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FT4 Goes to Space!

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000231 Tx 1780 + WA6DNR N7ZO CN85
000252 10 0.2 1884 + N7ZO WA6DNR +08
000300 Tx 1780 + WA6DNR N7ZO R+10
000307 7 0.1 1885 + N7ZO WA6DNR RR73
000315 Tx 1780 + WA6DNR N7ZO 73
000245 10 0.0 1239 + CQ W5SAT DM26
000326 Tx 1780 + W5SAT N7ZO CN85
000330 10 0.0 1237 + CQ W5SAT DM26
000337 Tx 1780 + W5SAT N7ZO CN85
000345 8 0.0 1239 + W5RKN W5SAT DM26
000352 Tx 1780 + W5SAT N7ZO CN85
000400 7 0.0 1239 + W5RKN W5SAT DM26
000407 Tx 1780 + W5SAT N7ZO CN85
000415 8 0.0 1238 + N7ZO W5SAT +14
000422 Tx 1780 + W5SAT N7ZO R+08
000430 5 0.0 1237 + N7ZO W5SAT RR73
000437 Tx 1780 + W5SAT N7ZO 73
000445 9 0.0 1238 + W5RKN W5SAT DM26
000452 Tx 1780 + CQ N7ZO CN85
000500 5 0.0 1239 + W5RKN W5SAT DM26
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AMSAT
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Operating WSJT-X FT4 on Satellites

Dave Beumer, W0DHB
Alan Bowker, WA6DNR
Carlos Cardon, W7QL
Ronald G. Parsons, W5RKN
Brad Schumacher, W5SAT
Robert Wright, N7ZO

Introduction

Many amateur radio satellite operators have attempted to operate digital communication via linear transponder satellites with mixed results. Problems with the constantly-changing satellite Doppler shift and weak and varying signal strength hindered their efforts.

With the advent of the FT4 mode available in the WSJT-X weak signal program, we were provided with an impetus to try anew. The FT4 protocol is fast with excellent weak-signal capabilities. A complete, confirmable contact requires only six transmissions, just 45 seconds if no retries are required, including the initial CQ and the final 73, such as:

CQ WA6DNR CM87
WA6DNR W5RKN EM10
W5RKN WA6DNR +03
WA6DNR W5RKN R+07
W5RKN WA6DNR RR73
WA6DNR W5RKN 73

The major problem has been to compensate for the Doppler shift of the satellite's signal as accurately as possible. SatPC32 calculates the Doppler shift once per second but provides a temporary 5x or 10x increase in this speed. Future versions will allow saving this speed. FlexSATPC by W0DHB for satellite use with FlexRadio transceivers also allows saving increased speed (up to once every 100 msec). We have found excellent decoding at 100 msec intervals of FT4 signals by WSJT-X even at the Time of Closest Approach (TCA) of low-Earth-orbit satellites.

Testing

We used WSJT-X v2.2.1. for the tests. The FlexRadio users in our group used FlexSATPC. All used SatPC32. To avoid interfering with other users of the satellites, we used the minimum power practicable and used 3 kHz of the satellite's passband starting 2 kHz above the bottom of the satellites receive passband. In the rare instance when other users were present in the WSJT-X passband, CW or voice, we noticed no interference to our reception, so the FT4 protocol is quite tolerant of other signals present. A decode often occurs of an FT4 station right at AOS when the signal is not yet visible on the receive panadapter.

For the past month or so, the authors and others have been testing WSJT-X FT4 on a variety of satellites including the XW-2 series, CAS-4A and CAS-4B and especially RS-44. The new satellite RS-44 was an especially attractive vehicle. Its orbit is higher than the XW and CAS satellites, and its receiver is very sensitive and the downlink signal strong. Its 60 kHz wide passband leaves room for lots of users to spread out. Its high orbit should enable setting some new distance records.

On the test pass illustrated in this paper, we had five of the authors of this paper simultaneously active during the entire pass, trying to make as many QSOs as possible. Combined we logged about 36 QSOs.

Doppler Shift Correction

The FT4 protocol was designed to extract data from weak signals, not from a signal with a center frequency that changes constantly or erratically. Thus, the smoothness and accuracy of the Doppler correction is a critical factor that relies on two variables:

1. Accurate knowledge of the orbit. This requires the use of the most recent available keps (Keplerian orbital parameters).
2. Frequent and accurate calculation of the Doppler correction. We have found that 100 msec intervals to be sufficiently often.

To test the accuracy of the Doppler correction, we tracked the CW beacon of RS-44. The keps were the most current at that time on nasabare. We measured two passes with maximum elevations of 9 and 85 degrees. The beacon signal audio after Doppler shift removal was passed to WSJT-X and plotted on its Wide Graph. The deviation over the passes is shown in Figure 1. The left part shows the maximum deviation from the value at TCA was about 350 Hz for the 85 deg pass. The right part shows 200 Hz maximum deviation for the 9-degree pass. We found that WSJT-X had no problem decoding FT4 with this amount of data frequency shift.

Equipment Configuration

W0DHB, WA6DNR and W5RKN operated FlexRadio transceivers with minor variations of the same configuration.

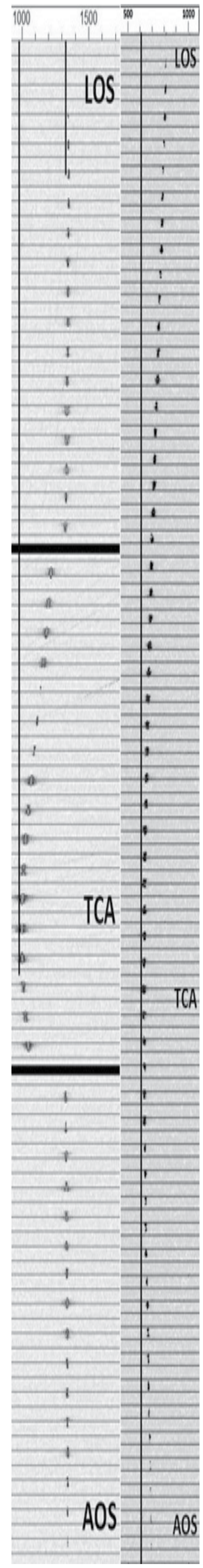

Figure 1 —Residual Doppler Error.

The transceiver used two transverters, 144 MHz and 435 MHz, connected to steerable antennas. SatPC32 steered the antennas. FlexSATPC provided Doppler correction, uplink calibration and other control functions. Two SmartSDR slices were used, A for receive and B for transmit. The receive audio was sent to WSJT-X via a DAX audio channel. The transmit audio also was sent to SmartSDR via a DAX audio channel. PTT was controlled by a CAT TCP port.

W7QL, W5SAT and N7ZO used an Icom IC-9700 with similar configurations. The IC-9700 Transceiver, with V 1.24 firmware, was controlled by SatPC32 via the standard USB Port. SatPC32 steered the antennas. SatPC32 with support for the IC-9700 was used for testing. WSJT-X received audio from the 9700 USB audio output and controls FT4 signal transmission PTT via the 9700 USB (B) port.

The FT4 Jamboree

On June 21, 2020, five of us gathered at our respective QTHs for the Grand Jamboree test pass. From approximately 2350Z to 0015Z, we made QSOs with the other members of the group. We completed a total of about 36 QSOs.

The coverage area of the middle of the pass is shown in Figure 2.

A two-minute excerpt from N7ZO's Band Activity display from WSJT-X is shown in Figure 3. This display is

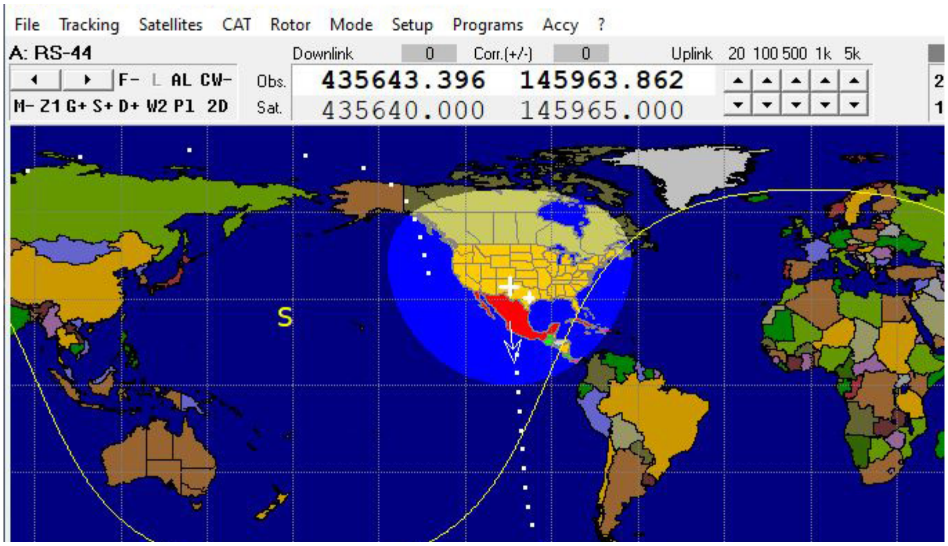

Figure 2 — Jamboree Coverage Area.

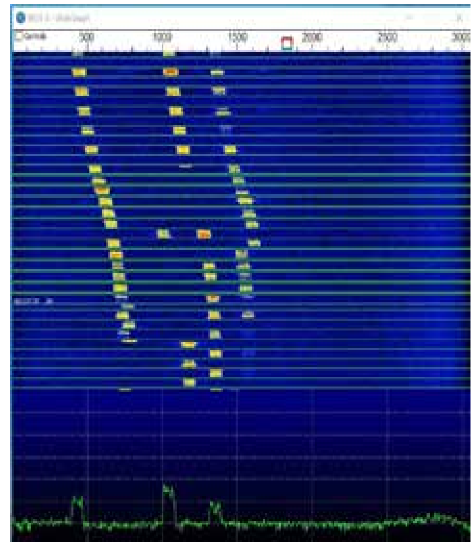

Figure 5 — W5RKN's WSJT-X Wide Graph display.

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000345 1 0.2 2175 + W5RKN W0DHB R+11
000352 2 0.2 1578 + CQ WA6DNR CM87
000352 9 0.0 1845 + W5SAT N7ZO CN85
000400 7 0.0 1239 + W5RKN W5SAT DM26
000400 2 0.1 2173 + W5RKN W0DHB R+11
000407 4 0.2 1573 + CQ WA6DNR CM87
000407 5 0.0 1846 + W5SAT N7ZO CN85
000407 0 0.1 2337 + CQ W5RKN EM10
000415 8 0.1 1238 + N7ZO W5SAT +14
000415 2 0.1 2174 + W5RKN W0DHB R+11
000422 -2 0.2 1579 + CQ WA6DNR CM87
000422 4 -0.0 1847 + W5SAT N7ZO R+08
000422 4 0.1 2346 + CQ W5RKN EM10
000430 5 0.1 1236 + N7ZO W5SAT RR73
000430 3 0.1 2167 + W5RKN W0DHB R+11
000437 -2 0.2 1576 + CQ WA6DNR CM87
000437 5 0.0 1847 + W5SAT N7ZO 73
000437 2 0.1 2357 + CQ W5RKN EM10
000445 8 0.0 1238 + W5RKN W5SAT DM26
000445 -1 0.1 2166 + W5RKN W0DHB R+11
000452 -5 0.2 1577 + CQ WA6DNR CM87
000452 1 0.0 1847 + CQ N7ZO CN85
000452 -3 0.1 2355 + CQ W5RKN EM10
000500 5 0.0 1239 + W5RKN W5SAT DM26
000500 1 0.1 2165 + W5RKN W0DHB R+11
000507 7 0.1 2366 + CQ W5RKN EM10
000515 4 0.1 1240 + W5RKN W5SAT DM26
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Figure 3 — N7ZO's Band Activity display excerpt.

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000231 Tx 1780 + WA6DNR N7ZO CN85
000252 10 0.2 1884 + N7ZO WA6DNR +08
000300 Tx 1780 + WA6DNR N7ZO R+10
000307 7 0.1 1885 + N7ZO WA6DNR RR73
000315 Tx 1780 + WA6DNR N7ZO 73
000245 10 0.0 1239 + CQ W5SAT DM26
000326 Tx 1780 + W5SAT N7ZO CN85
000330 10 0.0 1237 + CQ W5SAT DM26
000337 Tx 1780 + W5SAT N7ZO CN85
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000430 5 0.0 1237 + N7ZO W5SAT RR73
000437 Tx 1780 + W5SAT N7ZO 73
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000452 Tx 1780 + CQ N7ZO CN85
000500 5 0.0 1239 + W5RKN W5SAT DM26
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Figure 4 — N7ZO's Rx Frequency display excerpt.

from a receive-only instance of WSJT-X, which includes decoding himself.

The same period of N7ZO's Rx Frequency display from WSJT-X is shown in Figure 4. This is from the Tx instance of his dual WSJT-X installation.

An example of W5RKN's WSJT-X Wide Graph, which shows the waterfall display of approximately the same time period as the two N7ZO displays above, is shown in Figure 5.

Conclusion

We have shown that weak-signal digital communication using the WSJT-X FT4 mode is not only possible but also useful. Make use of its excellent weak-signal capability — go out and make some new distance records. Be considerate of other users on the satellite. Keep to the low end of the passband. Don't drift around, but compensate for Doppler shift. Use the lowest power possible. Have fun.