# CW Spectral Waveforms

Spectral waveforms show signal level as a function of frequency. Typically, they are measured by capturing a record of signal level as a function of time and applying a Fourier transform. That is what the new Elecraft P3 panadapter does. The P3 has (frequency) resolution bandwidth as narrow as 8 Hz over a span of 2 kHz, which is remarkable for an instrument in this price class, and far superior to the current generation of other panadapters.

The P3 is capable of showing the close-in sidebands of narrowband modes like morse code. I was curious to see if the P3 display could easily distinguish signals with clicks from signals without clicks. In the past decade there has been a new interest in this topic, due in part to the very poor characteristics of supposedly modern radios. W8JI has published considerable plain-talk information on his web site. W9GF has posted a detailed mathematical article on the topic.

The following charts show waveforms captured using the P3 Utility program. First, a set of K3 waveforms, for normal QSK mode and for QRQ mode, and for two frequency spans. Then, a set of TS-950SDX waveforms, for each of its four choices of keying "rise time." All of these are off-air recordings made by monitoring a sense port on a 100 Watt 50Ω dummy load. Last, an on-air recording of K4LTA.

My second K3 was set to transmit at 100 Watts (50 dBm) into the dummy load. The sense port is about 60 dB down, yielding 10 dBm. That port was connected to RX In of the K3+P3 setup through a step attenuator set at 20 dB. So the net carrier level into the receiver was about - 30 dBm, which is about S9 + 40 dB.

The K3 data were captured with the P3 Peak mode while sending dots with the internal keyer. The keyer speed is set at minimum, 8 WPM. Higher speeds do not affect the envelope of the spectral waveform — see the W9GF article for an explanation, and slower speeds yield less ripple in the envelope.

The P3 Scale was set to 80 dB. The reference level for the narrow span (2 kHz) data was set at -120 dBm, so that carrier peak is near the top of the plot. The reference level for the wider span (10 kHz) data was set at -140 dBm, where the minimum signal level is dominated by front-end noise.

In the K3 results, the discrete signals 2 kHz from the carrier are barely audible. They are more than 90 dB down from the carrier level. I'm not sure they are real, because they remain at the same location on the P3 frequency axis when I tune the receiver off the carrier. When listening to the receiver audio output, I cannot detect changes in noise floor due to CW sidebands beyond 2.5 kHz from the carrier frequency.

Bud, Hank (W6SX) and I made similar measurements for W2RU's TS-950SDX. That radio has a DSP-generated "gaussian" time-domain waveform with four choices of "rise time." The spectral envelope for the 8 ms case is quite similar to the K3 envelope. The K3 has a DSP-generated "raised-cosine" waveform with 5 ms "rise time." I haven't been able to find a single-source definition of either the waveform shape or rise time. The W9GF article introduces yet another waveform that he claims to be optimum in the sense of minimizing both rise time and spectral bandwidth. I suspect there is not a significant difference between the three variations of "good" keying envelope shapes.

An odd asymmetry — a shoulder at roughly 60 dB down on the low side — appears in both the K3 QRQ and the TS-950SDX 8 ms cases. That leads me to suspect that the shoulder is an artifact of the the P3 signal processing, rather than of the actual RF envelope.

K4LTA has prominent clicks. The spectral waveform below seems to confirm that, with the curious asymmetry indicating much larger sideband levels on the low side of the carrier than on the high side. For what it is worth, I've also seem signals with clicks that are almost perfectly symmetrical.

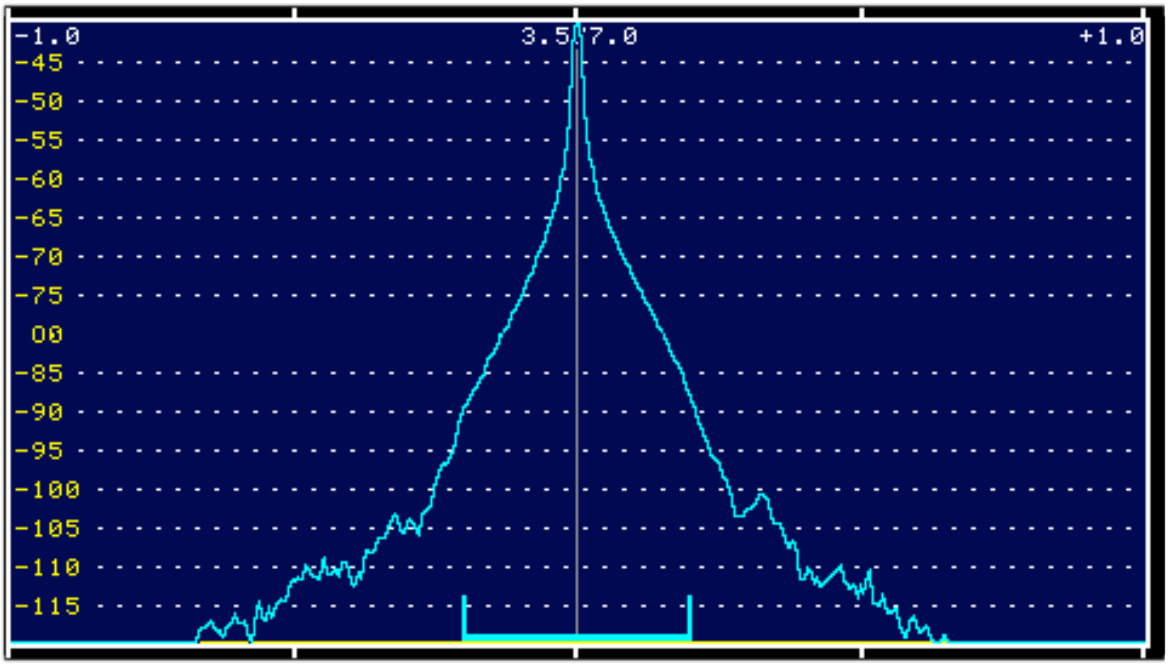
As a moderately-quantitative measure of "clickiness," I've estimated the (absolute value of the) slopes of the more-or-less linear portions of the spectral envelopes, commencing about 50 Hz away from the carrier. The estimated slopes are rounded to the nearest 5 dB/kHz, and listed as low-side/high-side when asymmetric.

*Estimated Sideband Envelope Slopes*

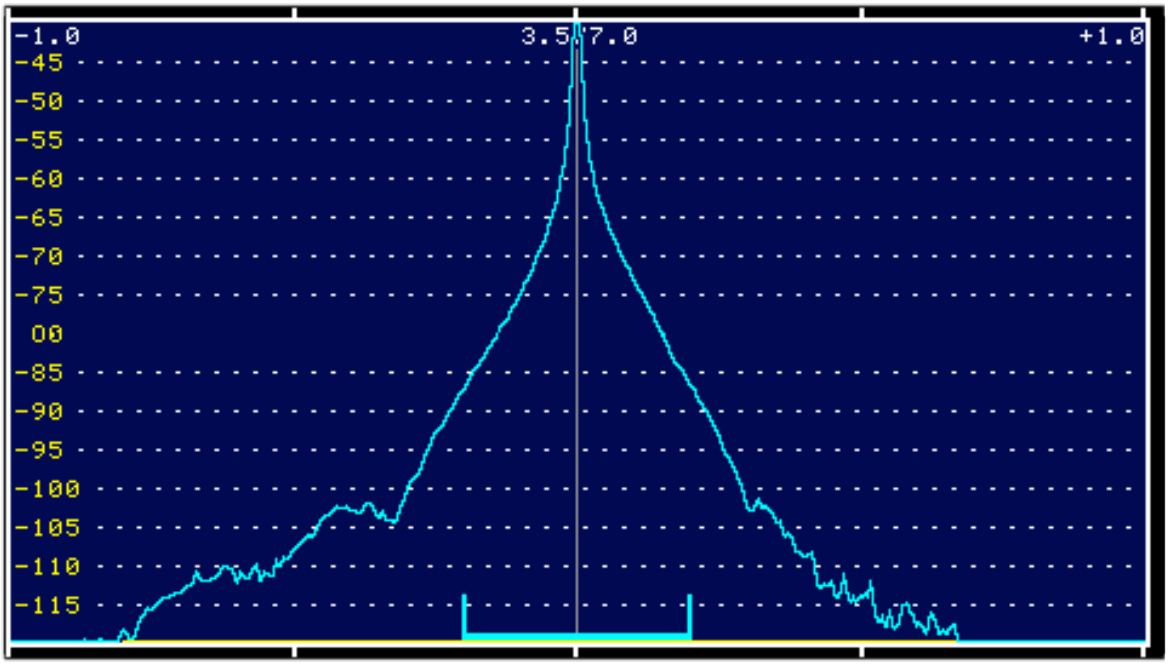
| Case | Slope (dB/kHz) |
|---|---|
| K3 QSK Mode | 150 |
| K3 QRQ Mode | 130 |
| TS-950SDX 8 ms | 100/160 |
| TS-950SDX 6 ms | 60/70 |
| TS-950SDX 4 ms | 45 |
| TS-950SDX 2 ms | 35 |
| K4LTA | 40/110 |

As a tentative conclusion, I'd say that slopes greater than 100 are good, and slopes much less than that are not good.

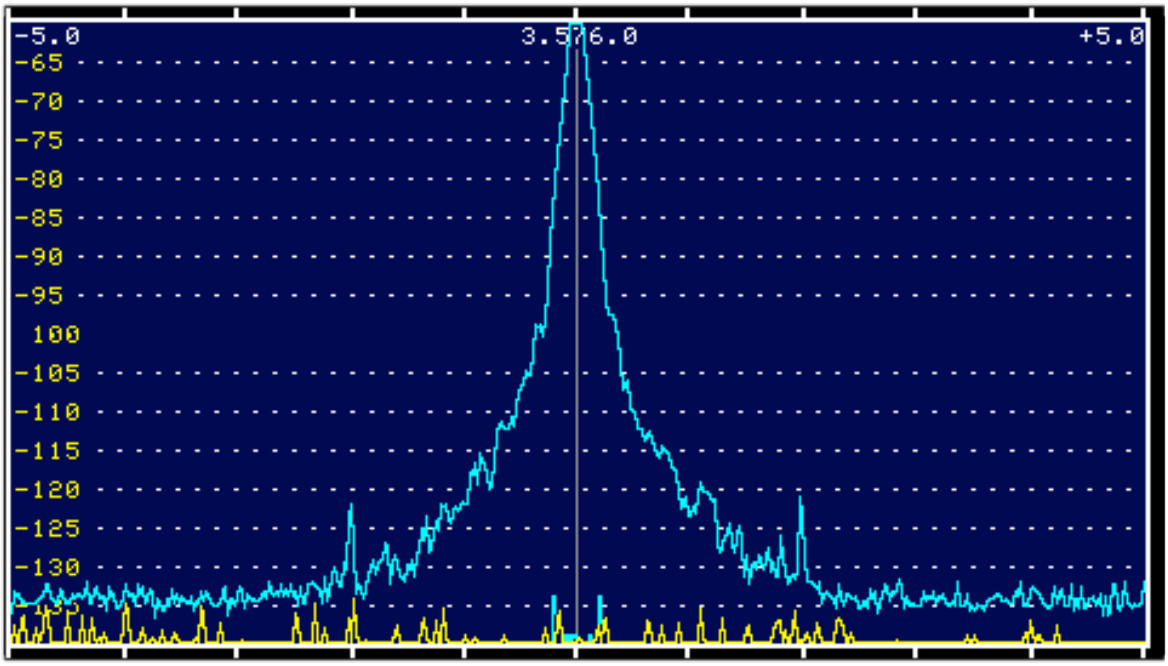
*K3 QSK Mode 2 kHz Span*



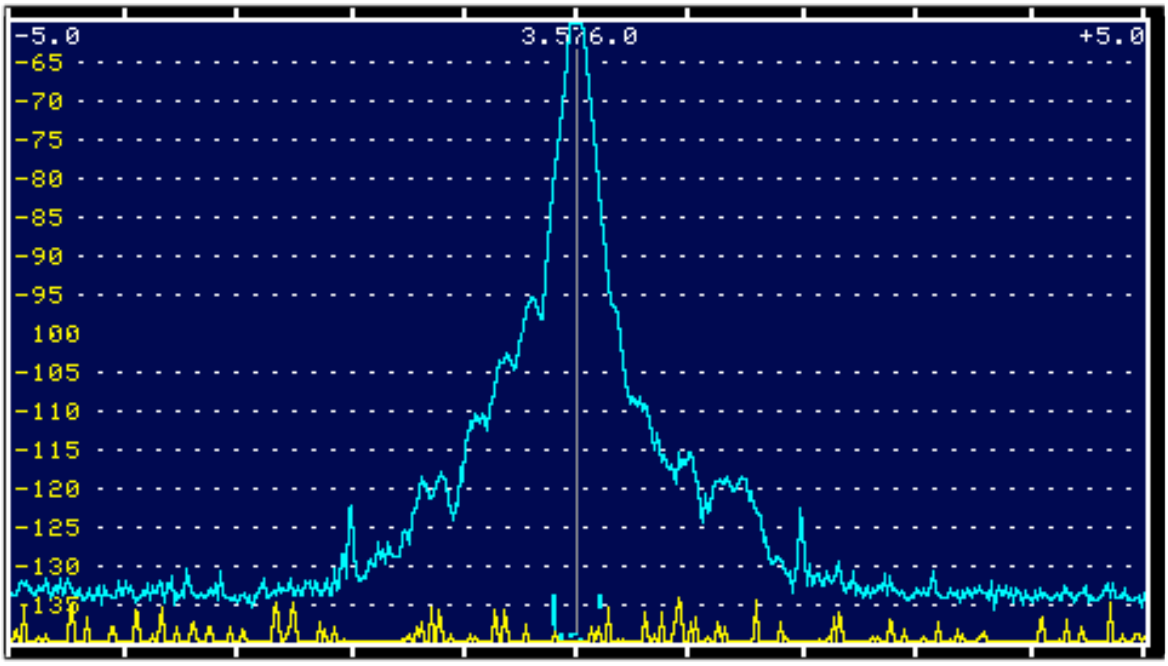

*K3 QRQ Mode 2 kHz Span*



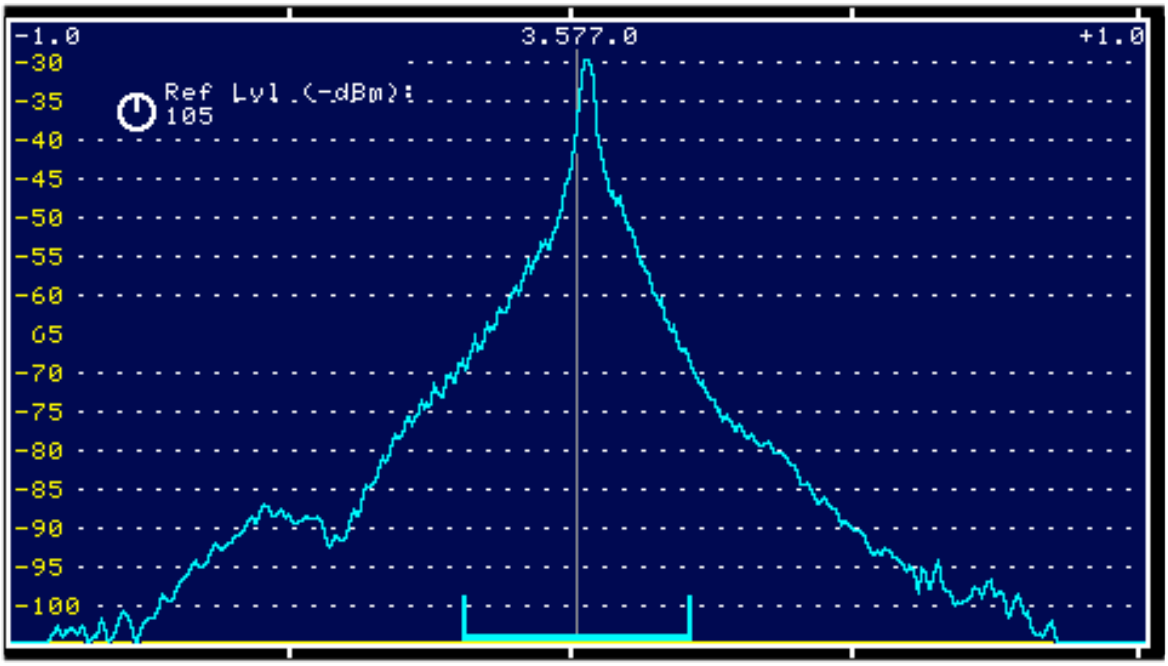
*K3 QSK Mode 10 kHz Span*



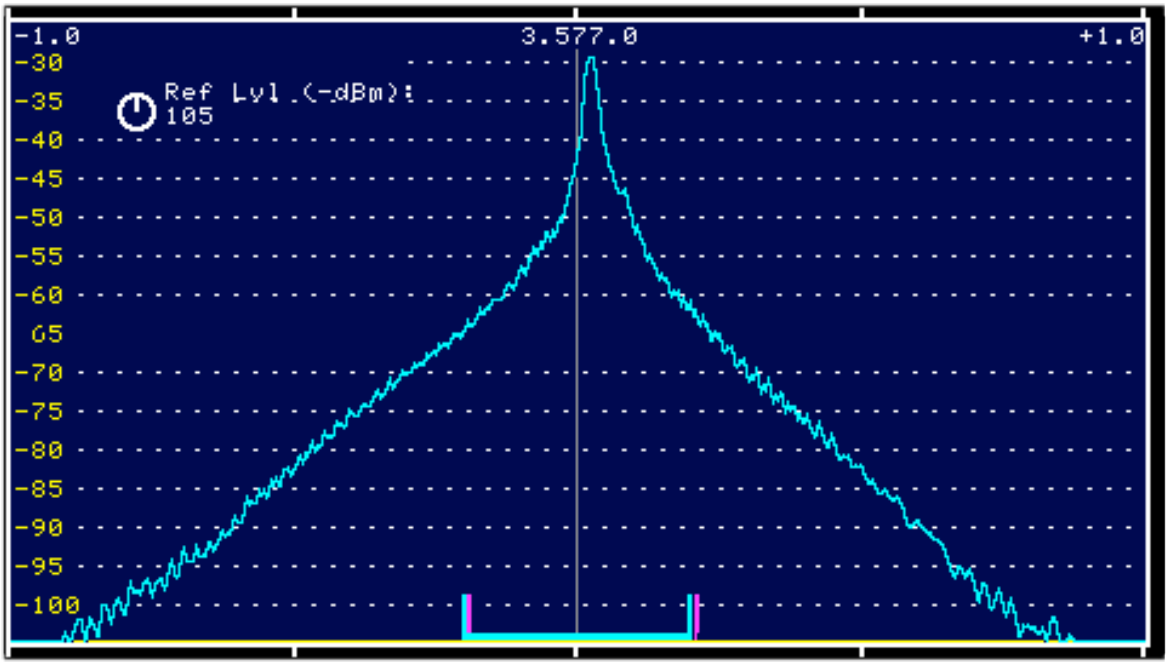

*K3 QRQ Mode 10 kHz Span*



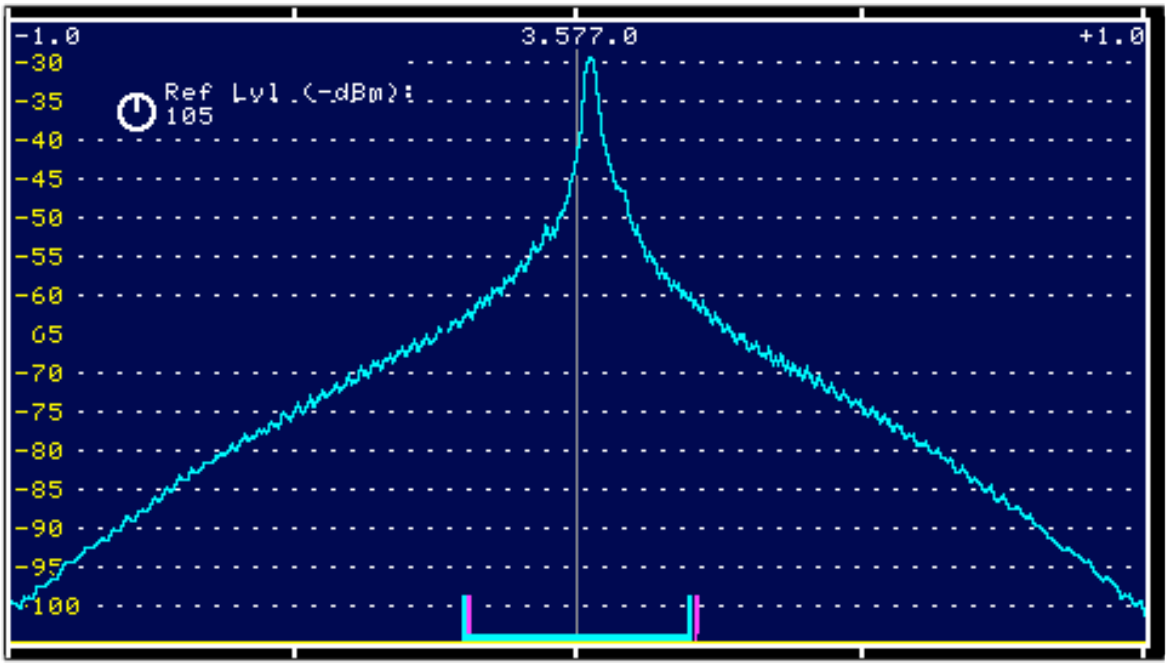
*TS-950SDX 8 ms*



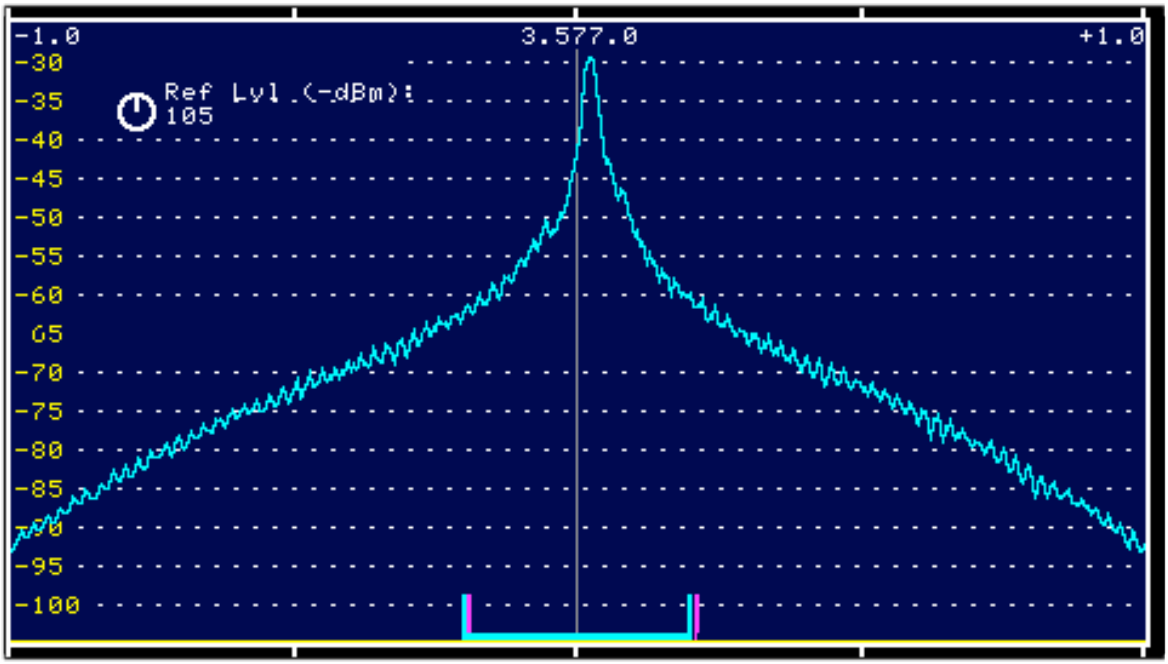

*TS-950SDX 6 ms*



*TS-950SDX 4 ms*




*TS-950SDX 2 ms*



*K4LTA On-air*