Work the World with *WSJT-X*, Part 1: Operating Capabilities

The first of a two-part tutorial about the most popular digital software in use today, from the people who designed and developed it.

Joe Taylor, K1JT; Steve Franke, K9AN, and Bill Somerville, G4WJS

One of the greatest pleasures in Amateur Radio is the thrill of establishing two-way communication with like-minded hobbyists far away, using one's own equipment. We enjoy making such contacts on our own, without recourse to commercial carriers or infrastructure. Since the 1930s, amateurs have known that worldwide communication is possible on the HF bands (at least some of the time) with power levels no more than 100 W and antennas as simple as half-wave dipoles. Twenty-first century digital communication techniques based on information theory make these things possible at much lower power levels, even with compromise antennas. Optimized methods of coding and modulation enable these and many other surprising feats — for example, DXCC using low power and an indoor antenna; two-way contacts on the 6- and 2-meter bands at any time over distances of 500 – 1,300 miles (800 – 2,100 kilometers) using reflections from ionized meteor trails; and Earth-Moon-Earth ("moonbounce") contacts over worldwide distances, whenever the Moon is up at both ends of a path.

Starting in 2001, the software program *WSJT* has facilitated making two-way contacts with extremely weak signals. The latest version of this open-source, multiple-author software package is called *WSJT-X*. It supports nine distinct protocols or modes, each optimized for a different frequency range or type of propagation. These modes
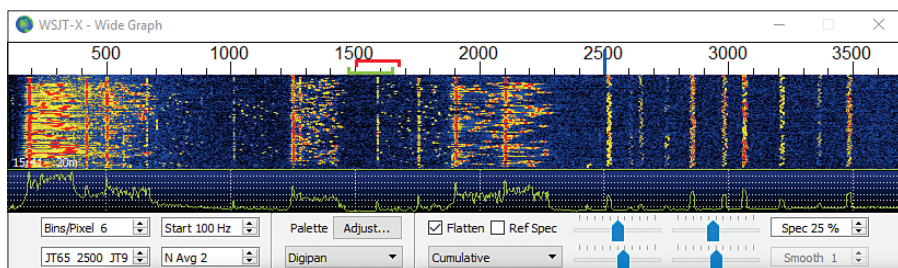

Figure 1 — Waterfall spectrogram recorded by *WSJT-X* at 14.076 MHz on September 19, 2015. The frequency scale gives audio frequencies in hertz above the transceiver dial frequency. Of the 23 decodable signals in this 1-minute recording, eight are so weak that they would be inaudible to a human — even if they were the only signal in the passband.

are not designed for long conversations, or "ragchewing." Rather, they concentrate on efficient exchange of such basic information as call signs, Maidenhead grid locators, signal reports, and acknowledgments at the lowest possible signal-to-noise ratios, in the space of a few minutes or less. Short user messages are encoded into audio-frequency waveforms that can be transmitted and received with stan-

This mathematically sophisticated method of encoding information ensures that with very high probability, messages displayed by the decoding software will be exactly those that were originally encoded.

dard SSB transceivers. At the receiving end, recovered audio is converted back to digital samples and the software carries out a reverse transformation to decode the message. All transmissions are timed and synchronized with Coordinated Universal Time (UTC). Infor-

mation required for a minimal valid QSO (contact) is typically exchanged and acknowledged after two or three successful transmissions from each station.

The first publicly available version of *WSJT*[1] was designed for meteor scatter on the VHF bands. The software has been in continual development since 2001, with improved performance, added user-convenience features, and new operating modes. The current program version supports four modes that use 1-minute transmit/receive (T/R) sequences. Each of these "slow" modes — JT4, JT9, JT65, and QRA64 — uses a distinct coding and modulation scheme designed to optimize weak-signal communication on a particular type of propagation path, with high reliability and good bandwidth efficiency. The most recently introduced slow mode is

called FT8, and it's less "slow" than the others — it uses T/R sequences of only 15 seconds.

The program also supports three "fast" modes — MSK144, JT9 (fast), and ISCAT — with selectable T/R sequence lengths of 5, 10, 15, or 30 seconds. The fast modes send information much more rapidly, repeating each message many times during a sequence. These modes are optimized for meteor scatter, aircraft scatter, and other propagation types that yield short bursts of usable signal strength. Finally, *WSJT-X* supports a quasi-beacon mode known as WSPR[2] (for "Weak Signal Propagation Reporter"), used for probing worldwide propagation conditions, and Echo mode for measuring reflections of your own signals from the Moon.

Except for ISCAT, all protocols in *WSJT-X* include a strong form of forward error correction (FEC). This mathematically sophisticated method of encoding information ensures that with very high probability, messages displayed by the decoding software will be exactly those that were originally encoded. Among many other obvious advantages, strong FEC means that in nearly all circumstances, received call signs, grid locators, signal reports, and other information are highly reliable.

This article is not a "how-to" guide for using *WSJT-X*; that purpose is best served by an extensive *WSJT-X User Guide* [3] and an active and user-friendly online support forum.[4] Instead, in Part 1 of this two-part article, we provide highlights illustrating the sort of things that can be done with *WSJT-X,* and we briefly outline the station equipment required. In Part 2, "Codes, Modes, and Cooperative Software Devel-

opment," we explain how the various protocols work. We also offer some insight into how this all-volunteer software project has created an extremely capable, open-source, fun-to-use software package that is freely available[5] to all radio amateurs — including its internal source code.[6] We invite others with programming, documentation, testing, and related skills and interests to consider joining and participating in our ongoing development project.

Open sharing of our protocol specifications and source code has had the desirable and beneficial side effect of encouraging other programmers to create offshoot open-source programs, such as *JT65-HF*, *JTDX*, and *MSHV*, which typically implement and support a small and targeted subset of the *WSJT-X* capabilities. At the time of this writing, we estimate there are roughly 5,000 users of *WSJT-X* active in a typical week, around the world. Almost as many more are using the *WSJT-X* modes and their encoding and decoding algorithms in one of the offshoot programs mentioned. This state of affairs is a fine example of good-ham-spirit cooperation in an age when state-of-the-art communication engineering usually involves software as well as hardware.

What *WSJT-X* Can Do

DXing with Weak Signals

The oldest of our slow modes, JT65, was designed for Earth-Moon-Earth (EME) communication[7] and is widely used for that purpose today. However, even greater usage of JT65 (and the newer modes, JT9 and FT8) can be found in spectral slices only a few kilohertz wide on bands from 160 through 6 meters. An example of the *WSJT-X* waterfall spectrogram for one such slice is shown in Figure 1, recorded on the 20-meter band about 2 years ago. *WSJT-X* decoded 13 JT65 signals in this arbitrarily chosen 1-minute time segment. All but three of these signals overlap in frequency with one or more others, but nevertheless they are decodable without errors. Ten JT9 signals appear at the right side of the spectrogram, above 2,500 Hz, and they are also decoded without errors. Evidently, at least 23 error-free contacts are taking place simultaneously in about 3.5 kHz of spectrum. More recently, we have sometimes seen twice this number of decodable JT65 and JT9 signals in a single minute, in one 4 kHz slice.

JT65, JT9, and FT8 are the most widely used *WSJT-X* modes, and probably the most popular machine-generated modes of any kind in Amateur Radio today. Thousands of contacts are made with them every day, on amateur bands from MF through microwaves. Many amateurs have completed WAC, WAS, DXCC, and other awards using these modes, often with low-power and simple antennas. Signals at least 10 dB below the threshold of audibility are generally decodable in all the 1-minute *WSJT-X* slow modes, and FT8 is only a few decibels behind. For most humans, the audible

Table 1
Conventional Dial Frequencies for FT8, JT65, JT9, and WSPR on the HF Bands

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

*Pending change from 3.5926, †Pending change from 50.276

threshold for such signals (and for Morse-coded CW) occurs at signal-to-noise ratios around −15 dB, measured in a reference bandwidth of 2,500 Hz.

By informal convention, subband slices for FT8, JT65, and JT9 currently begin at the upper-sideband dial frequencies listed in Table 1. If you're curious and have not previously used one of these modes, try downloading *WSJT-X* from the *WSJT* home page.[5] Install the program on your shack computer or laptop, set your transceiver to upper-sideband mode at 7.076 or 14.076 MHz, turn up the speaker audio, and start monitoring in JT65 mode using the computer microphone for audio input to *WSJT-X*. Be sure that your computer clock is set to the correct time, within a second or so. On an open band, you should hear the musical tones of JT65 signals, starting at the top of each UTC minute, and see the signals on the waterfall display. Near the end of each minute, decoded messages should appear in the *WSJT-X* Band Activity window. The messages will probably look something like these examples:

```
CQ UX1LW KN89
W3DJ LU2BN 73
PY4SM CP6UA −15
PY1ME PY6JB R−07
K7PWL K1NOX RRR
```

Two-way contacts in any of the *WSJT-X* modes usually start in the traditional way, with someone answering another operator's CQ. Messages exchanged in a minimal contact then proceed roughly as follows:

```
1. CQ KA2ABC FN20
2. KA2ABC G8XYZ IO92
3. G8XYZ KA2ABC −17
4. KA2ABC G8XYZ R−21
5. G8XYZ KA2ABC RRR
6. KA2ABC G8XYZ 73
```

Standard messages in *WSJT-X* usually consist of two call signs followed by a grid locator, signal report, acknowledgment, or 73; CQ or QRZ may be
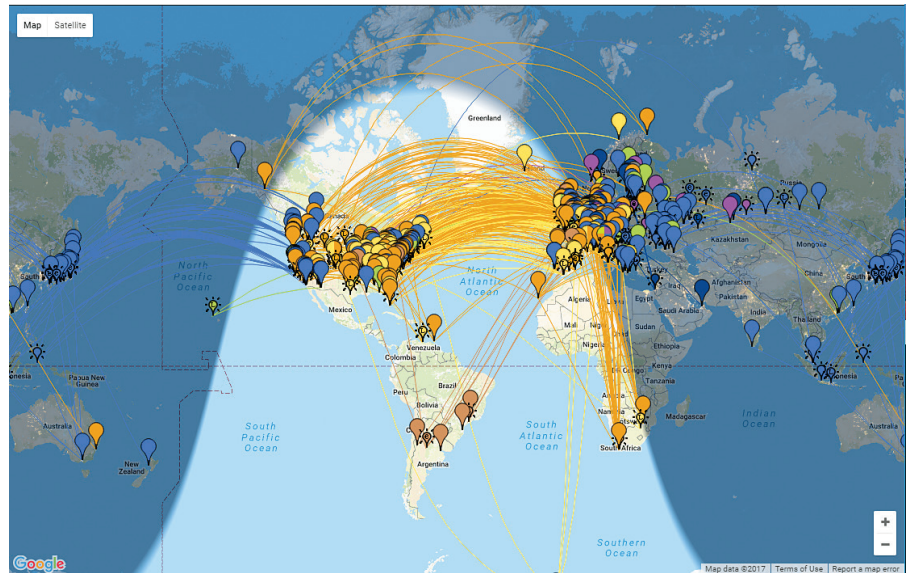

Figure 2 — *PSK Reporter* world map showing open propagation paths for spotted JT65 and JT9 signals over a 1-hour interval around 1630 UTC on February 13, 2017. Different colors indicate signals on different bands. Magenta is 80 meters, blue is 40 meters, yellow is 20 meters, and brown is 15 meters.

substituted for the first call sign. Signal reports are expressed as signal-to-noise ratios measured in a 2.5 kHz bandwidth. You can also send any free-text

These modes are not designed for long conversations or "ragchewing."

message containing letters, numbers, basic punctuation, and spaces up to a maximum of 13 characters — one might say, roughly equivalent to a "deci-Tweet." We already mentioned that these weak-signal modes are not designed for ragchewing! Consult the *WSJT-X User Guide* for additional details and limitations concerning message structure — for example, how to accommodate compound call signs like PJ7/KA2ABC.

Monitor Propagation Conditions
About a decade ago, we realized that because call signs and locators are decoded very reliably in FEC-enhanced modes like JT65, and because the computers in most ham shacks are connected to the internet, it should be possible to create "reverse

beacon" networks that show where a signal is being copied and what worldwide propagation paths are open at the present time. The central hub of one of the most successful such networks, *PSK Reporter*,[8] was developed by Philip Gladstone, N1DQ. *WSJT-X* optionally sends reception reports to its website, where you will find a world map showing open propagation paths color-coded by frequency band. *PSK Reporter* can also display reported call signs, locators, and other information, and can filter the displayed map by band, call sign, operating mode, and other criteria. In the background, it carries out other tasks, such as statistical analysis and limited archival storage of data. More than a million reception reports are currently received by *PSK Reporter* every day, and about 98% are for JT65, FT8, and JT9 signals. Figure 2 is an example screenshot showing open worldwide signal paths on the HF bands at mid-morning in the central United States.

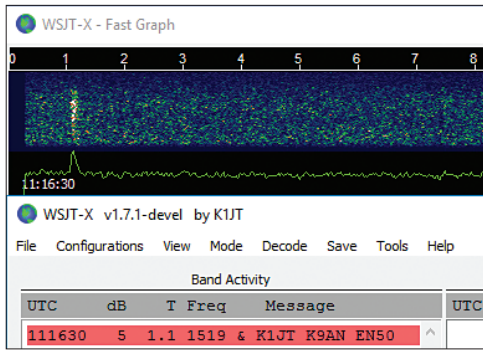WSPR mode provides another popular tool for probing propagation condi-

Figure 3 — Screenshot showing small portions of the *WSJT-X* Fast Graph window and main window when running in MSK144 mode. The bright vertical stripe at time *t* = 1.1 s is a moderate-strength meteor "ping" lasting about 70 milliseconds. The decoded message shows that K9AN is calling K1JT.

tions. In this case, the relevant signals are not part of two-way conversations between amateurs, but rather one-way, low-power quasi-beacon transmissions received at another location and reported automatically to the *WSPRnet* website.[9] All WSPR-mode capabilities, including coordinated band-hopping, have now been incorporated in *WSJT-X* (see Note 2 and the *WSJT-X User Guide* for further details).

Meteor Scatter

About a year ago, we started experimenting with MSK144, a new protocol designed explicitly for amateur meteor scatter (MS) communication. MSK144 has rapidly become the dominant mode for MS contacts, worldwide. On the 6-meter band, with 100 W and a modest antenna — say a three- or four-element Yagi, a two-element Moxon, or even a dipole or omni-directional halo up 20 feet or more — you can make contacts out to beyond 1,000 miles at essentially any time. More power and a better antenna will make for more (and quicker) contacts. On 2 meters, a good starter station for MS is 100 W and a ten-element Yagi. Figure 3 shows what a short, moderate-strength meteor-induced "ping" looks like on the *WSJT-X* horizontally scrolling spectrogram.

As an example of what can be done, we note that many hundreds of MSK144 contacts were made during the January 2017 VHF Sweepstakes. Most of these contacts yielded additional contest multipliers for the participating stations. Figure 4 provides a pictorial summary of 50 MHz MSK144 activity on a Saturday morning in February 2017, taken from the *PSK Reporter* website. February is generally a slow month for meteor scatter activity, because it includes no major and few minor meteor shower events. Sporadic meteors are present at nearly all times, and are sufficient for making MSK144 contacts.
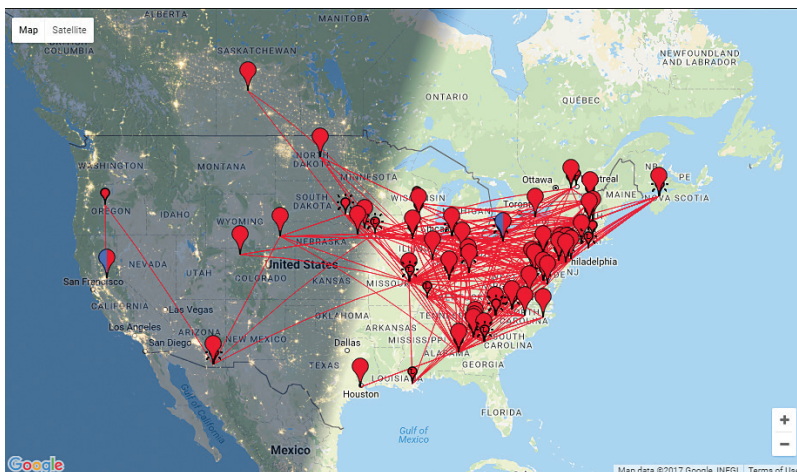
MSK144 is a "fast" mode with selectable sequence lengths. In North America and Europe, T/R sequences of 15 seconds have become the default standard. The MSK144 decoder operates in real time, so you see decoded messages immediately after each decodable ping. Pings as short as 0.1 seconds are usually decodable if the signal-to-noise ratio is 0 dB or higher. Weaker pings lasting ½ second or longer can be decoded at signal-to-noise ratios as low as –8 dB. Such pings are barely audible, if at all.

The MSK144 protocol uses strong FEC and the same structured messages as the *WSJT-X* slow modes. The resulting nearly error-free decoding makes it possible to use automatic message sequencing. The program can keep track of where you are in the standard contact sequence and automatically select the appropriate message to send for each transmission.

Meteors are several times more frequent around sunrise, so MS contacts are quicker in the morning than in the afternoon or evening. The duration of "pings" is inversely proportional to the square of frequency, so usable pings at 144 MHz and higher bands are both shorter and less frequent than those at 50 MHz. Nevertheless, MS contacts are still fairly easy at 144 MHz using MSK144, and with persistence they are possible at 222 and 432 MHz.

Moonbounce with Modest Equipment

The extremely high sensitivity of the slow modes in *WSJT-X* is particularly important on VHF and higher bands, especially on such difficult links as the Earth-Moon-Earth path. Simply stated, EME communication is at least "10 dB easier" with these modes than with CW or other traditional modes. The default mode for digital EME on the VHF and UHF bands is JT65. The new mode QRA64 is gaining popularity on these bands as well, and both

Figure 4 — A map from *PSK Reporter* showing activity with MSK144 on a Saturday morning (Eastern US) in February.

Figure 5 — The 12-element Yagi antenna used by DL1VPL to complete DXCC on 144 MHz. [Thomas Hartig, DL1VPL, photo]

Figure 6 — The portable EME-capable 10 GHz station of VK7MO, set up at roadside in the Australian Outback. [Rex Moncur, VK7MO, photo]

JT4 and QRA64 are used for EME on the microwave bands 2.3 GHz and higher.

We know of at least three hams with modest single-Yagi stations who have worked 100 or more different countries *on the 2-meter band.* Of course, most of the necessary contacts were made over the EME path. Figure 5 shows the 12-element Yagi used by Thomas Hartig, DL1VPL, to complete

his 2-meter DXCC award. Another example of "doing the most with the least" is the 10 GHz portable EME setup of Rex Moncur, VK7MO, shown in Figure 6. Rex's setup includes a 10 GHz transverter, a 50 W solid-state power amplifier, and a 2.5-foot (75-centimeter) dish mounted on a collapsible tripod. He has made hundreds of EME contacts with this equipment using the JT4 and QRA64 modes.

Most of these contacts are with stations in Europe, close to his antipodes.

Rig Control and Frequency Calibration

WSJT-X provides for optional computer-aided transceiver (CAT) control of nearly all modern radios. The necessary communication between radio and computer takes place over a USB or serial port. Relevant rig-control features include T/R switching, frequency and mode setting, and options such as split operation and automatic Doppler compensation for the EME path. The CAT-control portion of our software makes use of an open-source library known as Hamlib,[10] to which many active hams have contributed.

Many capabilities of *WSJT-X* depend on the software's use of signal-detection bandwidths of no more than a few hertz. This puts a special premium on frequency accuracy and stability. *WSJT-X* provides tools that 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 through a series of preset frequencies of carrier-based signals at reliably known frequencies. We find that major-city AM broadcast stations can serve as frequency calibrators
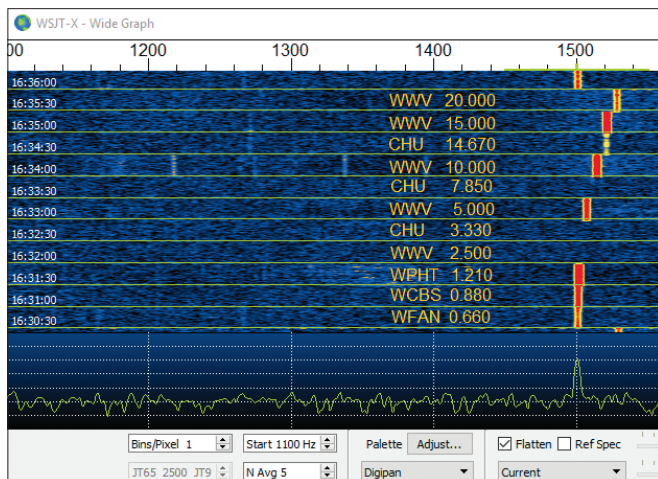

Figure 7 — The *WSJT-X* frequency calibration procedure cycles through a list of AM signals with reliably known frequencies, spending 30 seconds with the radio dial set 1,500 Hz below each frequency. Station call signs and frequencies in megahertz have been added to the figure.
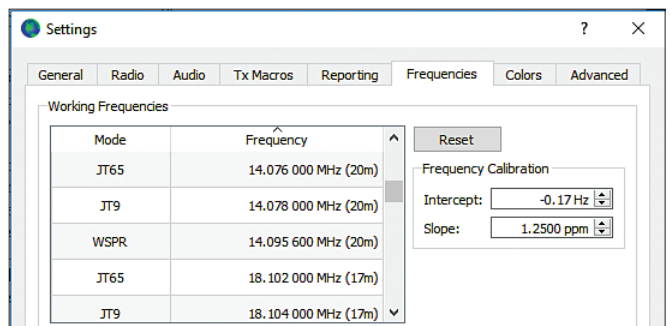

Figure 8 — Upper portion of the Settings → Frequencies tab, showing the entry fields for frequency calibration of your radio.
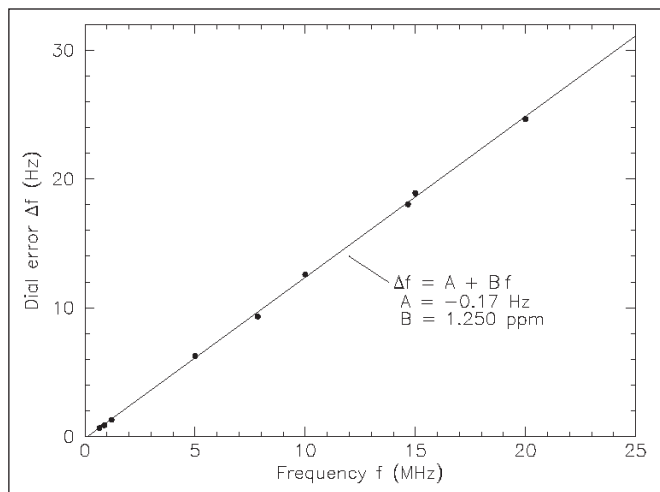
Figure 9 — Dependence of dial error on frequency, measured for a Yaesu FT-2000. Parameters of the best-fit calibration line are indicated in the figure.

$$\Delta f = A + B f$$
$$A = -0.17 \text{ Hz}$$
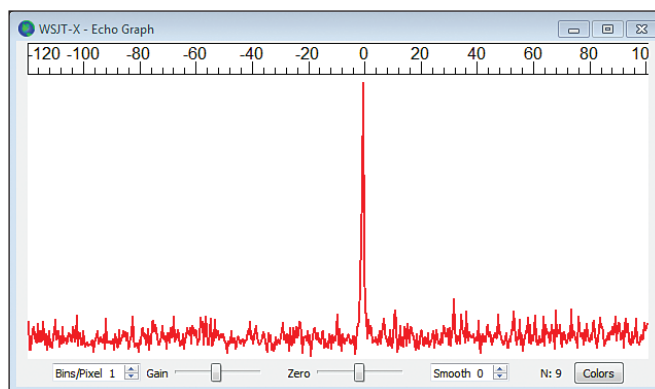$$B = 1.250 \text{ ppm}$$

Figure 10 — Lunar echo of the K1JT signal on 144 MHz measured using Echo mode in *WSJT-X*.

at the low frequency end of the spectrum, and in North America, we use the standard time-and-frequency broadcasts of WWV and CHU at

Many amateurs have completed WAC, WAS, DXCC, and other awards using these modes, often with low power and simple antennas.

higher frequencies. Similar shortwave signals are available in other parts of the world.[11] During the calibration procedure, the radio's USB dial frequency is offset 1,500 Hz below each frequency in the list. As shown in Figure 7, detected signal carriers therefore appear at about 1,500 Hz in the *WSJT-X* waterfall.

With modern synthesized radios, small measured offsets from 1,500 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 in Figure 7 produced a measured tone offset of 24.6 Hz. The resulting calibration

constant is 24.6/20 = 1.23 parts per million. This number may be entered on the Frequencies tab of the Settings window (see Figure 8). 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 Figure 9. Software tools for completing this task are included with the *WSJT-X* installation, and detailed instructions for their use are available online.[12] 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 periodic ARRL Frequency Measuring Tests.

Aircraft Scatter
The ISCAT mode is especially effective for microwave contacts using signals reflected from high-flying aircraft. ISCAT copes well with the rapid changes in Doppler shift and short bursts of signal lasting a second or so. VK3HZ, using a 60-centimer dish and 7 W at 10 GHz and working VK7MO as a rover, has increased his 10 GHz grid locator total to over 80 using mainly this mode of propagation.

Their longest contacts are over 900 kilometers (560 miles).

Echo Mode
Echo mode allows you to make sensitive measurements of your own signal echoes from the Moon, even when they are too weak to be heard. In this mode, *WSJT-X* transmits a 1,500 Hz fixed tone for 2.3 seconds, waits about 0.2 seconds for the leading edge of a return echo from the Moon, records the received signal for 2.3 seconds, and then analyzes, averages, and displays the result. The whole cycle is repeated every 6 seconds, and the program calculates and compensates automatically for continually changing Doppler shifts. As shown in the screenshot in Figure 10, return echoes should appear at frequency offset 0 Hz, the center of the Echo Graph window.

Station Requirements and Summary
Station requirements for using *WSJT-X* are essentially the same as those for other computer-assisted modes. You will need an SSB transceiver, an antenna, a computer preferably built in the past 6 or 8 years, and a monitor with at least 1,024 × 768 pixels resolution. Computer-to-radio interfacing usually requires a serial port or equiva-

lent USB device for T/R switching; using your rig's VOX is also possible. T/R switching uses CAT commands if your rig supports it, or serial port signals on either a CAT connection or a separate port. Output from the computer's sound card (or equivalent) should be patched to the radio's Data input, or Microphone if no Data input is available. Received audio goes to the computer's Line input or a combined Line input and Microphone connector. Auxiliary devices that handle these connections are widely available as homebrew projects or commercial products. Some recent radios have everything built in so that only a single USB cable is needed between computer and radio. You will also need a means for synchronizing the computer clock to UTC within ±1 second. Further details and setup instructions can be found in the *WSJT-X* User Guide (see Note 3). We recommend particularly the Basic Operating Tutorial and the downloadable sample files for each mode. You can get answers to specific setup questions from the online support forum (see Note 4).

Space requirements have limited us to a list of *WSJT-X* capabilities that is far from complete. Nevertheless, we hope to have given you a good feeling for the program's wide range of capabilities. In Part 2 of this two-part article, we outline some fundamentals of communication theory, describe the distinguishing features of each *WSJT-X* protocol, and explain how the program's seemingly all-but-magic tricks work. We then give a brief overview of the project's cooperative software development tools and procedures.

Notes

[1] Joe Taylor, K1JT, "*WSJT:* New Software for VHF Meteor-Scatter Communication," *QST,* Dec. 2001, pp. 36-41.
[2] Joe Taylor, K1JT, and Bruce Walker, W1BW, "WSPRing Around the World," *QST,* Nov. 2010, pp. 30-32.
[3] **www.physics.princeton.edu/pulsar/K1JT/ wsjtx-doc/wsjtx-main-1.7.1-devel.html**
[4] **groups.yahoo.com/neo/groups/wsjtgroup/ info**; e-mail address **wsjtgroup@ yahoogroups.com**.
[5] **physics.princeton.edu/pulsar/k1jt**
[6] Source code for *WSJT-X* and its sister programs is publicly available at **https:// sourceforge.net/projects/wsjt**
[7] Joe Taylor, K1JT, "The JT65 Communications Protocol," *QEX*, Sep./Oct., 2005, p. 3.
[8] Philip Gladstone, N1DQ, **https://pskreporter. info/pskmap**
[9] **wsprnet.org/drupal/node**
[10] **https://sourceforge.net/p/hamlib/wiki/ Hamlib**
[11] **www.smeter.net/stations/hf-time-frequency. php**
[12] **https://physics.princeton.edu/pulsar/k1jt/ FMT_User.pdf**

Joe Taylor was first licensed as KN2ITP in 1954, and has since held call signs K2ITP, WA1LXQ, W1HFV, VK2BJX, and K1JT. He was Professor of Astronomy at the University of Massachusetts from 1969 to 1981, and since then Professor of Physics at Princeton University, serving there also as Dean of the Faculty for 6 years. He was awarded the Nobel Prize in Physics in 1993 for discovery of the first orbiting pulsar, leading to observations that established the existence of gravitational waves. After retirement, he has been busy developing and enhancing digital protocols for weak-signal communication by Amateur Radio, including JT65 and WSPR. He chases DX from 160 meters through the microwave bands. You can reach Joe at **joe@princeton.edu**.

Steve Franke, K9AN, holds an Amateur Extra class license. He was first licensed in 1971 and has previously held call signs WN9IIQ and WB9IIQ. An early and abiding fascination with radio science led to his current position as Professor of Electrical and Computer Engineering at the University of Illinois in Urbana-Champaign. Steve is a member of ARRL and a Fellow of the IEEE. You can reach Steve at **s.j.franke@icloud.com**.

Bill Somerville, G4WJS, read Chemistry at the University of Bristol in the UK, graduating in 1978 with a Bachelor of Science degree. Since graduating, he has worked in computer software and hardware in a variety of industries including defense, software vendors, and financial services, more recently as a freelance consultant providing systems programming and related services to mid- to large-size software tool vendors. Bill has been an active radio amateur since 1981, holding the calls G6IJU and G4WJS. He enjoys HF and VHF bands, contest operating, and DX chasing using CW, phone, and data modes. He is a keen walker and swimmer. Bill participates in open-source software projects for Amateur Radio, with *WSJT-X* being the largest contribution. Bill is happy to provide input, drawing on his extensive software engineering experience, to help those with other important domain skills provide robust, professional standard, software-based Amateur Radio communication tools. You can reach Bill at **bill.8@classdesign.com**.

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New Products

SmartSDR for iOS from FlexRadio Systems and Marcus Roskosch, DL8MRE

SmartSDR for iOS offers FLEX-6300, FLEX-6500 and FLEX-6700 owners the ability to operate from home or remotely through their Apple mobile device. *SmartSDR for iOS* provides many of the same features as *SmartSDR for Windows* without the necessity of using a PC. You can operate in any mode, and the application can run along with programs on your PC such as *N1MM Logger+* or *CW Skimmer*. *SmartSDR for iOS* offers options such as a visual band plan and DX Cluster integration. Band limits, modes and DX-Cluster spots will be displayed right inside the panadapter.

To run *SmartSDR for iOS* the operator will need a FLEX-6000 series radio and an Apple device such as an iPad, iPhone or iPod Touch running *iOS* 9.0 or greater. A newer iPad (3, Air 1 or newer) or iPhone (5s or better) is recommended. To run this app at your home, only a regular WiFi connection is needed. You can immediately start using the app. To run the app and to operate your FLEX-6000 series radio from another location, you need to have a Virtual Private Network (VPN) connection to your home network. *SmartSDR for iOS* is available from the App Store for $49. Optional features such as the DX Cluster and Band Plan are priced at $4.99. For more information, visit **www.flexradio.com**.