SuperFox and FT8: Weak-Signal Performance

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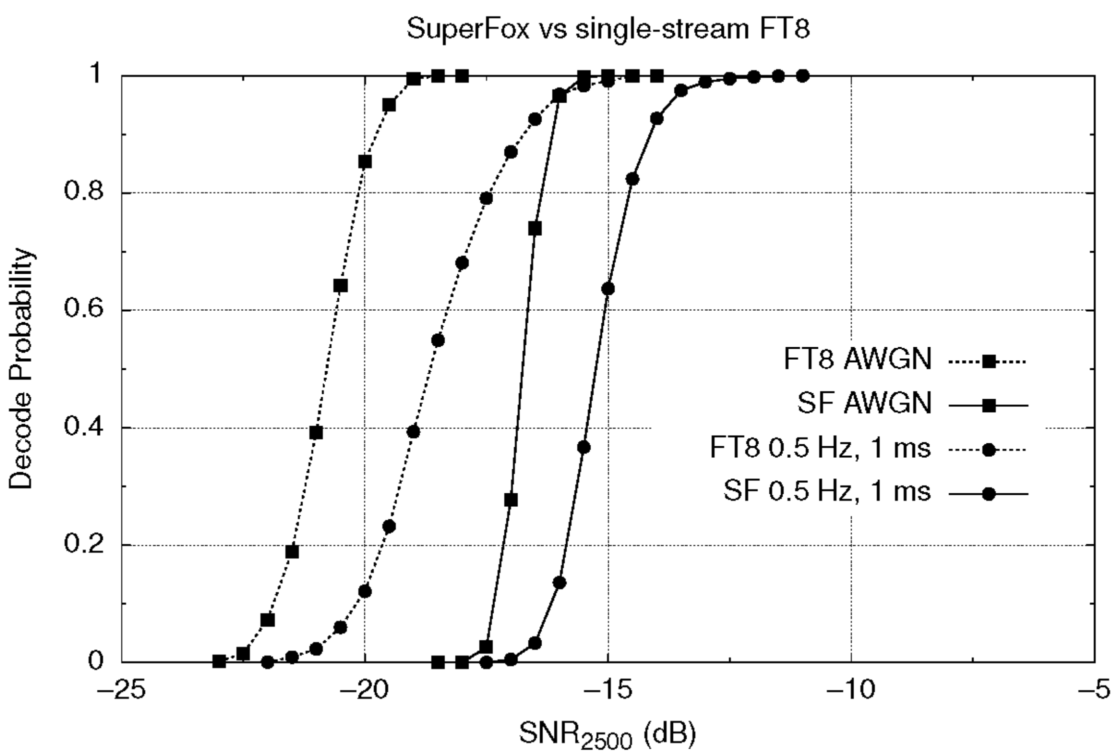
The experimental SuperFox operating mode in *WSJT-X 2.7.0* has now been thoroughly exercised by DXpeditions N5J (Jarvis Island) and CY9S (St. Paul Island). According to Club Log statistics, each of these major efforts made over a hundred thousand QSOs, of which about half (46% at N5J, 50% at CY9C) used FT8. When propagation was adequate to yield SNRs of –14 dB or better, each group used the SuperFox protocol most of the time and often achieved QSO rates more than 200 per hour. After pileups had thinned out, and in order to work weaker stations, operators sometimes switched to standard Fox-and-Hound mode with one or two FT8 streams.

Chatter on several WSJT-related forums shows that many Hound users are confused about how to compare the weak-signal performance of SuperFox and multi-stream FT8. As part of our development procedure we made exhaustive measurements of decoding probability for both protocols, using simulations that cover a wide range of signal strengths and propagation types. The following plot summarizes performance of SuperFox and single-stream FT8 on two simulated channels: additive white Gaussian noise (AWGN) and the ITU standard “Mid-latitude Moderate” (MM) channel, which assumes Doppler spread 0.5 Hz and differential delay 1 ms. In practice, on both channels standard FT8 can decode signals 3 to 4 dB weaker than SuperFox.



Transmitting FT8 with N=2, 3, 4, or 5 simultaneous streams necessarily attenuates each stream by respective amounts 6, 9.5, 12, or 14 dB. Thus, for example, circumstances that yield a SuperFox signal with SNR = –14 dB would yield two FT8 streams at –20 dB each. The graph shows that decoding probability on the MM channel is greater than 90% for SuperFox and less than 15% for each of the two FT8 streams. With everything else equal, a Fox is more likely to be decoded with FT8 than SuperFox *only* for the single-stream case, N=1. Otherwise, SuperFox always wins on decoding probability, and of course even more so for achievable QSO rate, since SuperFox messages can always include information for as many as 9 Hounds.

We have not yet seen statistical summaries that show the hourly QSO rates achieved at N5J and CY9C separately for SuperFox and standard Fox mode. Based on what we already know, we think the operators generally made wise decisions about when to switch from SuperFox to Fox using one or two streams. We note that for paths with the weakest signals, standard FT8 with N=1 would probably produce QSO rates at least as high as those for N=2, and often higher.

Curves in the plot show that SuperFox decoding thresholds are degraded less on more difficult propagation paths than those for FT8. Our simulations show that this trend continues over progressively worse paths, such as those over high-latitude regions. The SuperFox tone spacing is nearly twice that of FT8, so this behavior is just as expected. Moreover, the FT8 decoder tries to make use of available inter-symbol coherence, which difficult propagation paths tend to destroy. The SuperFox decoder uses only noncoherent demodulation of transmitted symbols, so again it is expected to degrade less on difficult propagation paths.

One further point deserves mention here. The plot shows that probability of decoding an FT8 signal with SNR = –23 dB is nearly zero, yet we sometimes see a decode with reported SNR = –24 dB. So what gives? For simulations we know the signal strength accurately, because we generate the signal! For received signals we obtain an estimate for SNR by averaging signal power over the full transmission, dividing by an estimate of baseline noise power in the same interval, scaled to a 2500 Hz reference bandwidth, and finally converting the ratio to decibels. Especially at the lowest decodable signal levels, the total SNR error budget can be as large as several dB, especially on the low side.