Quick-Start Guide to Q65

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December 10, 2020

WSJT-X 2.4.0 will introduce Q65, a digital protocol designed for minimal two-way QSOs over especially difficult propagation paths. On paths with Doppler spread more than a few Hz, the weak-signal performance of Q65 is the best among all *WSJT-X* modes. Q65 is particularly effective for tropospheric scatter, ionospheric scatter, and EME on VHF and higher bands, as well as other types of fast-fading signals.

Q65 uses 65-tone frequency-shift keying and builds on the demonstrated weak-signal strengths of QRA64, a mode introduced to *WSJT-X* in 2016. Q65 differs from QRA64 in the following important ways:

- A new low-rate Q-ary Repeat Accumulate code for forward error correction
- User messages and sequencing identical to those in FT4, FT8, FST4, and MSK144
- A unique tone for time and frequency synchronization. As with JT65, this "sync tone" is readily visible on the waterfall spectral display. Unlike JT65, synchronization and decoding are effective even when meteor pings or other short signal enhancements are present.
- Optional submodes with T/R sequence lengths 15, 30, 60, 120, and 300 s.
- A new, highly reliable list-decoding technique for messages that contain previously copied message fragments.

Basic parameters of Q65 for each of the five T/R sequence lengths are summarized in the table below. Threshold sensitivities (SNR in 2500 Hz bandwidth yielding 50% probability of decode) were measured for each submode using simulations over the additive white Gaussian noise (AWGN) channel. As with other recently developed modes in *WSJT-X*, a feature called *a priori* (AP) decoding improves sensitivity by several additional dB as information is accumulated during a standard minimal QSO.

T/R Period (s)	Symbol Length (s)	Tone Spacing (Hz)	Occupied Bandwidth (Hz)	Transmission Duration (s)	SNR (dB)	Max AP SNR (dB)
15	0.150	6.667	433	12.8	-22.2	-23.7
30	0.300	3.333	217	25.5	-24.8	-26.6
60	0.600	1.667	108	51.0	-27.6	-30.2
120	1.333	0.750	49	113.3	-30.8	-32.5
300	3.456	0.289	19	293.8	-33.8	-37.4

Forward error correction (FEC) in Q65 uses a specially designed (65,15) block code with six-bit symbols. Two symbols are "punctured" from the code, yielding an effective (63,13) code with a payload of $k = 13$ information symbols conveyed by $n = 63$ channel symbols. The punctured symbols consist of a 12-bit CRC computed from the 13 information symbols. The CRC is used to reduce the false-decode rate to a very low value. A 22-symbol pseudo-random sequence spread throughout a transmission is sent as "tone 0" and used for synchronization. The total number of channel symbols in a Q65 transmission is thus 63 + 22 = 85.

For each T/R sequence length, submodes A - E have tone spacings and occupied bandwidths 1, 2, 4, 8, and 16 times those specified in the above table. Full submode designations include a number for sequence length and a letter for tone spacing, as in Q65-15A, Q65-120C, etc. Tone spacings and occupied bandwidths for the wider submodes are summarized in the table below. Additional submodes -120F, -300F, and -300G might be implemented in future if there is a perceived need.

T/R Period (s)	B Spacing (Hz)	B Width (Hz)	C Spacing (Hz)	C Width (Hz)	D Spacing (Hz)	D Width (Hz)	E Spacing (Hz)	E Width (Hz)
15	13.33	867	26.67	1733	N/A		N/A	
30	6.67	433	13.33	867	26.67	1733	N/A	
60	3.33	217	6.67	433	13.33	867	26.67	1733
120	1.50	98	3.00	195	6.00	390	12.00	780
300	0.58	38	1.16	75	2.31	150	4.63	301

Q65 is more sensitive than any other *WSJT-X* mode when path Doppler spread is more than a few Hz. For examples of sensitivity details measured from simulations are plotted in Figures 1 and 2, on the next page.

An excellent example of targeted uses is ionospheric scatter on the 6 m band. Extensive tests on the 1150 km path between K1JT and K9AN have shown that with 300 W power output, nearly every Q65-30A transmission is copied correctly by the other station. Q65 will enable stations with a modest Yagi and 100 W or more and to work one another on 6 m at distances up to ~1600 km at most times, in dead band conditions. Ionospheric scatter is best near mid0day and in summer months, but is present at all times.

Tests of Q65 on EME, extreme troposcatter, and other potentially suitable paths are just now beginning. But we know from experience with QRA64 that suitable Q65 submodes will be highly effective in a wide variety of conditions. Decoding is effective for signals with Doppler spread up to ten times the tone spacing, and even beyond.

A few obvious suggestions for potentially fruitful applications are these:

- Q65-30A Fast (contest?) QSOs on 144 and 432 MHz
- Q65-30B Fast (contest?) EME QSOs at 1296 MHz
- Q65-60A,B EME on 144 and 432 MHz
- Q65-60B,C EME on 1296 MHz
- Q65E-120 Small-dish EME on 10 GHz

In early testing we will appreciate your detailed feedback on both successes and failures! The Q65 decoder makes internal adaptations that depend on the Doppler spread in received signals. Final optimizations will depend on having representative recordings of signals in a wide variety of propagation conditions. Please use the **Save All** facility in *WSJT-X* to preserve .wav files, and send them to us for later study, along with your own comments and suggestions. All such input will be appreciated!

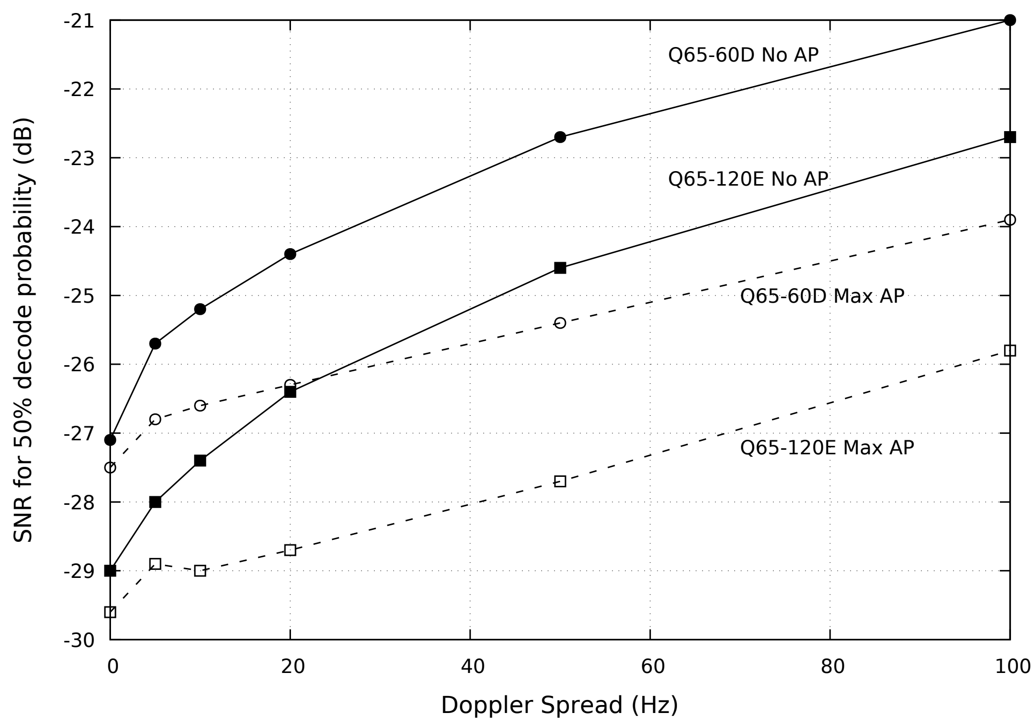

Figure 1. – Threshold sensitivities for Q65-60D and Q65-120E as a function of frequency spread.

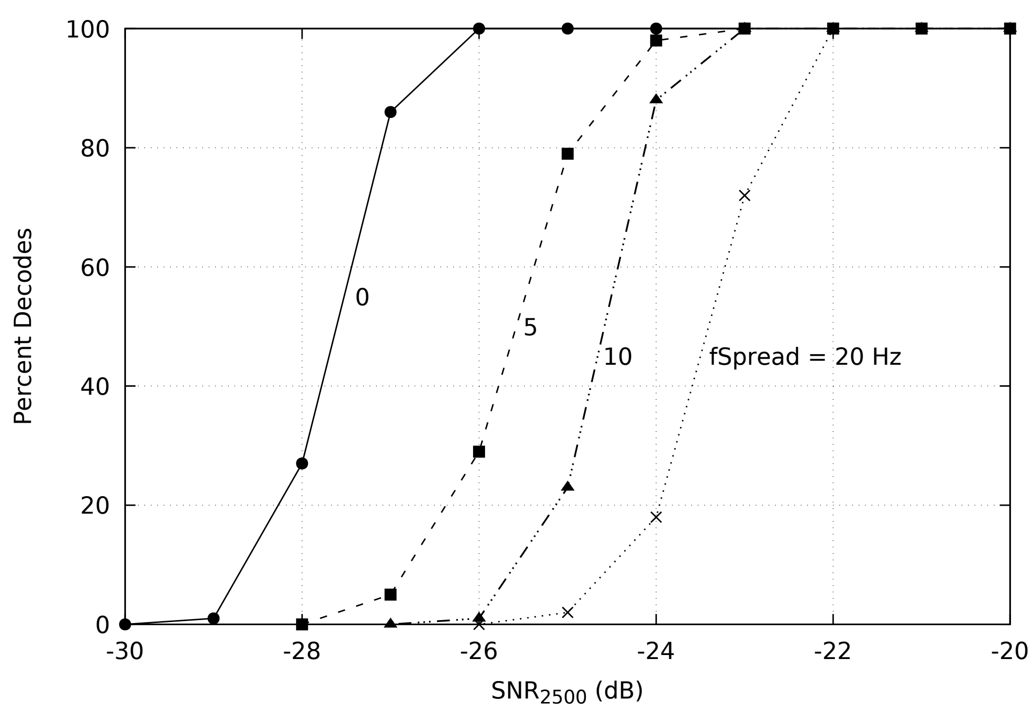

Figure 2. – Decoding probability of Q65-60A (no AP) as a function of SNR and frequency spread.