

The FT4 Protocol for Digital Contesting

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Introduction: FT4 is an experimental digital mode designed specifically for radio contesting. Like FT8, it uses fixed-length transmissions, structured messages with formats optimized for minimal QSOs, and strong forward error correction. T/R sequences are 6 seconds long, so FT4 is $2.5 \times$ faster than FT8 and about the same speed as RTTY for radio contesting. FT4 can work with signals 10 dB weaker than needed for RTTY, while using much less bandwidth.

Basic parameters: FT4 message formats are the same as those in FT8 and encoded with the same (174,91) low-density parity check code. Transmissions last for 4.48 s, compared to 12.64 s for FT8. Modulation uses 4-tone frequency-shift keying at approximately 23.4 baud, with tones separated by the baud rate. The occupied bandwidth (that containing 99% of transmitted power) is 90 Hz. Threshold sensitivity for 50% decoding probability is $S/N = -16.4$ dB, measured in the standard 2500 Hz reference noise bandwidth. *A priori* (AP) decoding can push threshold sensitivity down to -18 dB or better.

Installation and Initial Setup

To join the FT4 test group and participate in one or more upcoming “mock contest” practice sessions, follow these steps to install and configure a release candidate for *WSJT-X 2.1.0*:

1. Download the installation package from a link to be provided.
2. Install the program in the usual way for your operating system. To avoid conflict with your normal operation, you may wish to use a different installation directory from that used for *WSJT-X 2.0*.
3. Start the program as you normally would for FT8.
4. From the **Configurations** menu select **FT8 | Clone** (or **Default | Clone**).
5. **Rename** the resulting new configuration to **FT4**, and select the new configuration.
6. Select **FT4** from the **Mode** menu.
7. On the **File | Settings | Frequencies** tab, right-click any line in the **Working Frequencies** table and press the **Reset** button. This action will pick up the recommended working frequencies for FT4.
8. Check the box **Special operating activity** on the **Settings | Advanced** tab. Then select **RTTY Roundup messages** and enter your proper contest exchange in the field **RTTY RU Exch**.
9. Instructions for connecting *WSJT-X* to *N1MM Logger+* can be found in the *WSJT-X 2.1 User Guide*, [Section 4.5](#).

You now have a release candidate for *WSJT-X 2.1.0* configured for FT4 operation. You might find it useful to download and examine an FT4 sample file. Select **Download Samples** from the **Help** menu and tick the **FT4** box. Configure the **Wide Graph** controls as shown in Figure 1 and select **Deep** on the **Decode** menu, then open the sample file from the **File** menu. The recorded interval should produce 19 decodes, as seen in Figure 1. Most of the decoded signals are inaudible or barely audible in the audio file. Fewer than one-third are strong enough to be reliably decoded if they had been RTTY signals — and only then if they were spread out over a much wider frequency range.

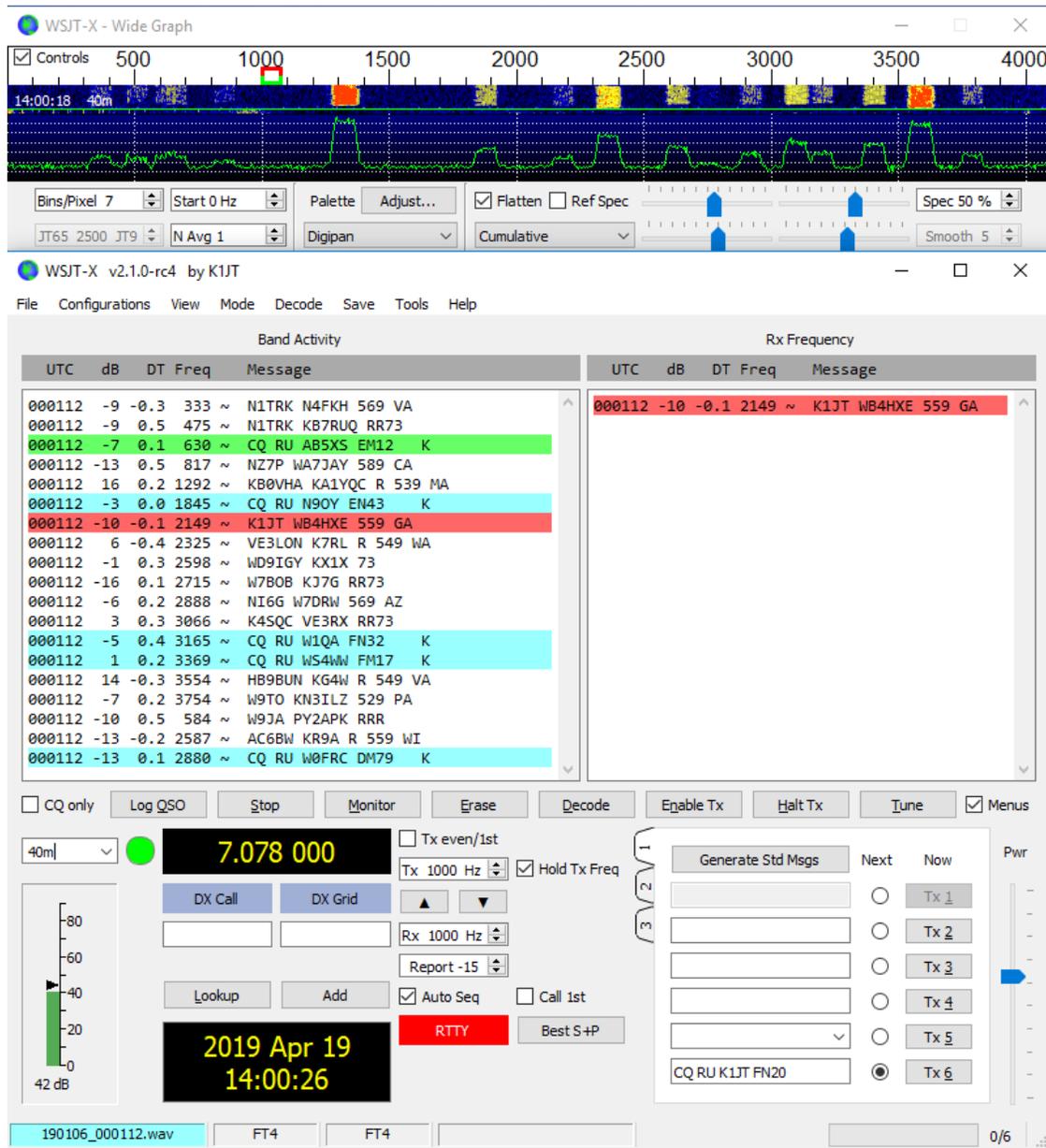


Figure 1. — Screen shot showing simulated FT4 signals and their decodes.

Operation: Aside from its much shorter T/R sequences, FT4 behaves essentially the same way as FT8. One new on-screen control is available for FT4 operation, a button labeled **Best S+P**, just below the **Call 1st** checkbox. Clicking this button during an Rx cycle arms the program to examine all CQ messages decoded at the end of the 6-second 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 ARRL RTTY Roundup rules) will be implemented soon. We may also provide additional priority rankings, for example “New Grid on Band” (useful for North American VHF contests), sorting by signal strength, etc.

For keyboard control of transmitted messages, check the box **Alternate F1–F6 bindings** on the **Settings | General** tab. In typical contest-style operation you can then hit function key **F1** to solicit a QSO by sending CQ. To respond to a CQ and send your contest exchange, double-click on the decoded message. Alternatively, you can click on **Best S+P** and let the selection algorithm choose a station to call. **Auto Seq** and **Call 1st** checkboxes behave as in FT8, and thus the remainder of a minimal QSO can continue without further operator action. Function keys **F2 – F5** may be used to send messages displayed in entry fields for Tx2 – Tx5 on tab 1, at bottom right of the main window. Function key **F6** toggles the checked status of **Call 1st**, and key combination **Alt+B** can be used to toggle the armed status of **Best S+P**.

FT4 is presently configured so that a station operating in Search-and-Pounce (“S+P”) mode logs a QSO when RR73 is transmitted, and the CQing (“Run”) station logs a QSO when RR73 is received. Like FT8, FT4 makes little distinction between an S+P station and a Run station. An operator can switch easily and frequently between these two ways of initiating QSOs, and contesting skill will depend on optimizing these and many other operating decisions. With a steady stream of available stations to work, single-radio QSO rates well above 100/hour are possible using FT4.

Transmitted signal: FT4 uses a modulation technique known as Gaussian frequency shift keying, or GFSK. The generated audio waveform consists of 105 symbols (tones) sent in sequence at one of four frequencies. The encoded series of distinct tones for part of a transmission might originally look like the upper (red) curve in Figure 2. However, in FT4 the sequence of frequencies is smoothed by convolution with a Gaussian function before being sent to the software modulator. The blue curve shows the corresponding smoothed sequence of frequencies actually sent to the modulator. The transmitted sequence no longer has any stepwise discontinuities.

Differences between the red and blue curves seem rather small, but spectra of the resulting audio waveforms are remarkably different. Figure 3 shows spectra for an FT4 signal (blue) and a standard continuous-phase FSK signal (red) for the same encoded bit sequence. The GFSK spectrum has steep skirts, occupying a bandwidth of only 75 Hz at –6 dB, 200 Hz at –60 dB, and 260 Hz at –80 dB. No additional filtering is applied to the audio waveforms.

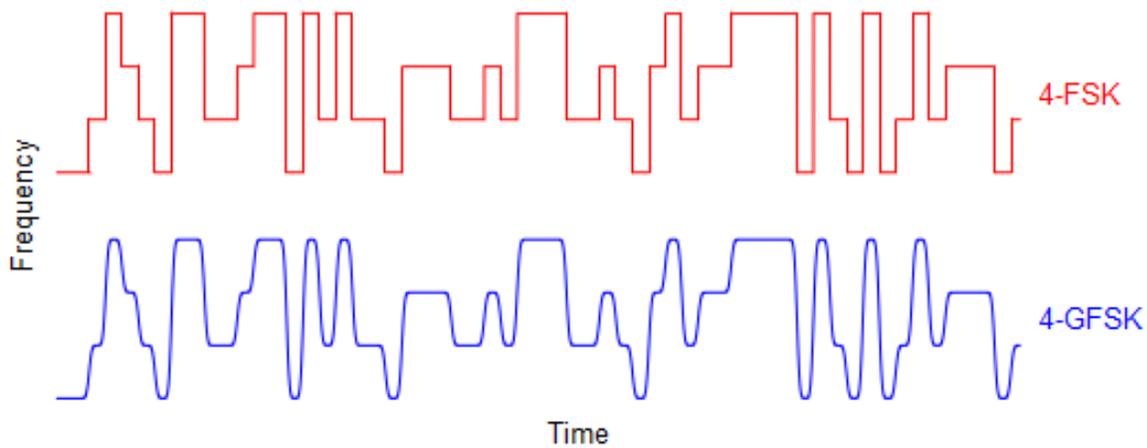


Fig 2. — Example of the encoded (red) and smoothed (blue) frequency sequences for part of an FT4 message.

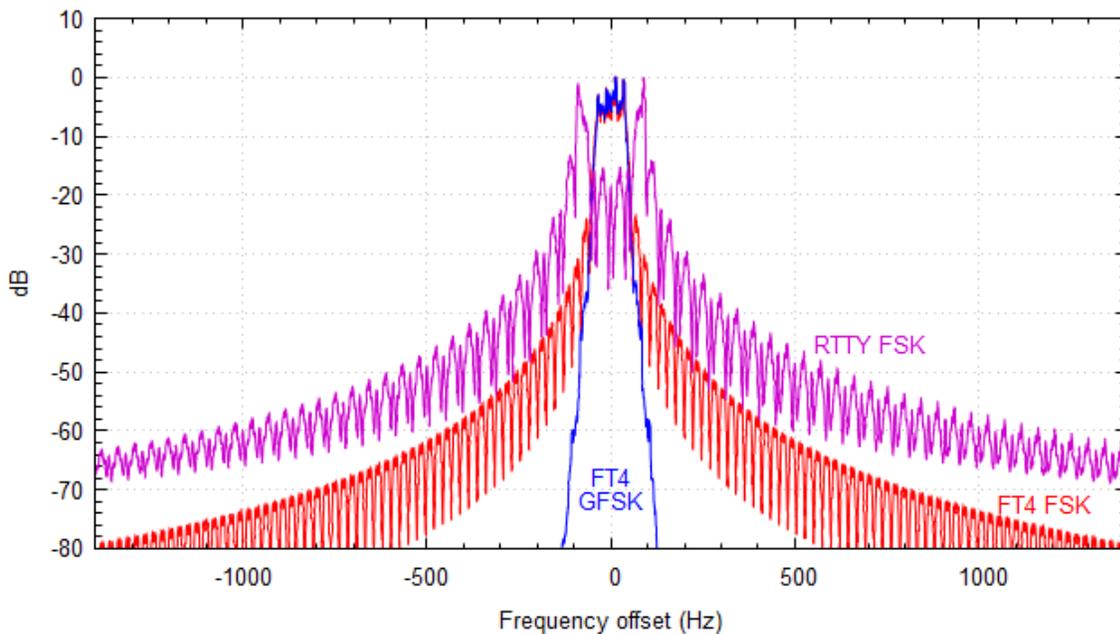


Fig 3. — Spectra of an FT4 signal transmitted with GFSK (blue), FT4 with FSK (red), and RTTY with continuous-phase FSK (purple).

Figure 3 also shows the spectrum of a standard RTTY signal (purple), which is more than 2000 Hz wide at -60 dB. Some ham software generating RTTY signals by audio frequency shift keying (AFSK) offers optional filtering of the waveform to reduce the unwanted keying sidebands. However, such post-modulation filtering necessarily destroys the constant-envelope nature of the continuous-phase FSK signal and leaves behind a waveform that must be amplified with good linearity to avoid generating new unwanted sidebands. In contrast, the GFSK signal of FT4 has a constant envelope and is immune to inter-modulation distortion.

Decoding and Frequency Usage: The FT4 decoder in *WSJT-X 2.1* identifies and decodes signals anywhere in a passband up to 5 kHz wide. As in other *WSJT-X* modes, received messages are “all or nothing” — there are no partial decodes, and false decodes are rare. Subtraction of decoded signals from the received data stream enables decoding of transmissions that overlap in frequency with other, possibly much stronger signals. The last three decodes shown in the Band Activity window in Figure 1 are examples of such second-pass decodes. With the normal odd/even sequencing of transmissions and signals spaced at intervals 120 – 150 Hz, as many as 50 stations can operate in a 3 or 4 kHz passband with little interference, even when signal strengths differ by as much as 60 dB.

Experience will tell what may be the best strategy for selecting dial frequencies during contests, and for how many ~3 kHz segments should be used for FT4 on each band. As initial guidelines we suggest the following default dial frequencies for FT4: 3.595, 7.090, 10.140, 14.140, 18.104, 21.140, 24.919, 28.180, 50.318, 144.170 MHz. We will welcome any feedback that could lead to better frequency choices.

Sensitivity: Figure 4 presents measurements of FT4 decoder sensitivity over a wide range of simulated propagation conditions. Paired numbers at the right give the Doppler spread (Hz) and two-path differential delay (ms) for various sets of ITU-standard conditions, using the Watterson model for ionospheric propagation. The left-most solid curves correspond to common mid-latitude propagation paths in undisturbed conditions. Dashed curves show the measured sensitivities for decoding with maximum *a priori* information, in two extremes of propagation conditions. For a rough comparison with RTTY, we note that in simulated mid-latitude moderate conditions RTTY has been shown to yield character error rates less than 10% only when SNR exceeds -1 to +4 dB, depending on the software modem in use. FT4 offers a sensitivity advantage of about 10 dB over RTTY.

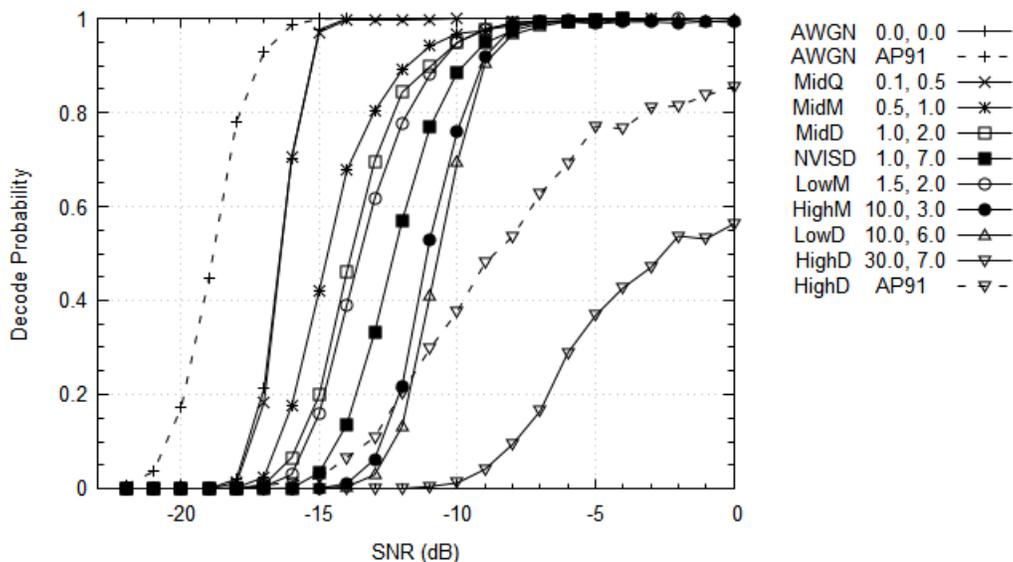


Fig 4. — Measured decoding probability for FT4 as a function of SNR. AWGN means Additive White Gaussian Noise; Low, Mid, and High refer to geomagnetic latitude; Q, M, and D imply Quiet, Moderate, or Disturbed ionospheric conditions; NVIS means Near Vertical Incidence Skywave; AP91 refers to *a priori* decoding of the RR73 message in a typical contest QSO.

Previous testing: Early release candidates of *WSJT-X 2.1.0* enabled us to explore the advisability of making FT4 an asynchronous mode with no fixed start times for T/R intervals. These tests served to highlight the significant advantages of using time-synchronized sequences. Fixed sequence lengths with prescribed start times ensure that a much larger fraction of received signals are decodable, especially in contest-like operating conditions where a given station may transmit roughly half the time. In terms normally used for communications engineering, synchronization increases channel capacity.

Schedule: A few parameters and operating behaviors of FT4 are still being tested and optimized. It will be very useful to hold several more mock contest practice sessions, with a larger group of active participants. Even if these reveal no serious bugs or inadequacies, we think FT4 is too new to be used in two upcoming events: the ARRL VHF Contest (June 8-10) and ARRL Field Day (June 22-23). Consequently we plan to build a release candidate *WSJT-X 2.1.0-rc5* that will “time out” on June 7, 2019. As far as possible, we plan to adhere to the following schedule:

- April 22: Public announcement about FT4, with a link to this document
- April 29: Second announcement, with links to downloadable installation packages for *WSJT-X 2.1.0-rc5*
- May 9, 0000 – 0100 UTC: FT4 practice session, 7.090 MHz
- May 14, 0000 – 0100 UTC: FT4 practice session, 7.090 MHz
- June 5, 0000 – 0100 UTC: FT4 practice session, 7.090 MHz (if needed)
- July 15: General Availability (GA) release of *WSJT-X 2.1.0*

Random concluding thoughts: FT4 is a special-purpose mode designed for rapid-fire contest QSOs. It serves this purpose very effectively, but like FT8 the mode is not useful for more extensive conversations. FT4 uses much less bandwidth than RTTY and provides reliable decoding at much lower signal levels. It has no need for “Super Check Partial” or similar contesting aids, and skilled operators using FT4 will find less motivation to use a DX Cluster or other non-radio aids. All information necessary to score well in a contest can be obtained over the air, during the contest, through one’s own antennas and radios. With FT4 there is little distinction between CQ and S+P operation, so it’s easy to switch frequently between the two ways of finding QSO partners. Stations using low power and compromise antennas can participate effectively in a contest using FT4.