Downconverter for EbNaut Reception using Sound Card Line-In

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A major issue limiting EbNaut[1] decoding is the very stringent stability requirement for both the receiver and the computer sound card. The most recent Spectrum Lab[2] software provides correction of computer sound card drift through a 1pps GPS (*Global Positioning System*) signal applied to one side of the stereo line-in. Commonplace receivers, even with high stability TCXOs (*temperature compensated crystal oscillators*), fail to realize the sensitivity potential of EbNaut. But it is not difficult to build one's own receiver, in the form of a down converter, that is GPS stable. That is the purpose of this note.

Even the most primitive sound cards provide sampling rates of at least 48 kbps. Thus, the goal here is for an EbNaut-capable down converter that converts the signal radio frequency to a frequency below 24 kHz so Nyquist is satisfied. GPS-locked 10 MHz signal sources are readily available today through eBay and can be used to provide LOs (*local oscillators)* that are synthesized from 10 MHz and move RF frequencies down to audio frequencies the sound card can handle. This note shows an easy way to generate such acceptable LOs, one for reception of signals in the 137.5 kHz ham band and one for reception of license-free beacons around the 185.3 kHz so-called watering hole.

Of course the down converter requires more than just a viable LO. A preselector filter to render the unwanted mixer sideband insignificant is needed to prevent 3 dB (or more) degradation of the receive noise figure. Additional gain is likely needed so quantization noise from the sound card analog-to-digital converter becomes unimportant. And finally a low pass filter after the mixer and before line-in is a good idea to protect against aliasing effects. The downconverter block diagram is then as follows:

EbNaut signal source (eprobe, beverage, loop, etc. antenna) → preselector filter → gain block → RF port of mixer → mixer → IF port of mixer → low pass filter → line-in, R port
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LO port of mixer ← divide-by-80 for 137.5 kHz reception ← 10 MHz GPSDO → 1pps to line-in
or divide-by-60 for 185.3 kHz reception R port

The parts necessary to build the above are available through eBay (GPSDO, GPS ant/amp, mixer, ICs) and most junk boxes (various R,C,L passive components). Because the frequencies are low, so-called dead bug construction works fine.

The particular GPSDO we used output a 1 Hz square wave. Spectrum Lab expects a pulse, not a 50% duty cycle waveform and failed to lock. To remedy this a monostable multivibrator (CD4090B IC) was added to produce approximately 100 ms output pulses on the rising edges of the 1 pps square waves from the GPSDO. A 1 kohm pot was included so the level can be adjusted from 5 V logic swings down to under 1Vpp for the sound card. Despite an acceptable level Spectrum Lab still refused to lock because the computer sampling rate was too far off the desired 48000 Hz. The Sampling Rate and Frequency Correction tab indicated the computer was sampling at about 48001.24 Hz and loading that value into the Audio I/O tab under Configuration and Display Control got things running correctly.

1 http://abelian.org/ebnaut/.
2 https://www.qsl.net/dl4yhf/spectra1.html.

Reception of local lowfer SIW on 185.185... kHz made it clear additional gain over what an eprobe provides may be necessary to raise the signal above sound card A/D quantization noise. To that end an VE7SL preamp[3] has been inserted between the eprobe output and downconverter input. Although the 137.5 kHz preselector includes some gain the VE7SL preamp may be necessary there as well.

Figures 5-7 show use of the downconverter to receive EbNaut transmissions from lowfer SIW. Comment on the “Start offset” and “Freq offset” values used in Figure 7 for ebnaut-rx.exe is in order. The lowfer transmission frequency is 185.185... kHz while the local oscillator frequency is 166.666... kHz. The lower sideband mixing product is thus 18518.518... Hz. With the Spectrum Lab FFT tuned to 18518 Hz the frequency offset is thus 0.518... Hz. The decoder program recognizes values to at least 6 places so the ideal frequency offset value is 0.518519 Hz, rounded to 6 places. However, the 0.5185 Hz value used in Figure 7 is adequate for such a strong signal. In practice with weak signals it may be advantageous to try small frequency adjustments around the nominal value to maximize decoder performance. The same holds for start offset. Nominally this is given by the difference between the file start time stated by the ebnaut-rx.exe decoder output and the known beginning time for EbNaut transmissions (top of the hour here), plus 4 divided by the Sample rate, also given by the decoder output.

To simplify the Spectrum Lab Scheduled Actions window, a single file can be specified. When this is done, later transmissions can be decoded by adding 3600-second multiples to the start offset. The SIW lowfer beacon sends unmodulated carrier after EbNaut transmissions end so adding 1800-second multiples to the start offset allows carrier decodes as “***...” (as many *'s as there are message characters).

Although collecting the received data into a single .wav file is convenient, it means that file may need to be parsed into multiple .wav files to carry out stacking. So if stacking is anticipated it may be best to schedule multiple .wav files, one for each EbNaut transmission. If the received signal phase is sufficiently stable over time, combining multiple .wav files can boost the signal power coherently while only increasing noise power incoherently, thus improving the signal-to-noise ratio and odds of correct message decode.

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3 https://qsl.net/ve7sl/burhans.html.

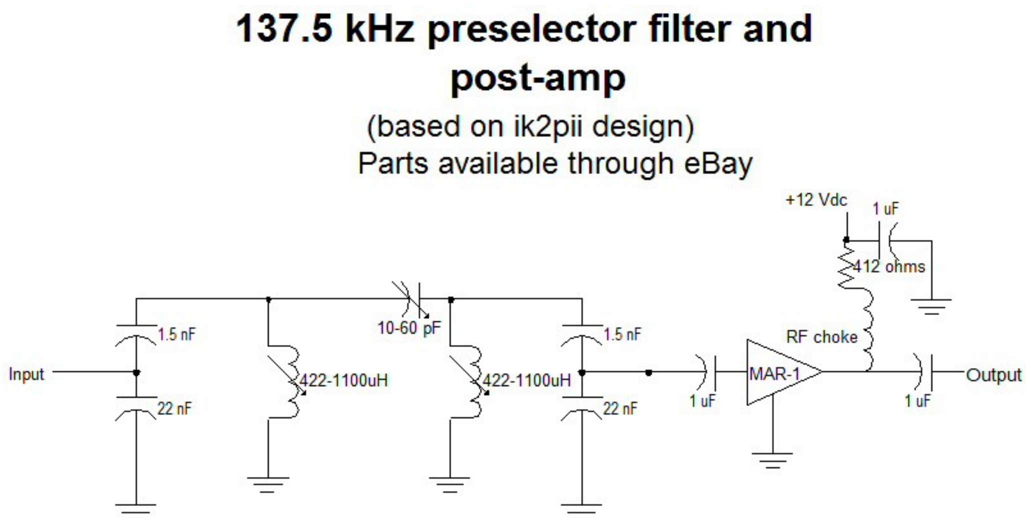

Figure 1 137.5 kHz band pass filter (also tunable to 185.3 kHz if desired).

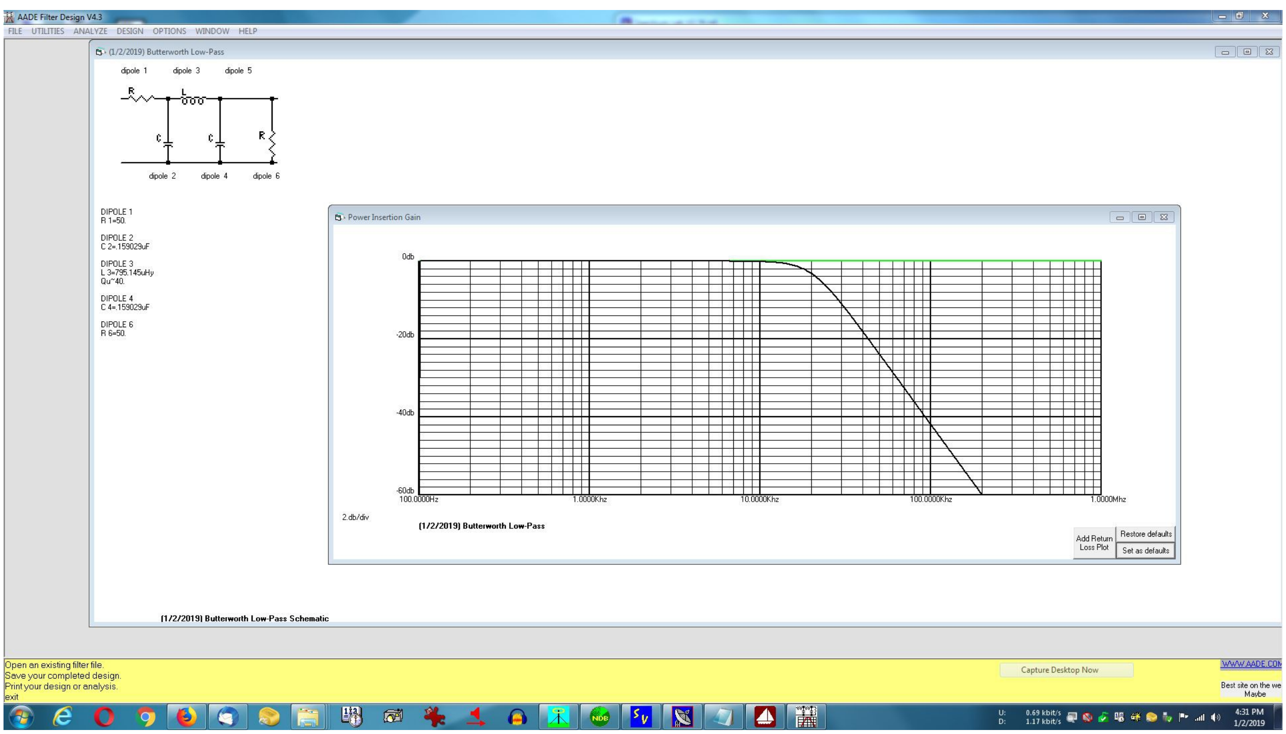

Figure 2 20 kHz low pass filter.

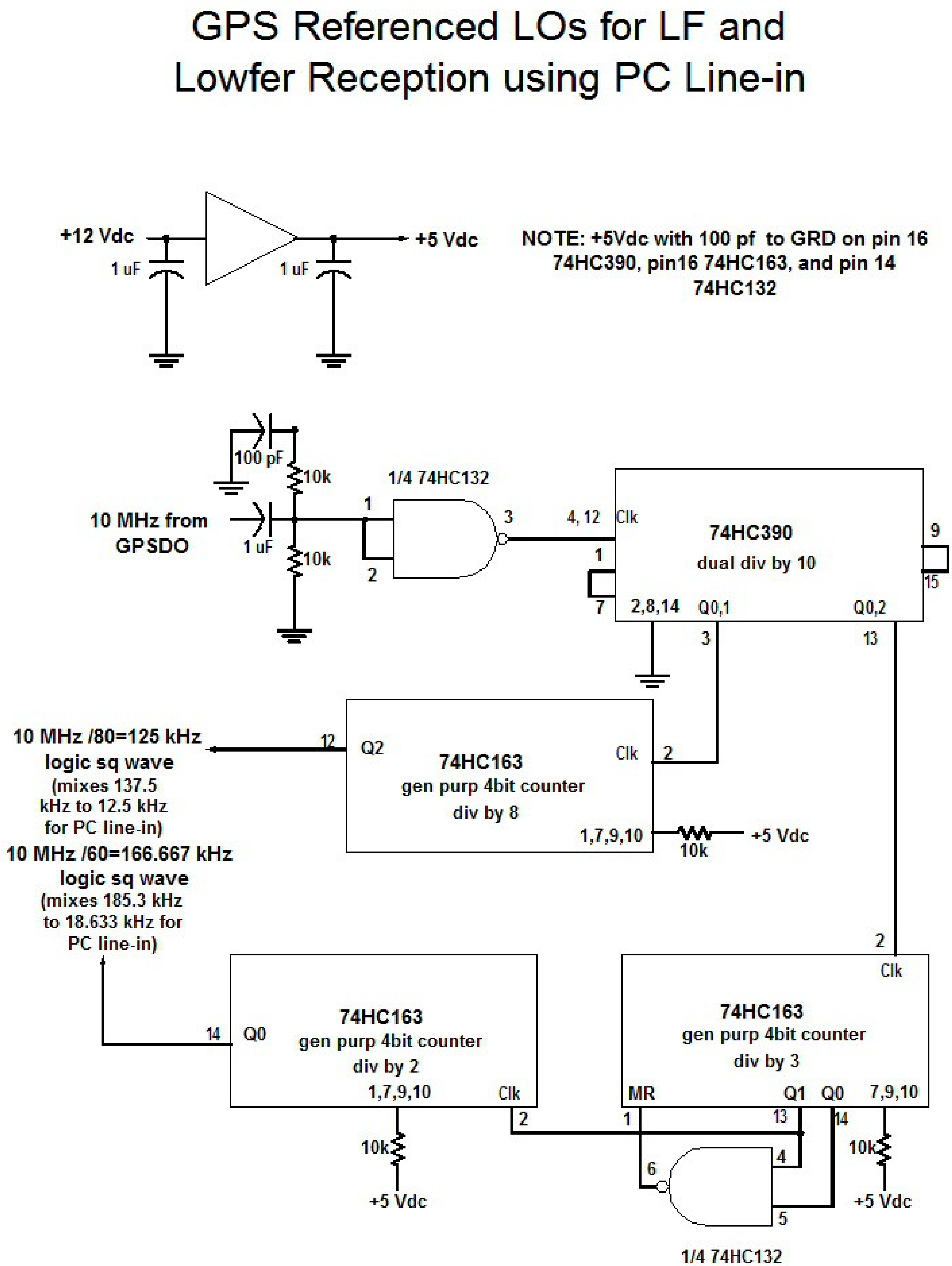

Figure 3 Dual LO Generation Schematic.

Figure 4 Completed Unit Bench Test: input= -10 dBm from HP Sig Gen @ 185 kHz, downconverted output @ 18.633 kHz (conversion loss including LPF on output < 10 dB); operation for 137.5 kHz input is similar except preselector with gain is included.

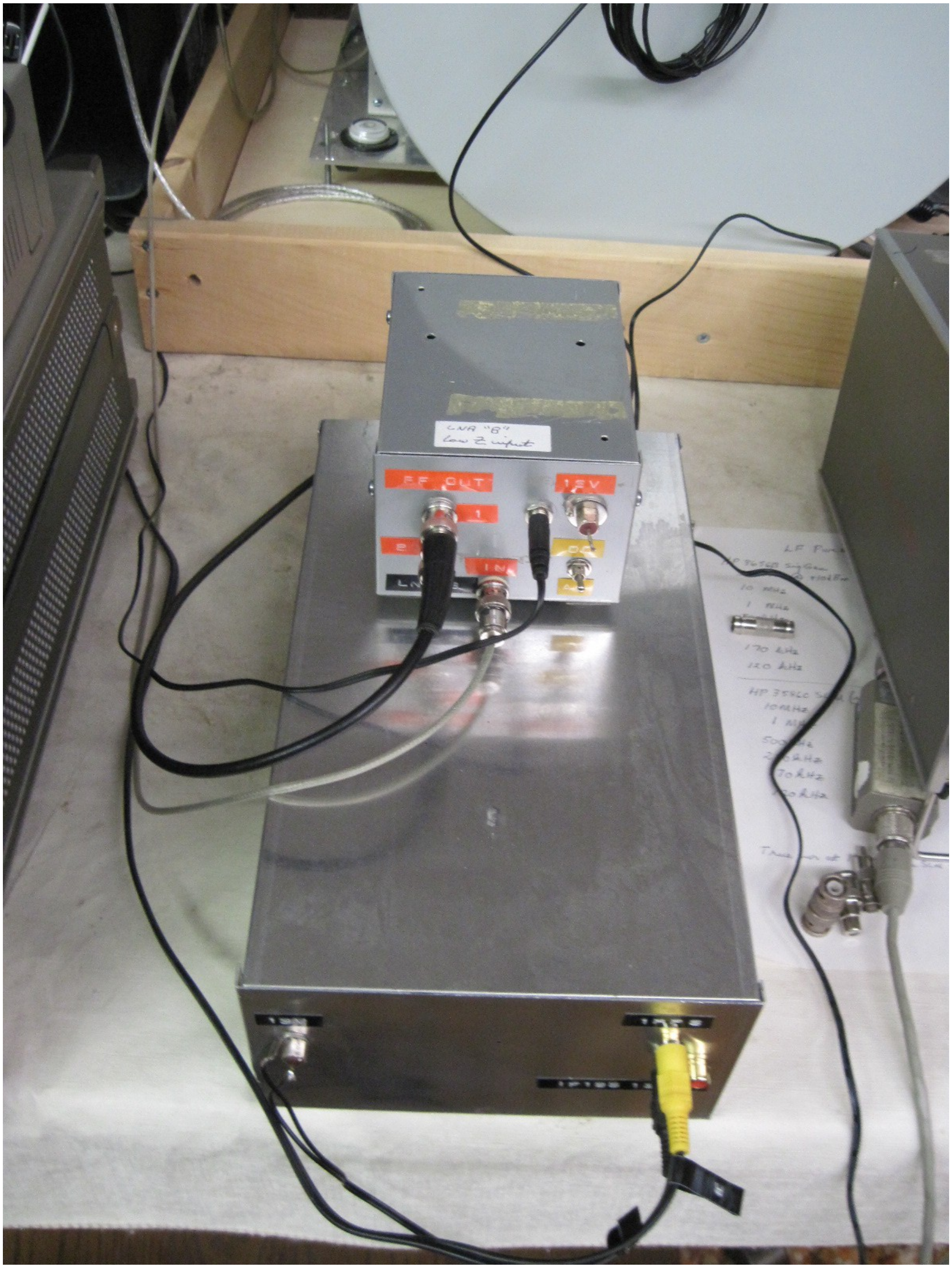

Figure 5 Downconverter box with VE7SL preamp atop.

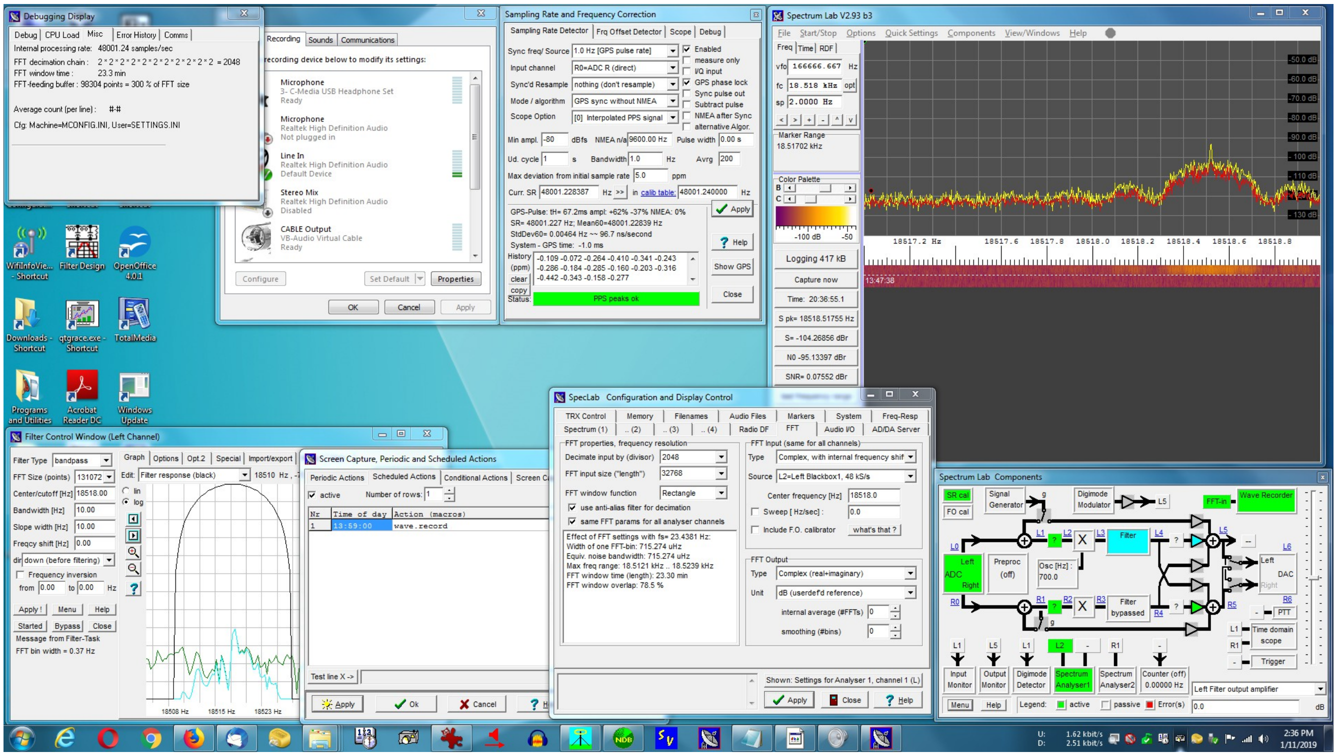

Figure 6 Screenshot of Spectrum Lab Receiving Lowfer SIW.

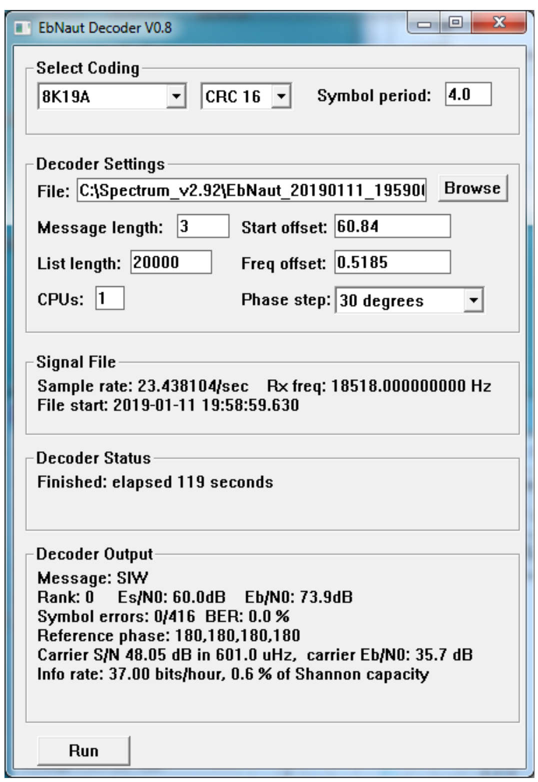

Figure 7 ebnaut-rx.exe Decoding Example for Lowfer SIW Received via Downconverter.