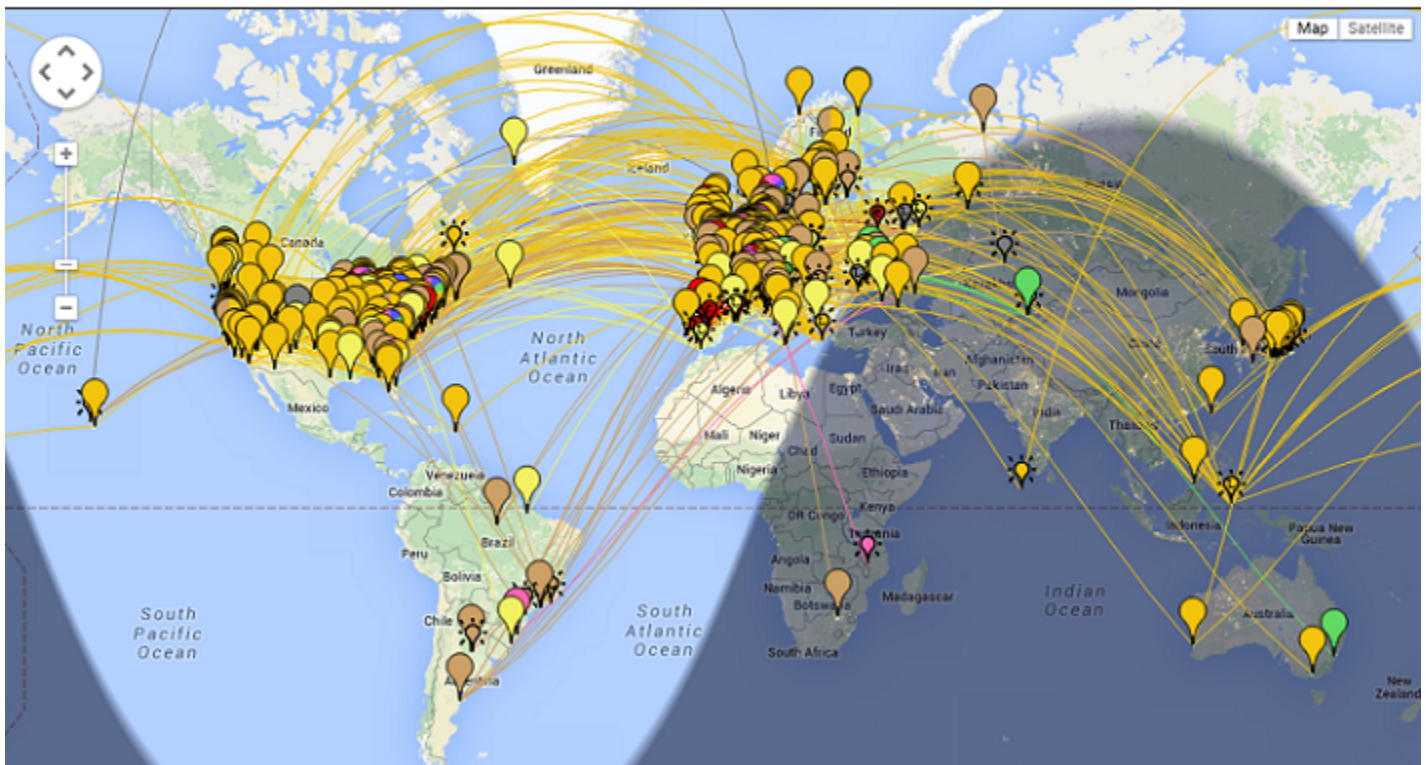
Further details on phase equalization and examples of fitted phase curves and eye diagrams can be found in the article on MSK144 by K9AN and K1JT published in [QEX](https://wsjt.sourceforge.io/MSK144_Protocol_QEX.pdf) (https://wsjt.sourceforge.io/MSK144_Protocol_QEX.pdf).

14. Cooperating Programs

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

- [DX Lab Suite](https://www.dxlabsuite.com/) (<https://www.dxlabsuite.com/>), [Omni-Rig](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](https://pskreporter.info/pskmap.html) (<https://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:

On **all bands** ▾, show **signals** ▾, sent/rcvd by **anyone** ▾, using **JT65** ▾ over the last **1 hour** ▾
Go! [Display options](#) [Permalink](#)
Automatic refresh in 5 minutes. Large markers are monitors. [Display all reports](#).
There are **587 active JT65 monitors**: **274 on 20m**, **152 on 15m**, **57 on 17m**, **49 on 6m**, **26 on 10m**, **20 on 30m**, **4 on 12m**, **3 on 40m**, **2 on unknown**. [Show all on all bands](#) [Legend](#)

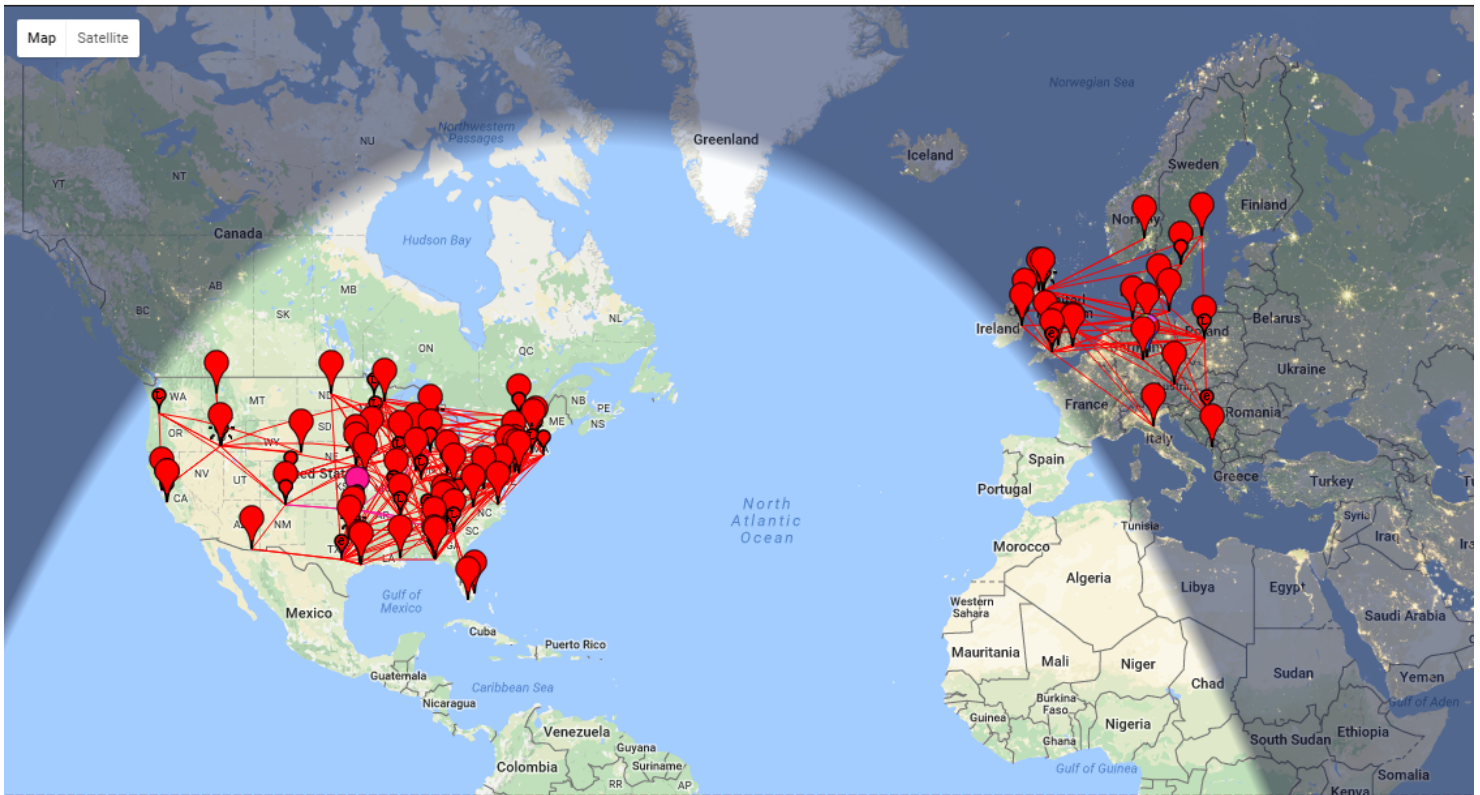


The following screen shot shows the PSK Reporter map configured to show MSK144 reports:

On **all bands** ▾, show **signals** ▾ sent/rcvd by **anyone** ▾ using **MSK144** ▾ over the last **1 hour** ▾ **Go!** [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](#)



- [JTAlert](https://hamapps.com/) (https://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](https://jt-bridge.eller.nu/) (https://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.
- [N1MM Logger+](https://n1mm.hamdocs.com/tiki-index.php) (https://n1mm.hamdocs.com/tiki-index.php) is a free, full-feature contest logging application. It is only available for Windows. *WSJT-X* can send logged QSO information to it via a network connection.
- [Writelog](https://writelog.com/) (https://writelog.com/) is a non-free, full-feature contest logging application. It is only available for Windows. *WSJT-X* can send logged QSO information to it via a network connection.

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.

15.1. 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 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=TS590
wsjtx --rig-name=FT847
```

3. *I am getting a "Network Error - SSL/TLS support not installed" message. What should I do?*

You need to install suitable *OpenSSL* libraries - see Instructions to install *OpenSSL*.

4. *I occasionally get Rig Control Errors if I adjust my Icom rig's VFO. What's wrong?*

By default, most Icom transceivers have "CI-V Transceive Mode" enabled. This will cause unsolicited CAT traffic from the rig that disrupts CAT control by a PC. Disable this option in the rig's menu.

5. *I want to control my transceiver with another application as well as *WSJT-X*, is that possible?*

This is only possible to do reliably via some kind of rig control server. That server must be able to accept both *WSJT-X* and the other application(s) as clients. Using a dumb serial port splitter like the VSPE tool is not supported; it may work but it is not reliable due to unmanaged CAT control collisions. Applications like the *Hamlib Rig Control Server (rigctld)*, *Omni-Rig* (<http://www.dxatlas.com/OmniRig/Files/OmniRig.zip>), and *DX Lab Suite* (<https://www.dxlabsuite.com/>) *Commander* are potentially suitable; *WSJT-X* can act as a client to them all.

6. *Rig control through OmniRig seems to fail when I click **Test CAT**. What can I do about it?*

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

7. *I am running *WSJT-X* under Ubuntu. The program starts, but the 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
```

8. *I am running *WSJT-X* on Linux using a KDE desktop. Why does **Menu**→**Configurations** misbehave?*

The KDE development team have added code to Qt that tries to automatically add shortcut accelerator keys to all buttons

including pop up menu buttons. This interferes with operation of the application (many other Qt applications have similar issues with KDE). Until this is fixed by the KDE team you must disable this feature. Edit the file `~/.config/kdeglobals` and add a section containing the following:

```
[Development]
AutoCheckAccelerators=false
```

See <https://stackoverflow.com/a/32711483> and https://bugs.kde.org/show_bug.cgi?id=337491 for more details.

17. Protocol Specifications

17.1. Overview

All QSO modes use structured messages that compress user-readable information into fixed-length packets. JT4, JT9, and JT65 use 72-bit payloads. Standard messages consist of two 28-bit fields normally used for callsigns and a 15-bit field for a grid locator, report, acknowledgment, or 73. An additional bit flags a message containing arbitrary free 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 for FST4, FT4, FT8, Q65, and MSK144 contain 77 bits. The 5 additional bits are used to flag special message types used for nonstandard callsigns, contest exchanges, FT8 DXpedition Mode, and a few other possibilities. Full details have been published in QEX, see [The FT4 and FT8 Communication Protocols](https://wsjt.sourceforge.io/FT4_FT8_QEX.pdf) (https://wsjt.sourceforge.io/FT4_FT8_QEX.pdf).

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 are 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 such as 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 2.3 and later 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 72-bit 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.

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. FST4

FST4 offers T/R sequence lengths of 15, 30, 60, 120, 300, 900, and 1800 seconds. Submodes are given names like FST4-60, FST4-120, etc., the appended numbers indicating sequence length in seconds. A 24-bit cyclic redundancy check (CRC) is appended to the 77-bit message payload to create a 101-bit message-plus-CRC word. Forward error correction is accomplished using a (240,101) LDPC code. Transmissions consist of 160 symbols: 120 information-carrying symbols of two bits each,

interspersed with five groups of eight predefined synchronization symbols. Modulation uses 4-tone frequency-shift keying (4-GFSK) with Gaussian smoothing of frequency transitions.

17.2.2. FT4

Forward error correction (FEC) in FT4 uses a low-density parity check (LDPC) code with 77 information bits, a 14-bit cyclic redundancy check (CRC), and 83 parity bits making a 174-bit codeword. It is thus called an LDPC (174,91) code. Synchronization uses four 4×4 Costas arrays, and ramp-up and ramp-down symbols are inserted at the start and end of each transmission. Modulation is 4-tone frequency-shift keying (4-GFSK) with Gaussian smoothing of frequency transitions. The keying rate is $12000/576 = 20.8333$ baud. Each transmitted symbol conveys two bits, so the total number of channel symbols is $174/2 + 16 + 2 = 105$. The total bandwidth is $4 \times 20.8333 = 83.3$ Hz.

17.2.3. FT8

FT8 uses the same LDPC (174,91) code as FT4. Modulation is 8-tone frequency-shift keying (8-GFSK) at $12000/1920 = 6.25$ baud. Synchronization uses 7×7 Costas arrays at the beginning, middle, and end of each transmission. Transmitted symbols carry 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.

17.2.4. 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
```

17.2.5. 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.

17.2.6. JT65

A detailed description of the JT65 protocol was published in [QEX](https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/JT65.pdf) (https://sourceforge.net/projects/wsjt/files/wsjt-2.7.0-rc4/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:

```
10011000111110101000101100100011100111101101111000110101011001
101010100100000011000000011010010110101010011001001000011111111
```

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, respectively. 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, respectively.

17.2.7. Q65

Q65 is intended for scatter, EME, and other extreme weak-signal applications. Forward error correction (FEC) uses a specially designed (65,15) block code with six-bit symbols. Two symbols are “punctured” from the code and not transmitted, thereby yielding an effective (63,13) code with a payload of $k = 13$ information symbols conveyed by $n = 63$ channel symbols. The punctured symbols consist of a 12-bit CRC computed from the 13 information symbols. The CRC is used to reduce the false-decode rate to a very low value. A 22-symbol pseudorandom sequence spread throughout a transmission is sent as “tone 0” and used for synchronization. The total number of channel symbols in a Q65 transmission is thus $63 + 22 = 85$. Q65 offers T/R sequence lengths of 15, 30, 60, 120, and 300 s, and submodes A - E have tone spacings 1, 2, 4, 8, and 16 times the symbol rate. Submode designations include a number for sequence length and a letter for tone spacing, as in Q65-15A, Q65-120C, etc. Occupied bandwidths are 65 times the tone spacing, ranging from 19 Hz (Q65-300A) to a maximum of 1733 Hz (Q65-15C, Q65-30D, and Q65-60E).

17.2.8. WSPR

WSPR is designed for probing potential radio propagation paths using low power beacon-like transmissions. WSPR signals convey a callsign, Maidenhead grid locator, and power level using a compressed data format with strong forward error correction and narrow-band 4-FSK modulation. The protocol is effective at signal-to-noise ratios as low as -31 dB in a 2500 Hz bandwidth.

WSPR messages can have one of three possible formats illustrated by the following examples:

- Type 1: K1ABC FN42 37
- Type 2: PJ4/K1ABC 37
- Type 3: <PJ4/K1ABC> FK52UD 37

Type 1 messages contain a standard callsign, a 4-character Maidenhead grid locator, and power level in dBm. Type 2 messages omit the grid locator but include a compound callsign, while type 3 messages replace the callsign with a 15-bit hash code and include a 6-character locator as well as the power level. Lossless compression techniques squeeze all three message types into exactly 50 bits of user information. Standard callsigns require 28 bits and 4-character grid locators 15 bits. In Type 1 messages, the remaining 7 bits convey the power level. In message types 2 and 3 these 7 bits convey power level along with an extension or re-definition of fields normally used for callsign and locator. Together, these compression techniques amount to “source encoding” the user message into the smallest possible number of bits.

WSPR uses a convolutional code with constraint length $K=32$ and rate $r=1/2$. Convolution extends the 50 user bits into a total of $(50 + K - 1) \times 2 = 162$ one-bit symbols. Interleaving is applied to scramble the order of these symbols, thereby minimizing the effect of short bursts of errors in reception that might be caused by fading or interference. The data symbols are combined with an equal number of synchronizing symbols, a pseudo-random pattern of 0's and 1's. The 2-bit combination for each symbol is the quantity that determines which of four possible tones to transmit in any particular symbol interval. Data information is taken as the most significant bit, sync information the least significant. Thus, on a 0 – 3 scale, the tone for a given symbol is twice the value (0 or 1) of the data bit, plus the sync bit.

17.2.9. FST4W

FST4W offers T/R sequence lengths of 120, 300, 900, and 1800 seconds. Submodes are given names like FST4W-120, FST4W-300, etc., the appended numbers indicating sequence length in seconds. Message payloads contain 50 bits, and a 24-bit cyclic redundancy check (CRC) appended to create a 74-bit message-plus-CRC word. Forward error correction is accomplished using a (240,74) LDPC code. Transmissions consist of 160 symbols: 120 information-carrying symbols of two bits each, interspersed with five groups of eight predefined synchronization symbols. Modulation uses 4-tone frequency-shift keying (4-GFSK) with Gaussian smoothing of frequency transitions.

17.2.10. Summary

Table 7 provides a brief summary of 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 7. 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)
FST4-15	LDPC	(240,101)	4	4-GFSK	16.67	66.7	0.25	9.6	-20.7
FST4-30	LDPC	(240,101)	4	4-GFSK	7.14	28.6	0.25	22.4	-24.2
FST4-60	LDPC	(240,101)	4	4-GFSK	3.09	12.4	0.25	51.8	-28.1
FST4-120	LDPC	(240,101)	4	4-GFSK	1.46	5.9	0.25	109.3	-31.3
FST4-300	LDPC	(240,101)	4	4-GFSK	0.558	2.2	0.25	286.7	-35.3
FST4-900	LDPC	(240,101)	4	4-GFSK	0.180	0.72	0.25	887.5	-40.2
FST4-1800	LDPC	(240,101)	4	4-GFSK	0.089	0.36	0.25	1792.0	-43.2
FT4	LDPC	(174,91)	4	4-GFSK	20.83	83.3	0.15	5.04	-17.5
FT8	LDPC	(174,91)	8	8-GFSK	6.25	50.0	0.27	12.6	-21
JT4A	K=32, r=1/2	(206,72)	2	4-FSK	4.375	17.5	0.50	47.1	-23
JT9A	K=32, r=1/2	(206,72)	8	9-FSK	1.736	15.6	0.19	49.0	-26
JT65A	RS	(63,12)	64	65-FSK	2.692	177.6	0.50	46.8	-25
Q65-15A	QRA	(63,13)	64	65-FSK	6.667	433	0.26	12.8	-22.2
Q65-30A	QRA	(63,13)	64	65-FSK	3.333	217	0.26	25.5	-24.8

Mode	FEC Type	(n,k)	Q	Modulation type	Keying rate (Baud)	Bandwidth (Hz)	Sync Energy	Tx Duration (s)	S/N Threshold (dB)
Q65-60A	QRA	(63,13)	64	65-FSK	1.667	108	0.26	51.0	-27.6
Q65-120A	QRA	(63,13)	64	65-FSK	0.750	49	0.26	113.3	-30.8
Q65-300A	QRA	(63,13)	64	65-FSK	0.289	19	0.26	293.8	-33.8
WSPR	K=32, r=1/2	(162,50)	2	4-FSK	1.465	5.9	0.50	110.6	-31
FST4W-120	LDPC	(240,74)	4	4-GFSK	1.46	5.9	0.25	109.3	-32.8
FST4W-300	LDPC	(240,74)	4	4-GFSK	0.558	2.2	0.25	286.7	-36.8
FST4W-900	LDPC	(240,74)	4	4-GFSK	0.180	0.72	0.25	887.5	-41.7
FST4W-1800	LDPC	(240,74)	4	4-GFSK	0.089	0.36	0.25	1792.0	-44.8

LDPC = Low Density Parity Check
RS = Reed Solomon
QRA = Q-ary Repeat Accumulate

Submodes of JT4, JT9, and JT65 offer wider tone spacings for circumstances that may require them, such as significant Doppler spread. Table 8 summarizes the tone spacings, bandwidths, and approximate threshold sensitivities of the various submodes when spreading is comparable to tone spacing.

Table 8. Parameters of Slow Submodes JT4, JT9, and JT65 with Selectable Tone Spacings

Mode	Tone Spacing	BW (Hz)	S/N (dB)
JT4A	4.375	17.5	-23
JT4B	8.75	30.6	-22
JT4C	17.5	56.9	-21
JT4D	39.375	122.5	-20
JT4E	78.75	240.6	-19
JT4F	157.5	476.9	-18
JT4G	315.0	949.4	-17
JT9A	1.736	15.6	-26

Mode	Tone Spacing	BW (Hz)	S/N (dB)
JT9B	3.472	29.5	-26
JT9C	6.944	57.3	-25
JT9D	13.889	112.8	-24
JT9E	27.778	224.0	-23
JT9F	55.556	446.2	-22
JT9G	111.111	890.6	-21
JT9H	222.222	1779.5	-20
JT65A	2.692	177.6	-25
JT65B	5.383	352.6	-25
JT65C	10.767	702.5	-25

Table 9. Parameters of Q65 Submodes

T/R Period (s)	A Spacing Width (Hz)		B Spacing Width (Hz)		C Spacing Width (Hz)		D Spacing Width (Hz)		E Spacing Width (Hz)	
15	6.67	4.33	13.33	867	26.67	1733	N/A		N/A	
30	3.33	217	6.67	433	13.33	867	26.67	1733	N/A	
60	1.67	108	3.33	217	6.67	433	13.33	867	26.67	1733
120	0.75	49	1.50	98	3.00	195	6.00	390	12.00	780
300	0.29	19	0.58	38	1.16	75	2.31	150	4.63	301

17.3. Fast Modes

17.3.1. 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 9, below.

17.3.2. MSK144

Standard MSK144 messages are structured in the same way as in FT8, with 77 bits of user information. Forward error correction is implemented by first augmenting the 77 message bits with a 13-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 90-bit augmented message is mapped to a 128-bit codeword using a (128,90) 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 ± 200 Hz.

17.3.3. Summary

Table 10. Parameters of Fast Modes

Mode	FEC Type	(n,k)	Q	Modulation Type	Keying rate (Baud)	Bandwidth (Hz)	Sync Energy	Tx Duration (s)
JT9E	K=32, r=1/2	(206,72)	8	9-FSK	25.0	225	0.19	3.400
JT9F	K=32, r=1/2	(206,72)	8	9-FSK	50.0	450	0.19	1.700
JT9G	K=32, r=1/2	(206,72)	8	9-FSK	100.0	900	0.19	0.850
JT9H	K=32, r=1/2	(206,72)	8	9-FSK	200.0	1800	0.19	0.425
MSK144	LDPC	(128,90)	2	OQPSK	2000	2400	0.11	0.072
MSK144 Sh	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.

2021 Mar 06	
UTC:	18:55:52
Az:	24.0
El:	-58.9
SelfDop:	1245
Width:	206
Delay:	2.53
DxAz:	144.5
DxEl:	19.7
DxDop:	6160
DxWid:	114
Dec:	-24.8
SunAz:	284.5
SunEl:	-16.7
Freq:	10368.2
Tsky:	3
Dpol:	16.1
MNR:	1.5
Dist:	379749
Dgrd:	-1.2
<input type="checkbox"/> Doppler tracking	

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; **Dist**, the distance from your location to the moon, in km; 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 reduces signal levels. Some stations have implemented mechanical polarisation adjustment to overcome this loss. 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 a counterclockwise 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 (https://wsjt.sourceforge.io/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 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.

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 R0	KA1ABC WB9XYZ R0	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. R0	R0	-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 User Forum (<https://groups.io/g/wsjtgroup>) at email address wsjtgroup@groups.io. 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 (<https://groups.io/g/wsjtgroup/join>).

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 preferably to the WSJT Developers email list (wsjt-devel@lists.sourceforge.net). You will need to subscribe to the list (<https://sourceforge.net/projects/wsjt/lists/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 by **K1JT** in 2001. Since 2005 it has been an Open Source project, and it has included the programs *WSJT*, *MAP65*, *WSPR*, *WSJT-X*, and *QMAP*. **G4WJS** (since 2013), **K9AN** (since 2015), **IV3NWV** (since 2016), **DG2YCB** (since 2021), and **N9ADG** (since 2022) have made major contributions to *WSJT-X*. Together with K1JT they now form the core development team. **G4WJS** and **W9MDB** have made major contributions to the *hamlib* library, on which *WSJT-X* depends for rig control.

All code in the *WSJT* project 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. For *WSJT-X* in particular, in addition to those mentioned above we acknowledge contributions from **AC6SL**, **AE4JY**, **DF2ET**, **DJ0OT**, **G3WDG**, **G4KLA**, **IW3RAB**, **K3WYC**, **KA1GT**, **KA6MAL**, **KA9Q**, **KB1ZMX**, **KD6EKQ**, **KI7MT**, **KK1D**, **ND0B**, **PY2SDR**, **VE1SKY**, **VK3ACF**, **VK4BDJ**, **VK7MO**, **W3DJS**, **W3SZ**, **W4TI**, and **W4TV**. Each of these amateurs has helped to bring the program's design, code, testing, and/or documentation to its present state.

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Development *WSJT-X* is a cooperative project to which many authors have contributed. If you use our source code, please have the courtesy to let us know about it. If you find bugs or make improvements to the code, please report them to us in a timely fashion.

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The algorithms, source code, look-and-feel of *WSJT-X* and related programs, and protocol specifications for the modes FSK441, FST4, FST4W, FT4, FT8, JT4, JT6M, JT9, JT44, JT65, JTMS, Q65, QRA64, ISCAT, and MSK144 are Copyright © 2001-2021 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.