WSJT 9.0: Supplement to User's Guide

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Overview

WSJT 9.0 is the latest version of the familiar weak-signal communication program WSJT. It offers a number of new features and capabilities, many of them based on experience gained with a temporary experimental release, WSJT 8. Until a complete WSJT 9.0 User's Guide is available, the present document should be read in conjunction with the older *WSJT6 User's Guide and Reference Manual*, most of which is still relevant.

New features in WSJT 9.0 (relative to WSJT 6 and WSJT 7) include the following:

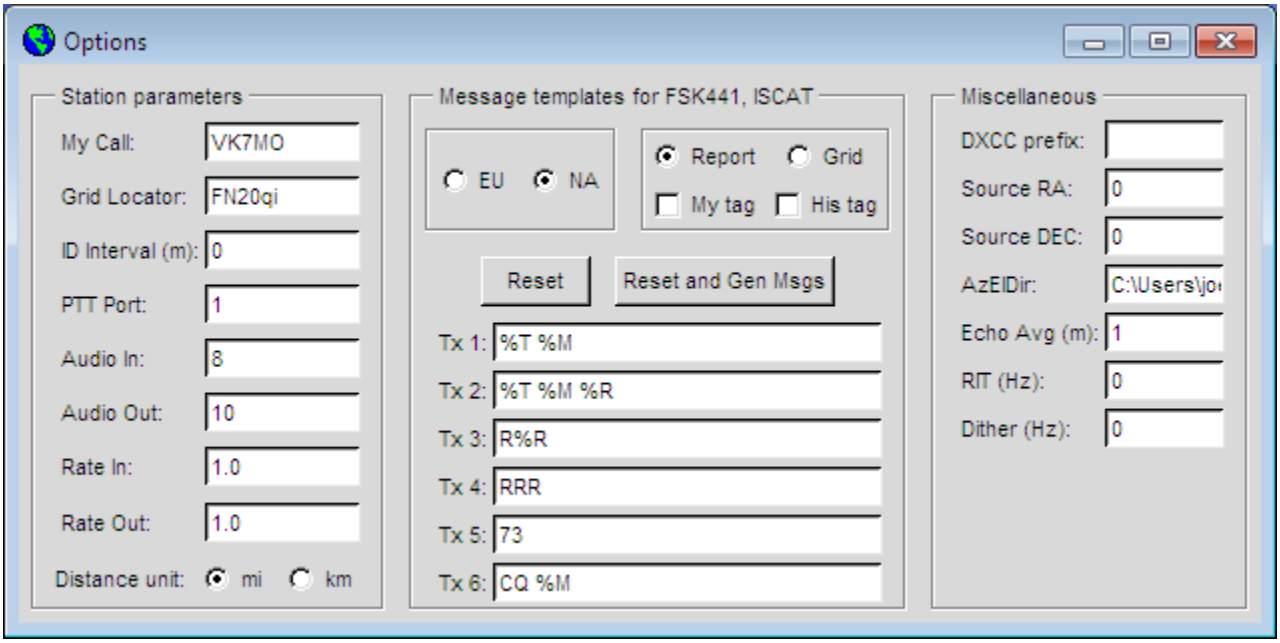
1. **New Modes**
   a. **ISCAT** is a new mode that replaces JT6M. It has significantly better performance on the propagation paths where JT6M has been popular, such as tropospheric and ionospheric scatter and weak Es or F2 on 6 meters. If you liked and used JT6M, you will like ISCAT even better. Please note: *this mode is not the same as the temporary one called ISCAT in WSJT 8.*
   b. **Echo** mode has been missing in recent versions of WSJT, but is re-introduced in WSJT 9.0. It allows testing for echoes of your own signal from the moon.
2. **Enhancements to FSK441:** an improved decoder does a better job of (1) determining frequency offset DF and (2) rejecting non-FSK441 signals and noise spikes, thereby producing fewer " garbage" decodes. Sensitivity to legitimate FSK441 signals is unchanged.
3. **T/R period** for ISCAT is normally 30 seconds, the same as for FSK441. However, WSJT 9.0 also supports optional T/R sequence lengths of 15 s for both FSK441 and ISCAT modes. The shorter sequences may be useful in particular situations such as contests, multi-hop Es, etc.
4. **Message Templates:** the **Setup | Options** screen offers an improved user interface for setting your preferences for templates that generate messages for the FSK441 and ISCAT modes.
5. **Lunar Librations** cause EME signals to exhibit fading at VHF/UHF frequencies and Doppler spreading at higher microwave frequencies. WSJT 9.0 computes these effects in real time and displays the expected frequency spread both for your own echoes and for the DX station. Fading timescale is the inverse of frequency spread.
6. **User interface** has been cleaned up and simplified in several ways. In general, only those controls relevant to the selected mode appear on screen.

Installation

WSJT 9.0 can be downloaded from the WSJT Home Page, http://www.physics.princeton.edu/pulsar/K1JT/. Click on the WSJT link at the left margin and then on the appropriate download link. Install the program in the usual way for your operating system. Under Windows, execute the downloaded file and follow the installation instructions.

During a test period you may wish to have both WSJT 7 and WSJT 9.0 available on your computer; in this case you should install WSJT 9.0 in a different directory, for example the Windows folder C:\HamRadio\WSJT9. (In the Vista or Windows 7 operating systems, if you use the default location C:\Program Files\WSJT9 you may need to set some access permissions explicitly.) For installation under Debian-based **Linux** distributions, see **Appendix A**.

Setup



The **Station parameters** section at left of the **Setup | Options** window is described in the WSJT6 User's Guide.

The **Message templates** section applies only to the non-structured modes, i.e., FSK441 and ISCAT. The templates facilitate automatic generation of messages for minimal QSOs, based on your own preferences or regional customs. Suggested message formats are provided for IARU Regions 1 (EU) and 2 (NA), and for messages containing signal reports or Maidenhead grid locators. New macros %S and %H are provided to insert your own callsign suffix ("My tag") or that of the station being worked ("His tag") into a message. You should experiment with these new controls to learn how they work. The complete list of template macros is as follows:

%M = My call
%S = Suffix of My call (i.e., ABC for the call K1ABC, 2X for AA2X)
%T = His call (the callsign in **To radio**)
%H = Suffix of His call
%R = Signal report (contents of box labeled **Rpt**)
%G = My grid (4-character grid locator)
%L = Long grid (6-character locator)

The **Reset** button causes new templates to be generated, based on the selected template options. You can also edit the templates to suit your own preferences. **Reset and Gen Msgs** also generates the corresponding messages in the main screen's Tx message windows. Messages in the **JT65** and **JT4** modes have protocol-specified structure and do not have user-editable templates.

Parameters for **Echo** mode are set in the bottom three entries under **Miscellaneous**. See the **Echo Mode** section below for details on how to use them.

Message Formats

Messages in the **FSK441** and **ISCAT** modes have no fixed structure and no error-correction capabilities. You can send anything you like, up to a maximum of 28 characters per message. Short messages offer better performance than long ones — that is, lower S/N thresholds and greater probability of full copy.

JT65 and **JT4** use structured messages and include synchronization and strong forward error correction (FEC). In these modes, you normally get perfect copy of what was transmitted, or you get nothing at all.

As in WSJT 7, structured messages can have one of three basic formats:

1. Two to four alphanumeric "words" of specified form
2. Arbitrary text, up to 13 characters
3. Shorthand messages for RO, RRR, and 73 (but no shorthands in **JT4**)

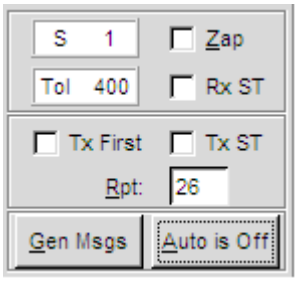
Words of a type 1 message normally consist of two standard callsigns, an optional grid locator, and the optional signal report OOO. CQ or QRZ can be substituted for the first callsign. An add-on callsign prefix followed by "/", a suffix preceded by "/", a signal report of the form –nn or R–nn, or the message fragments RO, RRR or 73 can be substituted for the grid locator. Each message of type 1 or type 2 conveys exactly 72 bits of user information.

Additional details on the coding and modulation schemes used in WSJT 9.0 are provided in Appendix B.

Mode-Specific Controls

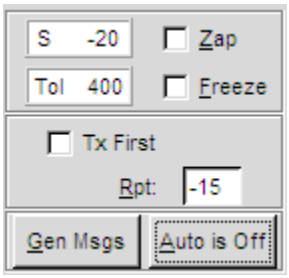
The user interface has been simplified and clarified in a number of ways. Obsolete, little-used, or redundant controls have been removed. Controls generally appear on the main screen only when relevant to the active mode, and those relevant to receiving and transmitting appear in separate groups.

For example, in **FSK441** mode the lower central part of the main screen looks like this:

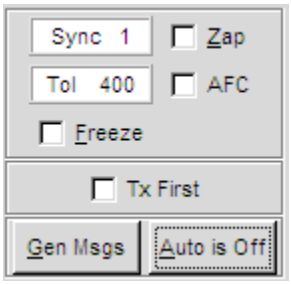


Decoding of single-tone shorthand messages for R26, R27, RRR, and 73 can be enabled by checking the box labeled **Rx ST**. Similarly, transmission of single-tone messages is enabled by checking **Tx ST**. Other controls have their familiar meanings from WSJT 7.

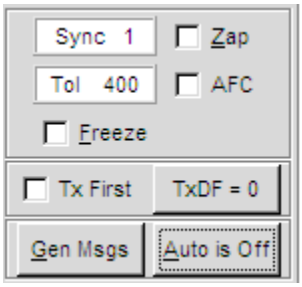
ISCAT mode allows you to set a selected value of **Freeze DF** using the F11 and F12 keys, and to narrow the range of DF by checking **Freeze** and reducing **Tol**. The control area looks like this:



The **JT65** and **JT4** modes include optional provisions for automatic frequency control, selected by checking the **AFC** box.



The narrow-band **JT65A** and **JT4A** sub-modes, which are popular at HF, also include a button labeled **TxDF** that offsets the frequency of the transmitted signal to match the selected value of **Freeze DF**.



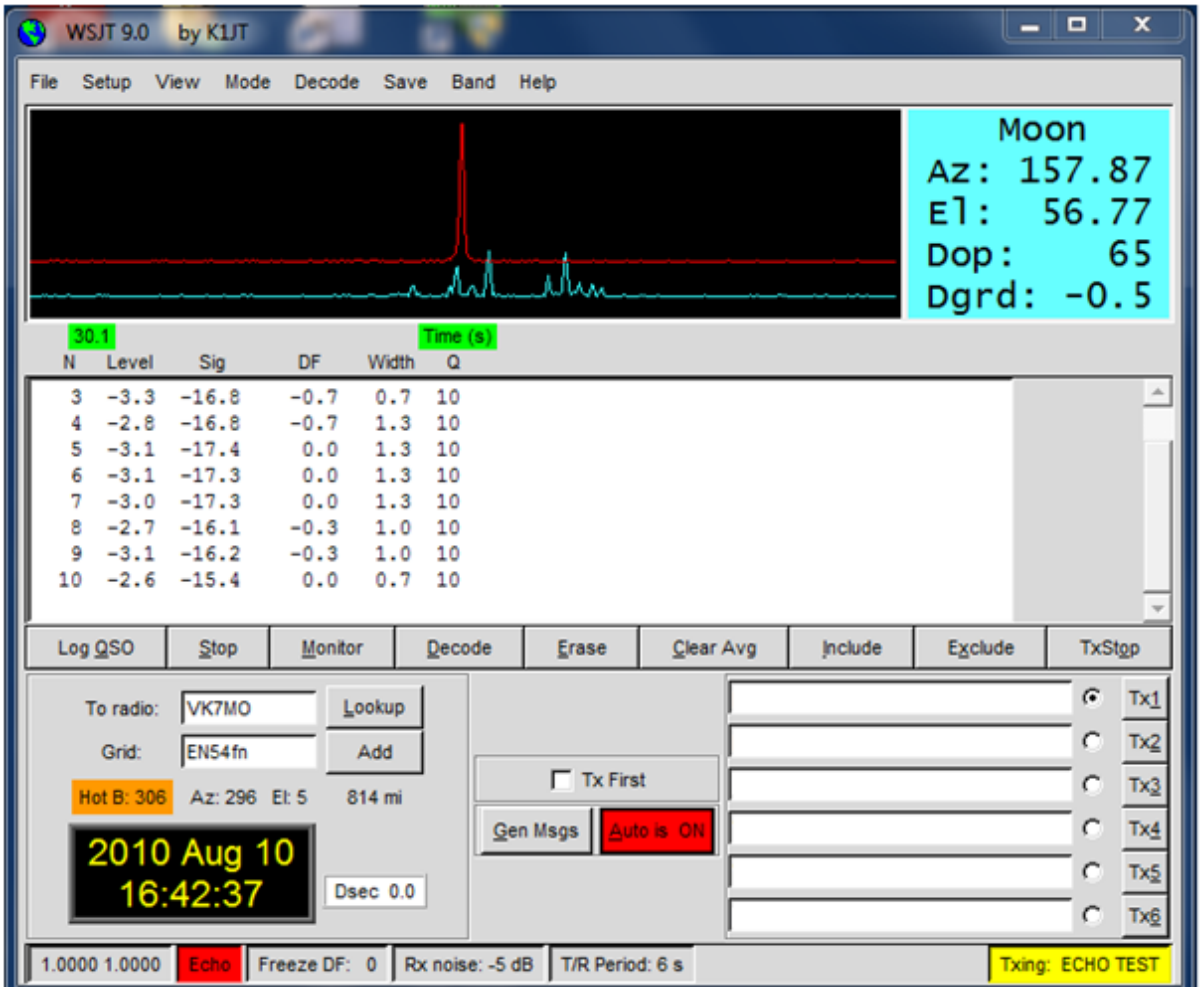
Echo Mode

Echo mode was a popular feature of early versions of WSJT and has been re-introduced in WSJT 9.0. It allows you to make sensitive measurements of your own echoes from the moon, even when they are too weak to be heard. To use it, select **Echo** from the **Mode** menu, aim your antenna at the moon, pick a clear frequency, and toggle the **Auto** button to **ON**. The program will then start cycling through the following loop:

1. Transmit a fixed tone for 2.0 s
2. Wait about 0.5 s for start of return echo
3. Record the received signal for 2.0 s
4. Analyze, average, and display the results
5. Repeat from step 1

At the start of each transmission the frequency of the transmitted tone can be offset randomly around a nominal value of 1500 Hz. A number in the entry field **Dither** (under **Miscellaneous** on the **Setup | Options** screen) controls the magnitude of the random offset. The observed spectrum of each echo is shifted by the dither amount before being accumulated into the average. This procedure is very effective in minimizing the impact of birdies in the receiver passband. In the average spectrum, a fixed-frequency birdie is smeared out over a frequency range equal to the **Dither** value. For an example see the screen shot on next page: the red curve is the corrected echo spectrum, while the blue curve is the raw (uncorrected) data.

Information displayed in the main text box gives the number **N** of completed echo cycles, the average **Level** of receiver background noise in dB, the average echo strength **Sig** in dB, its measured frequency offset **DF** in Hz (after correction for Doppler shift), its spectral **Width** in Hz, and a relative quality indicator **Q** on a 0–10 scale. Background noise level is given with respect to the nominal “0 dB” level used for all WSJT modes. Signal strength is measured in dB relative to the noise power in a 2500 Hz passband. Low numbers for **Q** mean that an echo has not been detected, or is unreliable; for **Q**=0 the values of **DF** and **Width** are meaningless, and **Sig** may be considered an upper limit. Larger values of **Q** imply increasingly believable echo measurements. If you can hear your own lunar echoes, you will see reliable echo numbers within a few seconds after toggling **Auto ON**. If your echoes are 15 to 20 dB below the audible threshold you should get significant results within a minute or so.



By default EME Echo mode assumes that your receiver and transmitter are tuned to the same frequency. The entry field **RIT** on the Echo Mode tab lets you inform the program of any offset receiver tuning — for example, to accommodate a large Doppler shift. Suppose you are running a test on 23 cm and the predicted Doppler shift at the start of the run is –1400 Hz. In that case the 1500 Hz transmitted audio tone would be detected at 100 Hz, probably below the low-frequency cutoff in your receiver's passband. Use your transceiver's RIT control to offset the receiver tuning by the predicted Doppler shift (or a nearby rounded value) and enter this offset in the RIT box before starting the echo measurement. The program will track subsequent Doppler changes up to about ±800 Hz, if necessary, without further adjustment. Your echo should appear at **DF**=0, as usual. You won't need to use the RIT feature on 6 or 2 meters, where Doppler shifts are much smaller.

The frequency of a valid echo should be well defined, stable, and very close to **DF**=0. If you toggle **Auto** off and then on again or click **Clr Avg**, a new measurement will be started. The echo signal should build up again at the same **DF**. To be absolutely certain that you are seeing you own echo, offset your transmitter frequency by a known amount, say 50 Hz, while holding the receiver frequency constant. A valid echo will shift by the same 50 Hz.

Before using **Echo** mode at high power, I recommend that you test it to be sure of proper sequencing of PTT, the audio tones, and your T/R relays.

Appendix A: Linux Installation

First make sure you have installed the following Linux packages (can be done with Synaptic Package Manager):

python-numpy
python-tk
python-imaging-tk
libfftw3-3

Download the current release of WSJT9 from the WSJT home page. The filename should be something like wsjt_9.0_r2117_i386.deb, where “2117” is the current revision number.

Move wsjtyyrxxxx_i386.deb into the directory (normally your home directory, e.g., /home/yourname) where you want the WSJT installation directory to reside. Open a command-line terminal and execute the following command:

```
$ sudo dpkg --instdir=. -i wsjtyyrxxxx_i386.deb
```

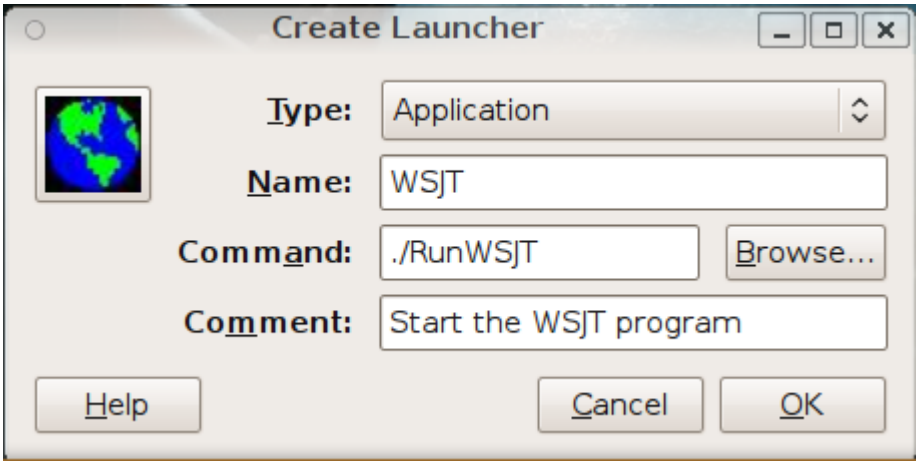
To start WSJT, enter these commands:

```
$ cd WSJT
$ ./wsjt
```

Alternatively, you can create a Desktop-icon for program startup. First create a file in your home folder named "RunWSJT" with this content:

```
#!/bin/sh
cd ~/WSJT
./wsjt
```

Make sure the file is executeable (Filemanager → Properties → Permissions). Then right-click on the Desktop → Create Launcher and fill out the form as appropriate:



Double-Click the icon and select your preferred desktop icon – I use `wsjt.jpg`, a copy of which can be found in the WSJT9 installation directory. Press OK and you're done, you can now launch WSJT by double-clicking the desktop icon.

This procedure has been validated on Ubuntu 9.04, 9.10 and 10.04, and should work for all Debian derivatives.

Some sound systems do not like WSJT's attempt to set the sample rate. You must therefore provide another means to convert the native sampling rate to the 11025 Hz required by WSJT. Create a hidden file with the name

`/home/yourname/.asoundrc`

with the following content:

```
pcm.radio {
        type hw
        card 1
        device 0
}
pcm_slave.radioslave {
        pcm radio
        rate 48000
}
pcm.radioconv {
        type rate
        slave radioslave
```

The number following "card" above is the hardware soundcard number, the "x" in "hw:x,0". It might be some number other than 1.

Reboot the computer and restart WSJT. You should now see a new sound device named "radioconv". Select this device for audio input and output.

Appendix B: Coding and Modulation

One of the principal motivations for WSJT has been to explore the strengths and weaknesses of different coding and modulation schemes for the various propagation modes relevant to amateur VHF/UHF weak-signal communication. For example, meteor scatter requires fast transmission to take advantage of very short bursts or "pings" above the background noise level, while EME needs a mode that can take advantage of extremely weak but relatively stable signals. Different forms of coding and modulation offer advantages for these and other very different propagation conditions. An important constraint is that all modes must be compatible with the equipment and licensing restrictions available to most amateurs.

Some basic numerical parameters of the modes in WSJT 9.0 are summarized below. For each mode the table gives the T/R sequence length in seconds, modulation method, forward error correction code, number of 11025 Hz samples per symbol, keying rate, tone separation Δf, nominal bandwidth BW, transmission rate in characters per second (or total length of transmission TxT in seconds), and approximate S/N threshold in dB. Full technical details of FSK441 were published in QST for December 2001, and those of JT65 in QEX for September-October 2005. Like these two modes, ISCAT and JT4 also use continuous-phase frequency shift keying. Study of the table can give you some feeling for the major internal differences between WSJT modes.

Parameters of WSJT Modes

Mode	T/R	Mod	FEC	Nsps	Baud	Δf	BW	cps	S/N
	(s)					(Hz)	(Hz)	s^{-1}	(dB)
FSK441	15, 30	4-FSK	-	25	441	441	1764	147	-1
JTMS	15, 30	MSK	parity	8	1378	689	2067	197	-1
ISCAT	15, 30	42-FSK	-	256	43.1	43.1	1809	32.3	-17
								TxT (s)	
JT65A	60	65-FSK	RS(63,12)	4096	2.69	2.69	178	46.8	-25
JT65B	60	65-FSK	RS(63,12)	4096	2.69	5.38	355	46.8	-24
JT65C	60	65-FSK	RS(63,12)	4096	2.69	10.77	711	46.8	-23
JT4A	60	4-FSK	K=32,r=1/2	2520	4.375	4.375	17.5	47.1	-23
JT4B	60	4-FSK	K=32,r=1/2	2520	4.375	8.75	35	47.1	-22
JT4C	60	4-FSK	K=32,r=1/2	2520	4.375	17.5	70	47.1	-21
JT4D	60	4-FSK	K=32,r=1/2	2520	4.375	39.375	157.5	47.1	-20
JT4E	60	4-FSK	K=32,r=1/2	2520	4.375	78.75	315	47.1	-19
JT4F	60	4-FSK	K=32,r=1/2	2520	4.375	157.5	630	47.1	-18
JT4G	60	4-FSK	K=32,r=1/2	2520	4.375	315	1260	47.1	-17
Diana	30	42-FSK	-	2048	5.38	5.38	226	23.4	-22

Experimental Modes: Development versions of WSJT 9.0 have also included two experimental modes: **JTMS** for meteor scatter, and **Diana** for EME. (Diana is the Roman name for the goddess of the moon.) As indicated in the table, JTMS uses a variation of FSK called Minimum Shift Keying (MSK), which allows a faster transmission rate per unit bandwidth. JTMS performs approximately as well as FSK441, and tends to produce cleaner decodes. Diana is considerably different from JT65, the widely used digital EME mode. Diana is about 2 dB less sensitive, a result of using T/R sequences of half the length. It uses non-structured (free-text) messages and has no forward error correction.

Experimental modes **JTMS** and **Diana** are normally hidden and unavailable in WSJT 9.0, but they can be enabled by creating a file named `experimental` in the WSJT9 installation directory. The contents of this file are ignored — it can be an empty file.

If you choose to experiment with the JTMS or Diana modes, please do it in a way that does not conflict with the normal MS and EME modes, FSK441 and JT65. For example, don't call CQ in JTMS mode on the FSK441 calling frequency. Your comments and suggestions concerning the experimental modes will be greatly appreciated, and will help to determine whether they will become permanent features of WSJT.

Acknowledgment

A number of WSJT users have put hundreds of hours into testing WSJT 9.0, finding bugs, and suggesting improvements. I particularly wish to thank K0AWU, N5SIX, W8WN, OZ1PIF, OE5MPL, IW4ARD, VK7MO, VK3SO, VK4JMC, W5WVO, WA5UFH, G4DEZ, and G4IGO. Hope I didn't forget anyone!