EbNaut LF Reception of K3RWR using SDR-IQ

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This note describes how LF EbNaut transmissions can be decoded using an SDR-IQ receiver whose clock is locked to GPS. Such clock stability is essential and even with it the full potential of EbNaut decoding is probably not realized due to computer sampling rate drift. Such drift can be eliminated by referencing the sampling rate to GPS also, but that requires down conversion from LF to baseband with a GPS-referenced local oscillator. The Windows 7 computers in use here have relatively primitive sound cards so that baseband only handles frequencies up to 24 kHz per the Nyquist criteria. Thus, to receive K3RWR transmitting on 137.477 kHz an LO of at least 113.477 kHz is required. This note will not consider down conversion and instead will rely on receiving with an SDR-IQ tuned just below the transmit frequency.

The SDR-IQ setup is described by the following screen captures:

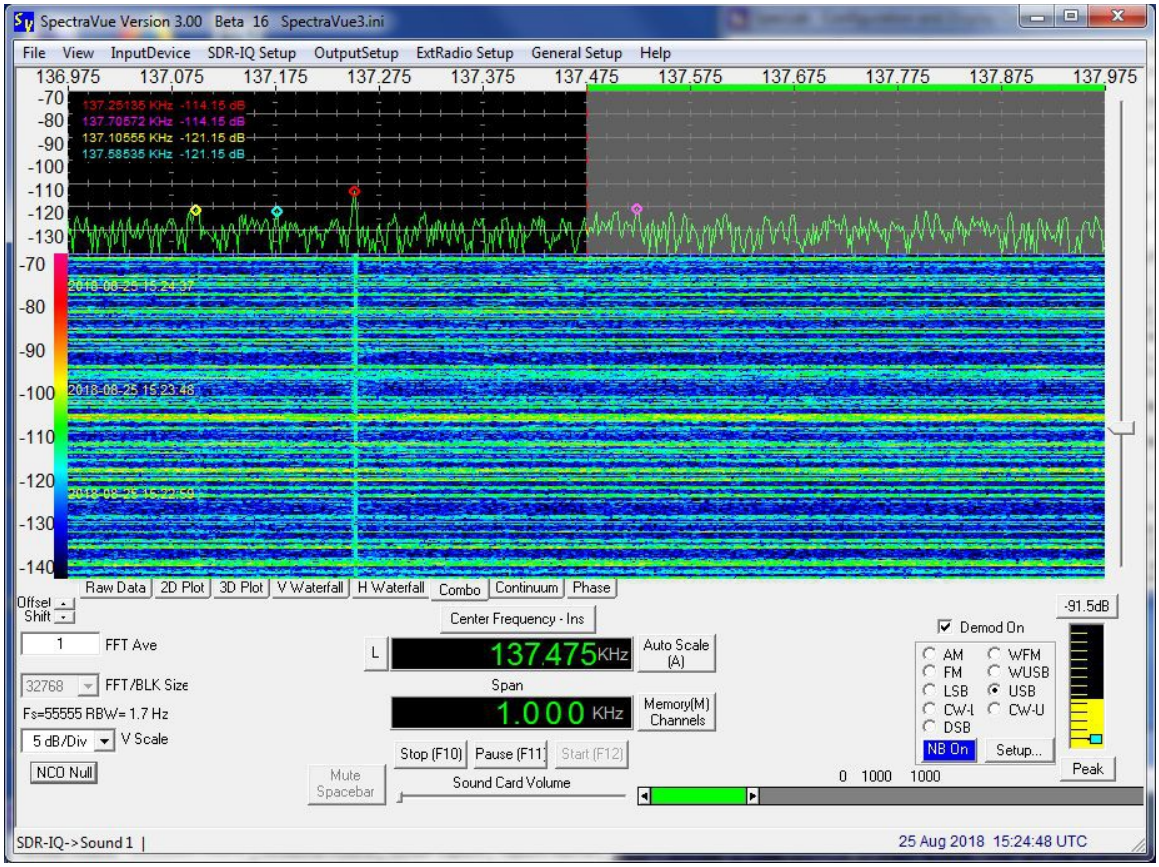

Figure 1 SpectraVue software used to run SDR-IQ with eprobe1 input.

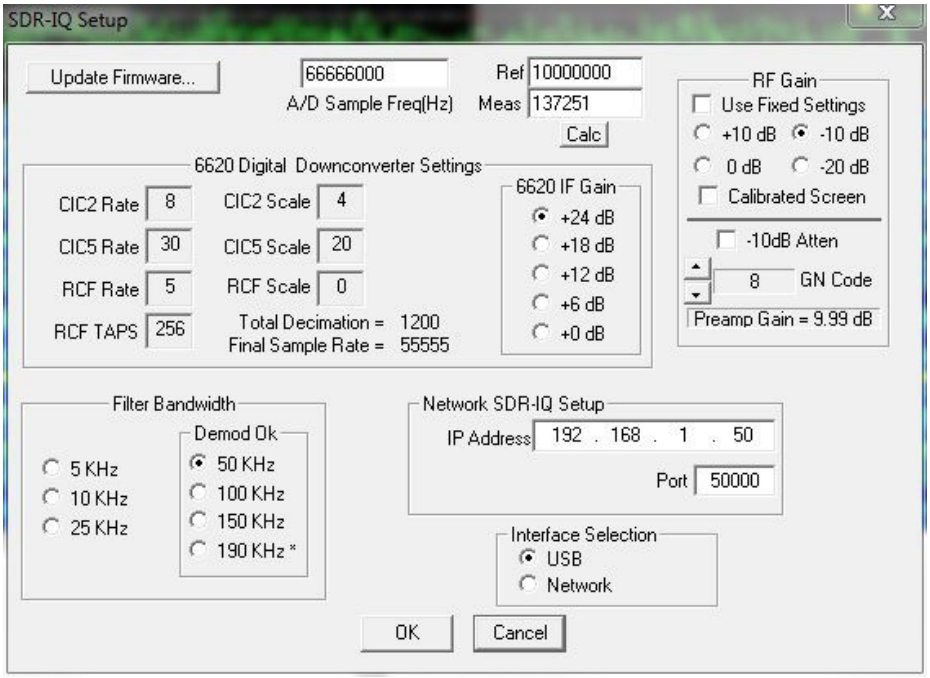

Figure 2 SDR-IQ setup window.

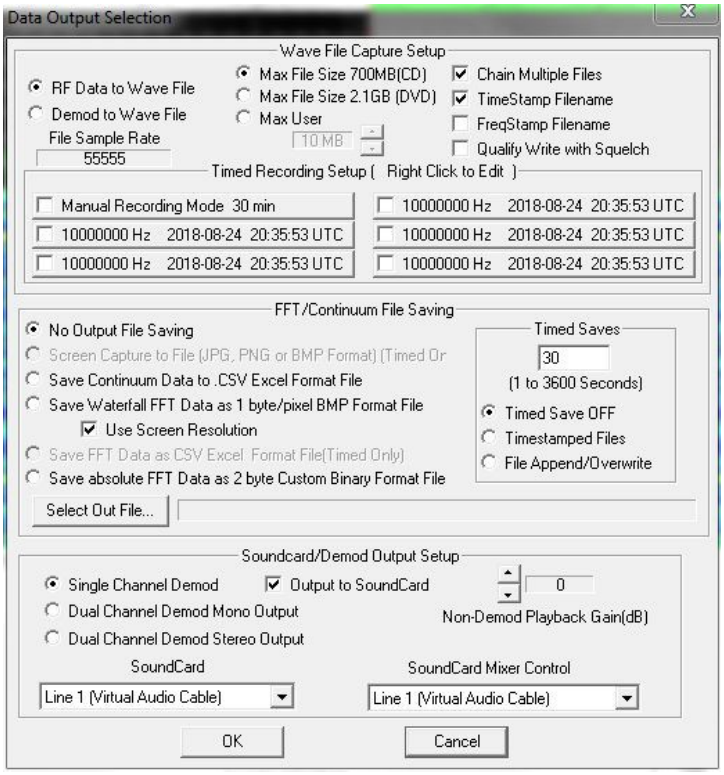

Figure 3 SDR-IQ data output selection window.

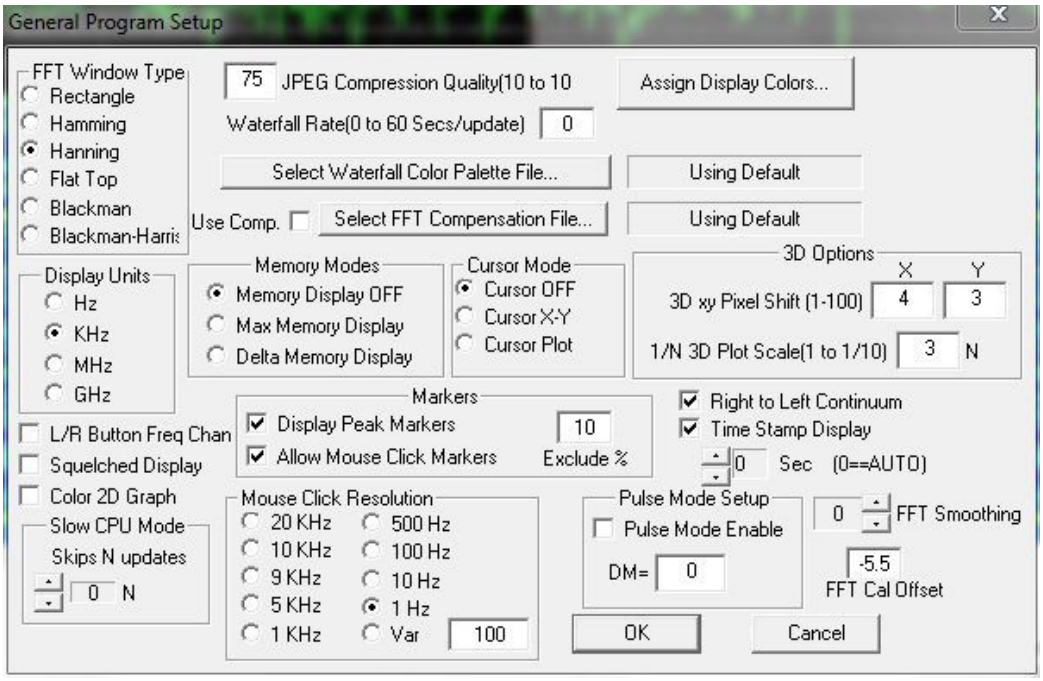

Figure 4 SDR-IQ general program setup window.

The SDR-IQ output feeds Spectrum Laboratory software (v2.93 b3) via a virtual audio channel for post processing and display as described by the following screen captures:

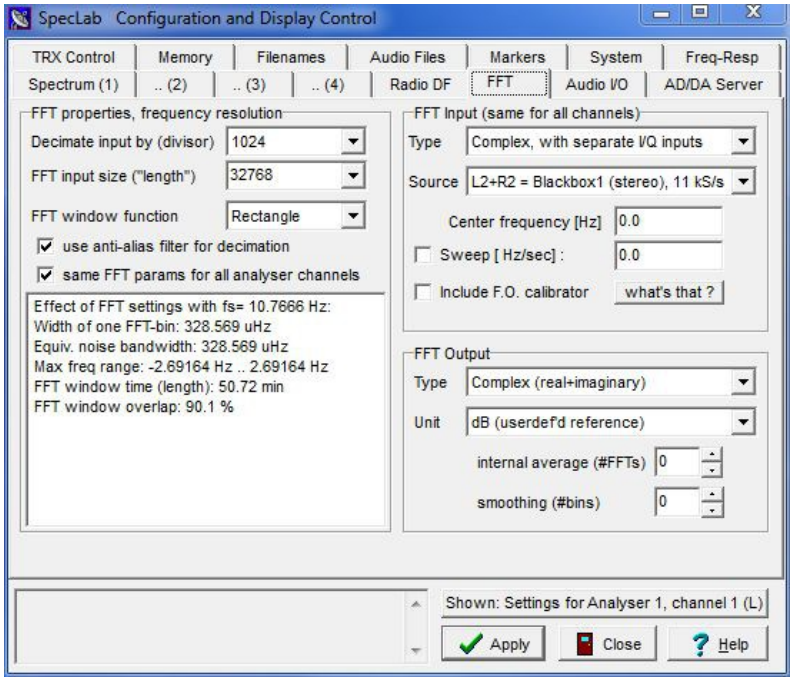

Figure 5 Spectrum laboratory FFT window.

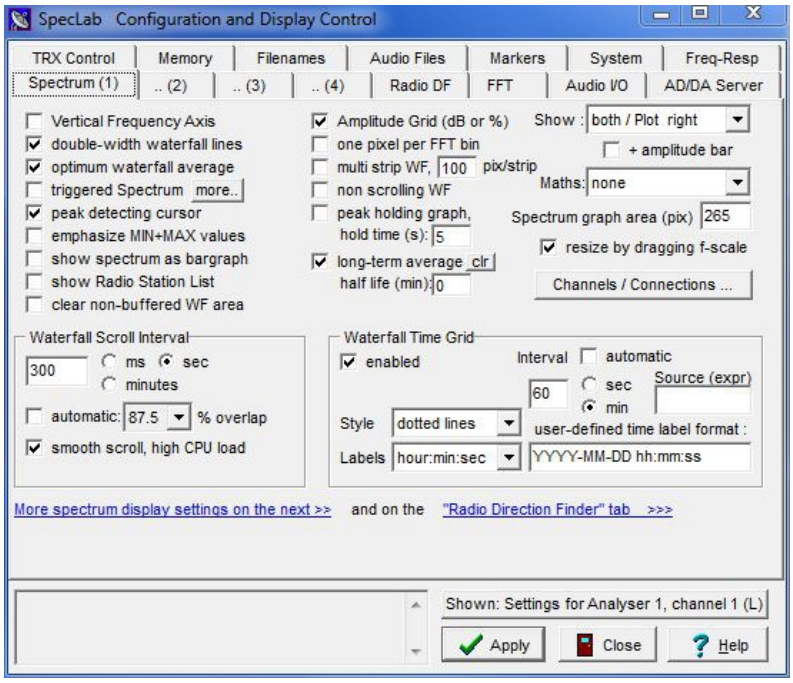

Figure 6 Spectrum laboratory spectrum(1) window.

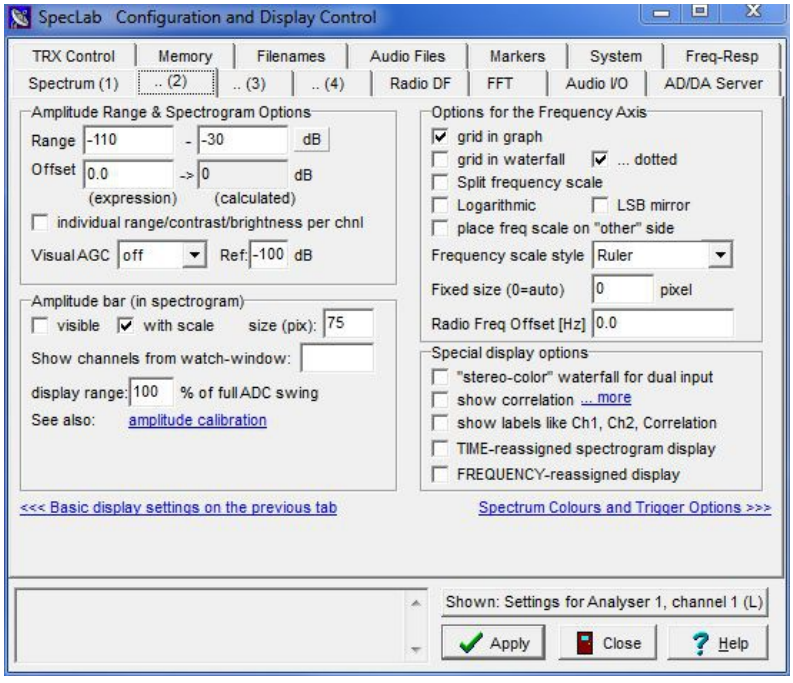

Figure 7 Spectrum laboratory spectrum(2) window.

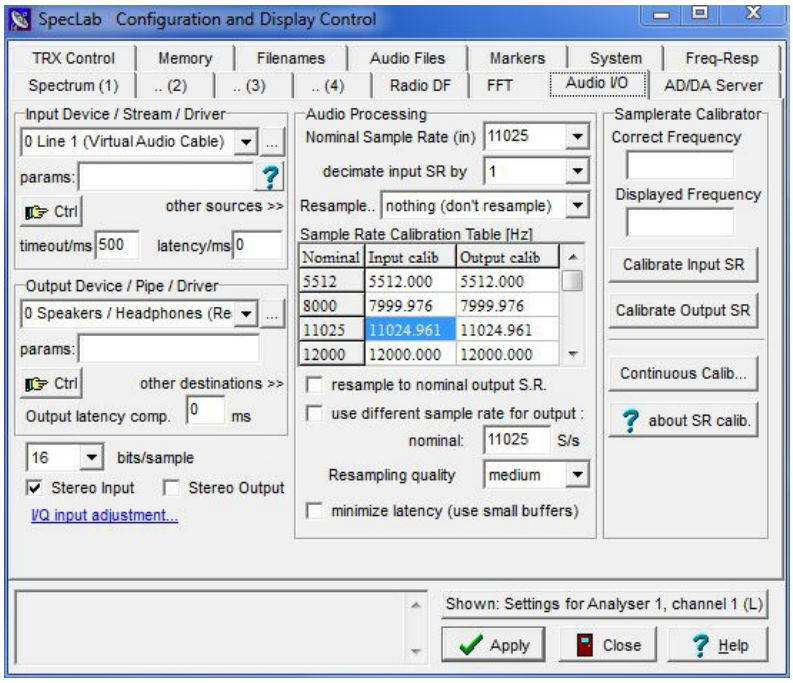

Figure 8 Spectrum laboratory audio I/O window.

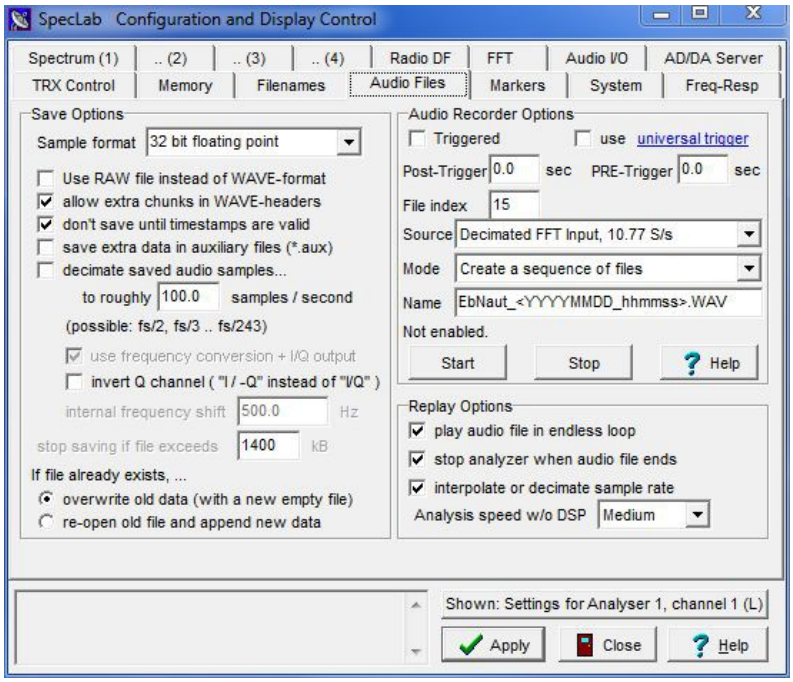

Figure 9 Spectrum laboratory audio files window.

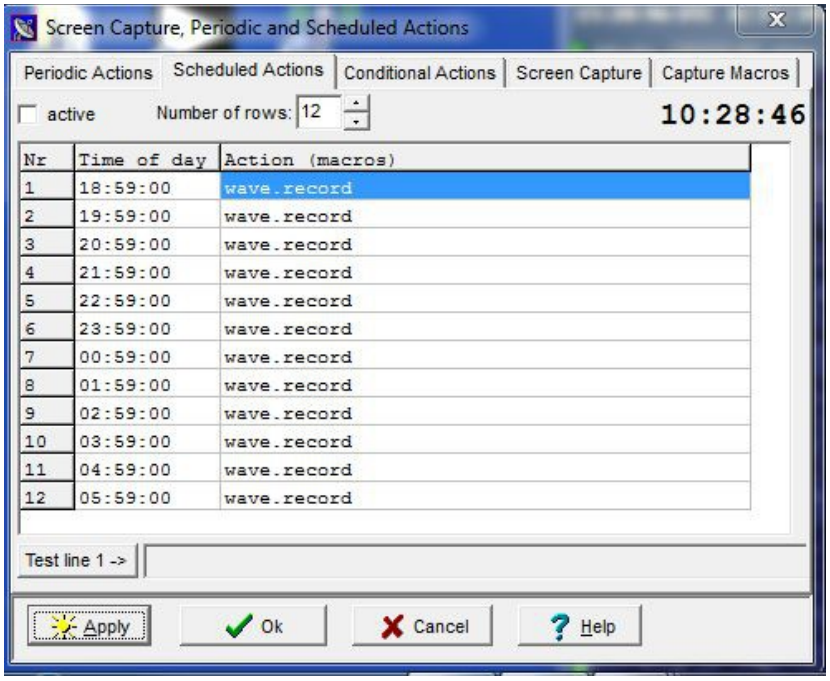

Figure 10 Spectrum laboratory scheduled actions window.

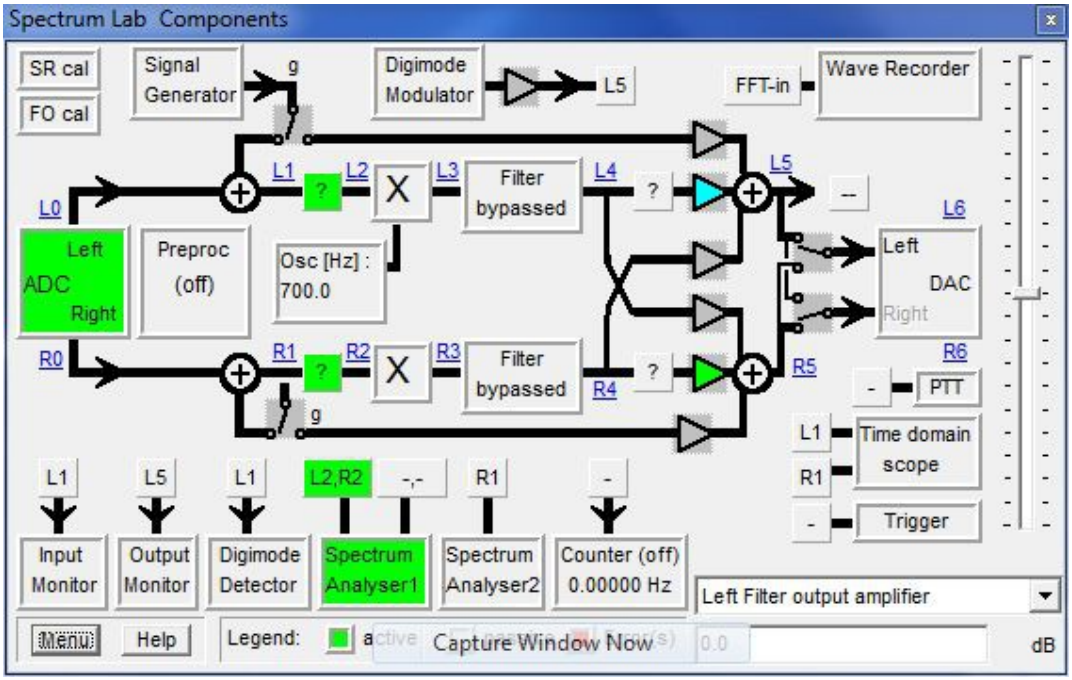

Figure 11 Spectrum Laboratory components window.

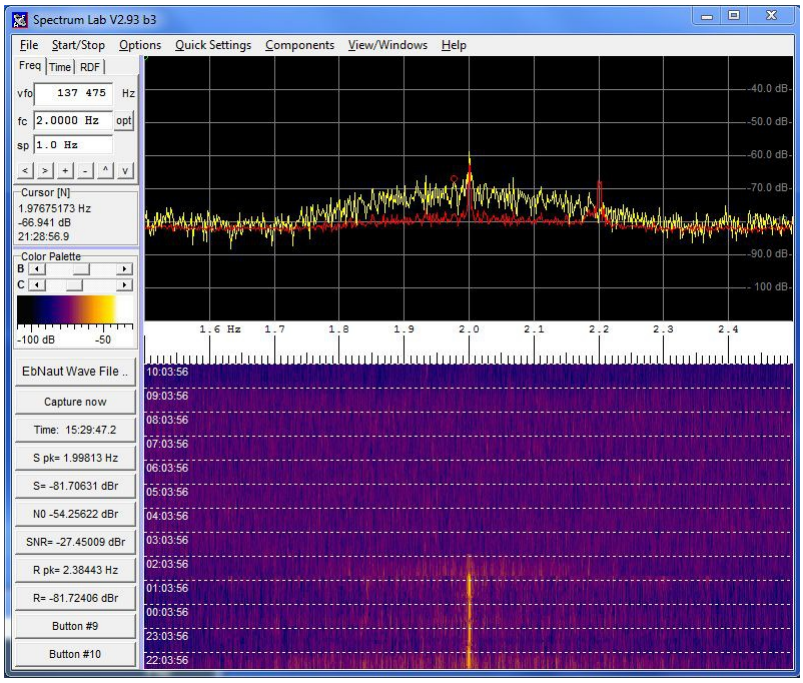

Figure 12 Spectrum Laboratory main window.

The .wav files created by spectrum laboratory are examined after the fact by the ebnaut-rx.exe program to decode the message. An example is:

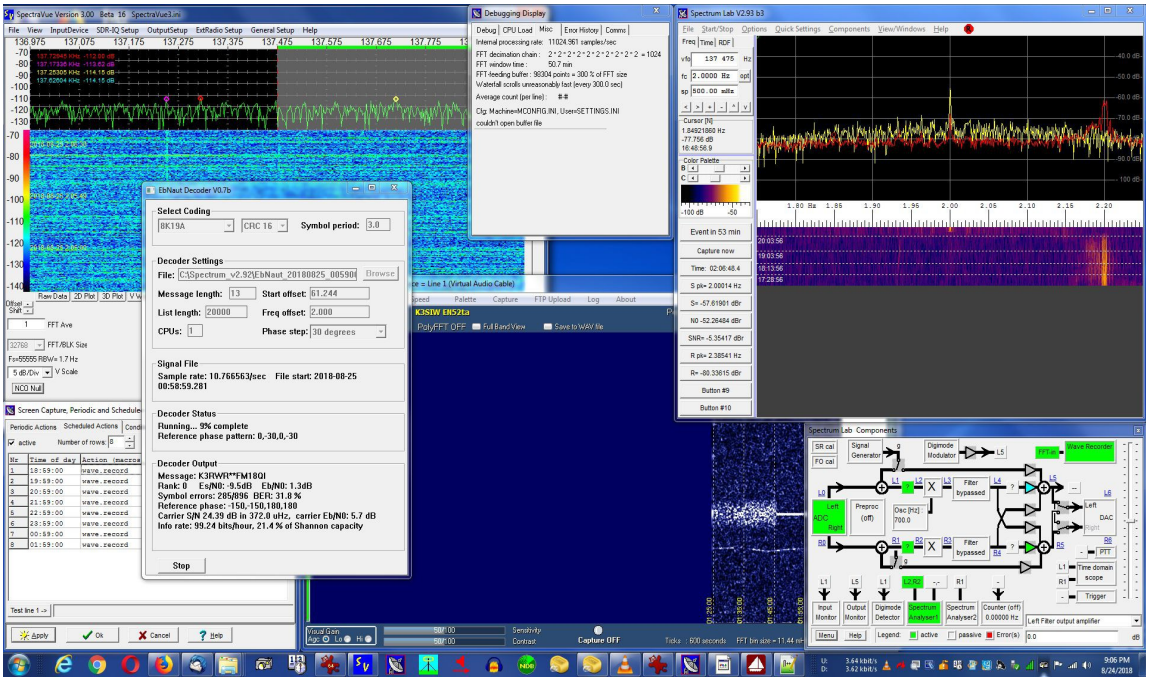

Figure 13 Screen capture including ebnaut-rx.exe decode window.

The decoded SNR would normally use a start offset equal to the difference between file start time and transmit start time (which here is on the hour) plus 4 divided by the sample rate (for receive processing delay) and 0.3 seconds (for transmit start delay). However, SNR and Eb/N0 can be increased through trial-and-error variation of that nominal start offset. For this data we find an average Eb/N0 boost of 1.8 dB when the offset is increased by about half a second. This is important when signals are very weak as it can represent the difference between a correct decode and an erroneous decode.

Table 1 shows decoding results for 6 one-hour time periods, using both the nominal start delay and approximately the best start delay. SNR varies substantially over the period, probably mainly due to nearby rain and thunderstorm activity (Figures 14 and 15). In fact, data collection was stopped for safety considerations after the 05:58:59.47 Z file completed.

Figure 14 Sample view of local rain activity.

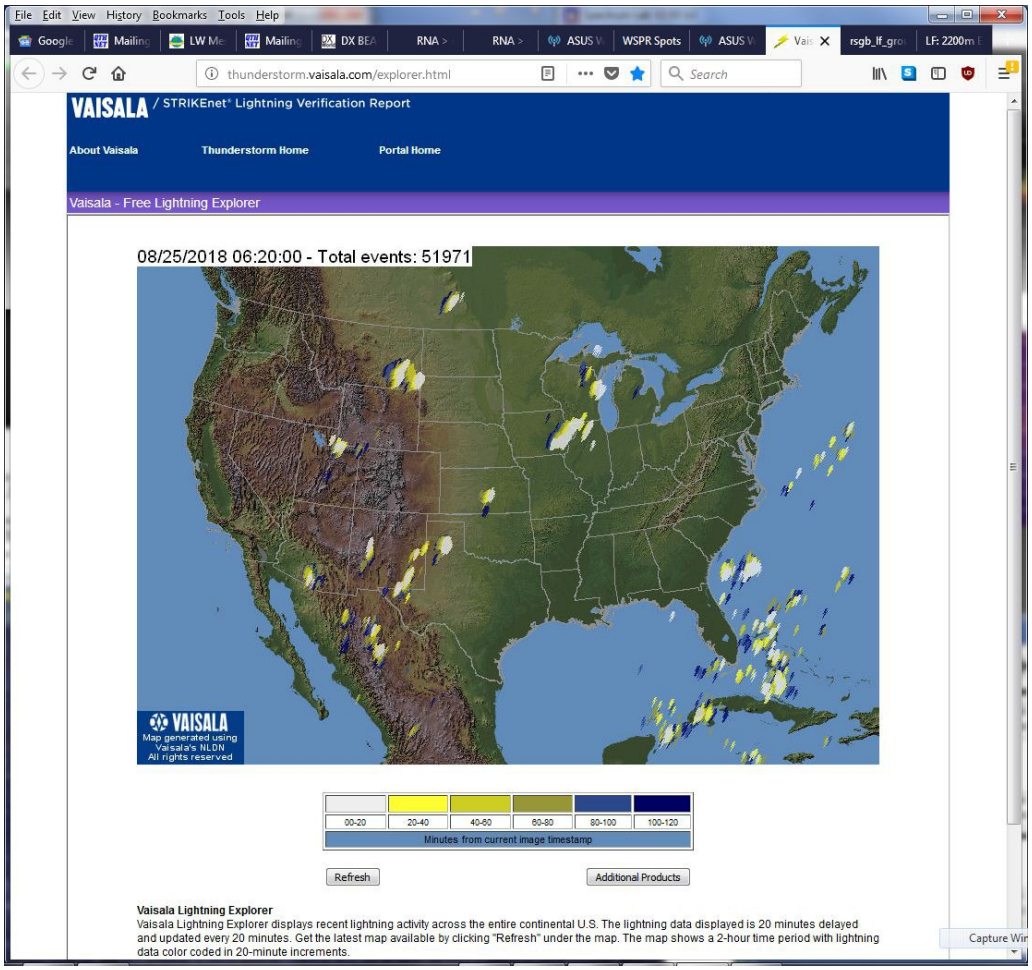

Figure 15 Sample view of nationwide thundrstorm activity.

Table 1 Summary of EbNaut Decodes for K3RWR on 137.477 kHz, Aug 25, 2018.

				start delay (sec)	61.394		61.9	
Time	Rank	Ph1	Ph2	Ph3	Ph4	Eb/N0	SNR	Eb/N0	SNR
Z		deg	deg	deg	deg	dB	dB	dB	dB
00:58:59.28	0	-30	-30	0	0	7.07	25.76	8.96	27.66
01:58:59.32	0	180	180	180	180	17.21	35.93	19.04	37.74
02:58:59.35	0	30	0	60	30	9.87	28.57	11.81	30.51
03:58:59.39	0	60	90	90	120	12.46	31.15	14.42	33.12
04:58:59.43	0	-30	-60	-60	-90	8.23	26.93	9.82	28.52
05:58:59.47	0	-30	0	0	30	15.32	34.02	17.04	35.74

The phase progression information includes a steady case, a case with no net advance, 3 advancing cases, and a receding case (i.e., just about everything). This is probably related to imperfect baseband sampling rate but also may be tied to storm activity.