**Radio Observations of the HAARP Winter 2018 Research Campaign**

Whitham D. Reeve

# 1. Introduction

The *High Frequency Active Auroral Research Program* (HAARP) conducted research campaigns during spring, summer and winter 2018. I previously reported my radio observations of the spring and summer campaigns in {Reeve18-1} and {Reeve18-2}, respectively, and I will discuss the winter campaign here. The winter campaign ran 29 November through 4 December, 2018, and spanned approximately 2 to 4 h each day from a couple hours before local sunset to a couple hours after. My main interests with respect to HAARP are propagation phenomena, receiver instrumentation and antennas.

Note: Links in braces { } and references in brackets [ ] are provided in **section 7**.

This article includes brief discussions of some of the phenomena produced by HAARP and descriptions of the observatory instrumentation and the observations themselves. The observations consist mostly of spectra and waterfall screenshots displayed by the software defined radio (SDR) receivers accompanied by short narratives noting displayed center frequency, frequency span and other facets of the observations. All observations were at Anchorage, Alaska USA.


Figure 1 ~ HAARP Ionospheric Research Instrument antenna with collocated transmitters as it appeared on 25 August 2018. With all transmitters active, the IRI is capable of transmitting about 2 GW effective radiated power (ERP) to heat a spot in the ionosphere, but not all were serviceable during the winter campaign. Image © 2018 W. Reeve

All times and dates in this paper are Coordinated Universal Time (UTC) unless noted otherwise. Additional information on HAARP's primary transmitter and antenna system, the Ionospheric Research Instrument, IRI (figure 1), and related diagnostic instruments can be found in {Reeve16} and {Reeve17}, respectively.

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## 2. Phenomena

This section briefly discusses the purposes of the HAARP winter research campaign and is not a science analysis. The HAARP IRI is used to heat a *spot* in the ionosphere above HAARP, generally in the F-region within 30° of terrestrial zenith. Many experiments require pointing the antenna toward *magnetic zenith* (magnetic zenith, denoted MZ, is the direction parallel to the local magnetic field, which at the HAARP site is approximately 14° from terrestrial zenith).

The heating takes place where the radio waves resonantly interact with ionized gas (plasma), effectively heating the electrons and atomic oxygen ions. The heating generally takes place in the altitude range of 200 to 300 km where the electron density is highest. Many phenomena are produced and have been observed and studied including field aligned electron density irregularities (FAI), scatter by high-frequency enhanced Langmuir waves (also called HF-enhanced plasma lines, HFPL), stimulated electromagnetic emissions (SEE), emissions at ELF through LF and airglow. Airglow (artificial aurora) is an optical phenomenon whereas all others are radio phenomena.

One aspect of the winter 2018 campaign that interested me was the attempted detection of radio frequency mixing caused by nonlinear processes in the heated ionosphere (figure 2). When a frequency, $f_{TX}$, from, say, a VHF or UHF transmitter, is beamed at the heated spot in the ionosphere above HAARP, frequency mixing may take place that produces additional frequencies, $f_{RX}$, such that $f_{RX} = f_{TX} \pm f_0$, where $f_0$ is the HAARP IRI frequency. For example, if the HAARP IRI frequency $f_0$ = 4.5 MHz and the UHF transmitter frequency $f_{TX}$ = 432.0 MHz, the resulting scattered frequencies $f_{RX-}$ = 432.0 – 4.5 MHz = 427.5 MHz and $f_{RX+}$ = 432.0 + 4.5 MHz = 436.5 MHz. Certain geometries between HAARP and the transmitter and receiver are favored. High-gain antennas are required and the antennas must be accurately pointed at the spot produced by HAARP. The location of the spot can be calculated from the HAARP coordinates, magnetic field components and ionosphere height (the latter determined from locally produced ionograms by a Digisonde).

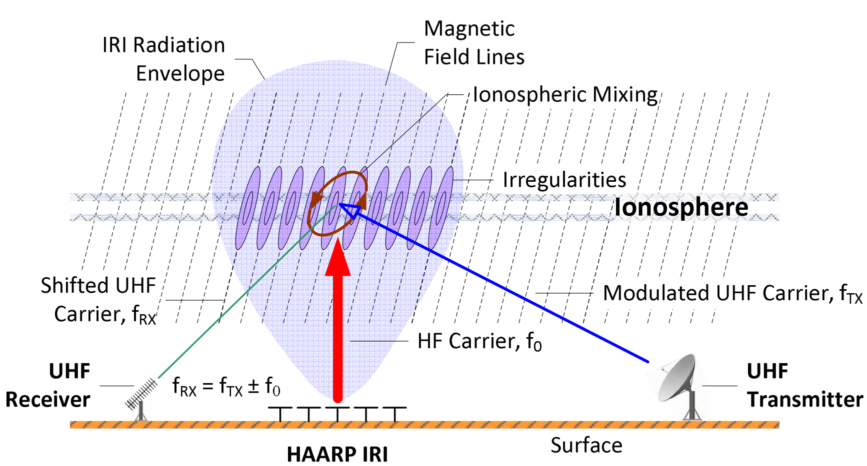


Figure 2 ~ Frequency mixing and scattering experiment schematic. The HAARP IRI produces electron density striations (irregularities) in the ionosphere. Frequency mixing can take place such that a signal transmitted toward the spot above HAARP is mixed with the HAARP transmitter frequency to produce sum and difference frequencies that are scattered. The winter 2018 campaign included attempts by radio amateurs to detect this phenomenon. Image adapted from {DTIC}

The attempts to receive the mixed and scattered transmissions involved several radio amateurs who setup UHF transmitters at Fairbanks and Anchorage and UHF receivers at Gulkana and Chistochina for 432 MHz (70 cm wavelength) transmissions (figure 3). I joined this group as an interested observer but otherwise did not participate in the associated planning; however, I did attempt to receive the transmissions at my Anchorage observatory as described in section 4. The attempts during the winter campaign were similar to apparently successful attempts in March 1999, when radio amateurs used VHF transmitters and receivers (see [QSTJun99] and [QSTAug99]).

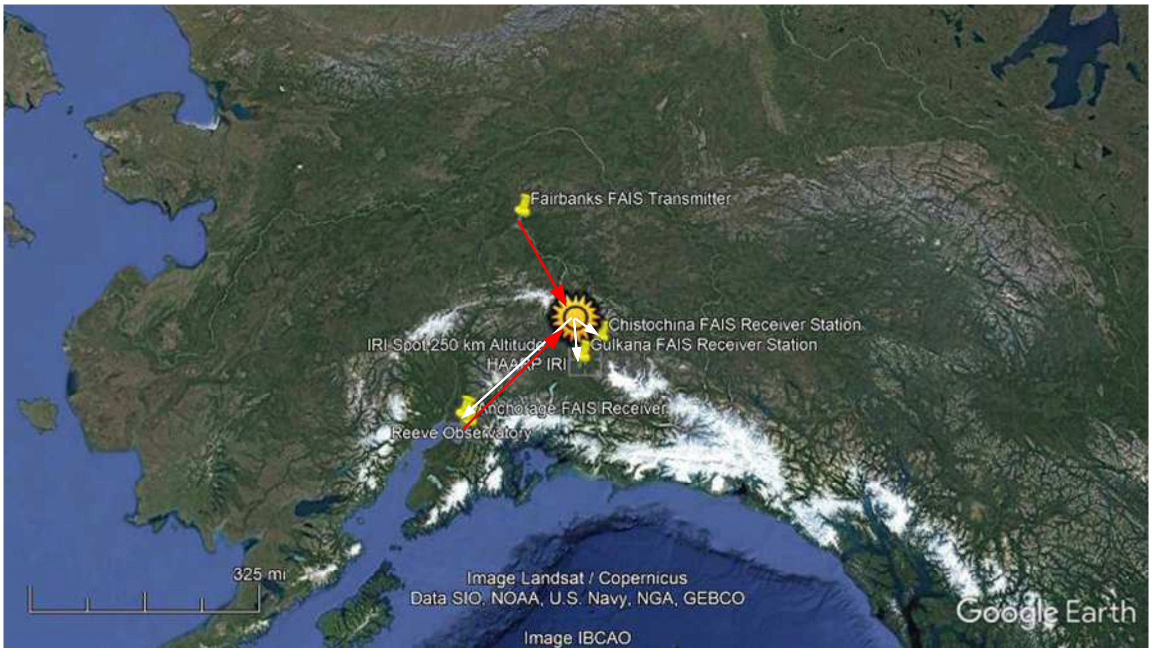


Figure 3 ~ Geographic layout of the frequency mixing and scattering experiment. Transmitter and receiver locations are indicated by push-pin icons. Transmitters were located in Anchorage in southcentral Alaska and in Fairbanks in interior Alaska. Receivers were located in Anchorage, Gulkana, Chistochina and in Edmonton in Canada (Edmonton not shown in this image). The Gulkana and Chistochina sites were, respectively, about 43 and 91 km from the ground projection of the spot produced by the IRI. The spot itself, shown at the center of the image was estimated to be 62 km south-southwest of the HAARP IRI at an altitude of 250 km. Image source: Google Earth.

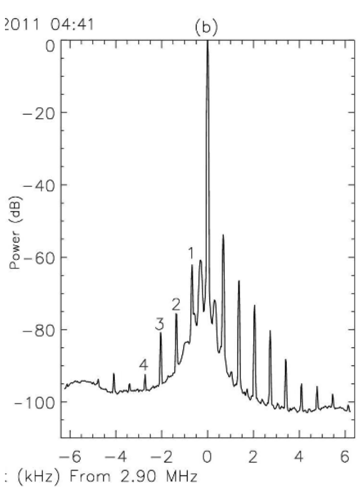


Figure 4 ~ Stimulated Electromagnetic Emissions (SEE) are seen as narrow spectra adjacent to the transmit frequency. This spectral plot has been normalized with the transmit frequency 2.90 MHz ($2f_{ce}$) at the center of the horizontal scale. Image adapted from [Workshop]

In addition, stimulated electromagnetic emissions (SEE) may have been observed during the winter campaign. SEE is secondary electromagnetic radiation generated when the ionosphere is heated (figure 4). SEEs have been observed in previous experiments with frequency offsets up to 100 kHz from the HAARP transmit frequency. SEEs occur when the transmit frequency is close to harmonics of the ionosphere's electron gyro-frequency (also called cyclotron frequency); that is, when $f_0 \approx nf_{ce}$ where $f_0$ = HAARP transmit frequency and $f_{ce} \approx 1.4$ MHz (typical conditions). The detection and analysis of SEEs allows characterization of plasma turbulence, field-aligned striations, electron temperature and heating interaction altitude, among other effects. As with the other phenomena, very high transmitter powers are required to produce SEEs, making the HAARP IRI an ideal instrument for their investigation.

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## 3. Receiver and Antenna Instrumentation at Anchorage

This section describes the equipment and software setups for the HF radio observations. My activities related to the frequency mixing and scattering experiment are separately described in the next section. The geographical data for the transmitting and receiving stations are given in table 1.

Table 1 ~ Transmitting and receiving station characteristics (stations used for FAIS experiment at 432 MHz not shown) (AMSL: above mean sea level; AGL: above ground level, TN: True North)

| **Station** | **Function** | **Latitude** | **Longitude** | **Elevation (m AMSL)** | **Antenna height (m AGL)** | **Distance (km)** | **Direction (°TN)** |
|---|---|---|---|---|---|---|---|
| HAARP (IRI) | Transmit | 62° 23’ 32.7” N | 145° 09’ 02.0” W | 570 | 22 | 285 | 60 ↔ 244 |
| Anchorage | Receive | 61° 11' 58.0" N | 149° 57' 22.9" W | 14 | 13 | | |

I used three SDR receivers, the RFSpace Cloud-IQ and NetSDR and the Icom R-8600, all setup for the HF band and connected to the same antenna through a 4-port receiver multicoupler (figure 5). The HF antenna is a log periodic dipole array (LPDA) with 8-elements and a design frequency range of 18 to 32 MHz. The antenna is horizontally polarized. I routinely use this antenna above and below the design range but it obviously is not optimum for reception of HAARP transmissions, which are limited to the 2.7 to 10 MHz frequency range. The antenna is directional and its vertical and horizontal beamwidths are approximately 60° in the design frequency range; the radiation patterns likely differ significantly from those in the design range. The antenna is mounted on an azimuth-only rotator with Its elevation fixed at 0°. I rotated the antenna to point directly toward the HAARP site.

The great circle azimuth to the HAARP site from Anchorage and the elevation angle at Anchorage for observations of the ionosphere directly above HAARP (figure 6) were calculated from {Reeve14-1} and {Reeve14-2}. As mentioned previously, the heated area above HAARP is not necessarily directly above but can be offset to align with Earth's magnetic field. The great circle path between the two sites is entirely over land (figure 7).

In terms of software, I used SpectraVue with both the Cloud-IQ and NetSDR. I setup separate instances of SpectraVue by using different IP ports, one for each receiver. I used the RS-8600 receiver control software with the R-8600 receiver. This software actually consists of two components: One is a server that connects to the receiver through the local area network (LAN), and the other is the receiver control software itself, which connects to the receiver through the server. This arrangement allows some flexibility in how the receiver audio is handled, although for the most part this is not relevant to my observations. The R-8600 receiver control software and receiver display includes what Icom calls a *Spectrum Scope* but it is not nearly as useful as the spectral displays and waterfalls produced by SpectraVue and most other SDR software.

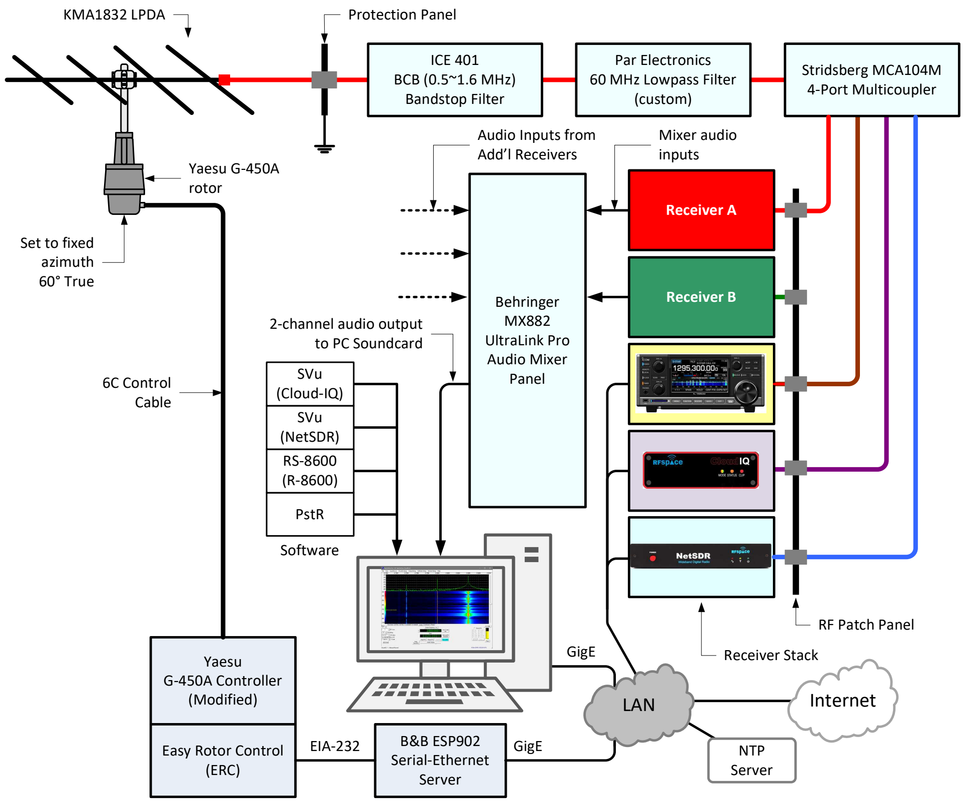


Figure 5 ~ System block diagram at Reeve Observatory. The rotator was set to 60° T and left in position for the duration of the observations. The NetSDR is at the bottom of the receiver stack with the Cloud-IQ immediately above. The R-8600 is above the Cloud-IQ. Receivers A and B (both Icom R-75 general coverage receivers) and the audio mixer panel were not used but are shown because they are integral to the station. Software: SVu – SpectraVue, PstR – PstRotator, RS-8600 – R-8600 control. Image © 2018 W. Reeve

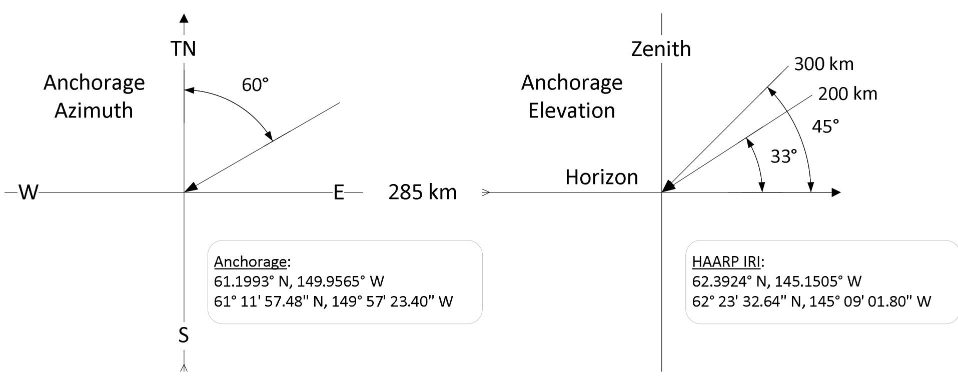


Figure 6 ~ Approximate azimuth (left) and elevation (right) for the propagation path to the F-region ionosphere directly above the HAARP site; Different HAARP beam angles will change the values slightly. Two ionosphere heights are shown because it can vary. Azimuth is with respect to True North (TN). Image © 2018 W. Reeve

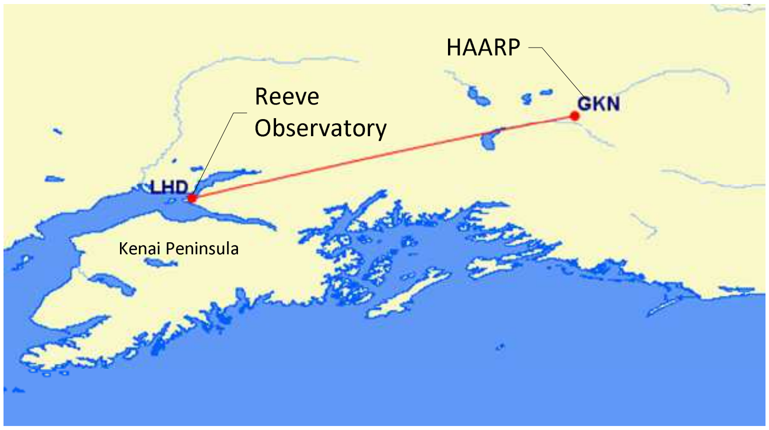


Figure 7 ~ Great circle propagation path between the airports nearest to Reeve Observatory in Anchorage (Lake Hood, LHD) and the HAARP site (Gulkana, GKN). The path is entirely over mountainous terrain. Underlying image produced by Great Circle Mapper {GCMap}

I took screenshots of the displayed spectra and waterfalls for the different receivers, in many cases within a few seconds of each other for comparison. Many of the screenshots are shown in section 5. I also setup to record audio WAV files throughout the campaign whenever interesting modulation was being used. For these I used the internal recording facilities in SpectraVue and RS-8600 receiver software.

## 4. Frequency Mixing and Scattering at 432 MHz

I observed the frequency mixing experiment on the local late afternoons of 29 and 30 November. I primarily used the NetSDR, which has the down-converter option to extend its upper frequency range to about 700 MHz. I set its center frequency at or near the expected receive frequency based on the sum and difference of the 432 MHz (70 cm) amateur radio transmit frequency and the HAARP transmit frequency. SpectraVue was set for various frequency spans and FFT averaging. I also tried setting the center frequency to 432.0 MHz and a span that included the expected sidebands as discussed in section 2.

For this experiment I used a 1 x 2 antenna array (figure 8) connected through a 4-way power splitter to the receivers (figure 9). I had plenty of font-end gain so splitter loss (~7 dB) could be ignored. The antennas were Diamond model A430S15 15-element Yagis on a Diamond model SB430 dual antenna stacking boom mount. The antennas were interconnected by a Diamond model SS770R phasing harness. Each antenna has an advertised gain of 14.8 dB. Connecting them with the phasing harness in a 1x2 array probably increases the net gain by about 2 dB, giving a total array gain of about 16.8 dB. The antennas were configured for vertical polarization (a choice based on the mounting mechanics).

The antenna boom mount was fastened to a short mast on a roof tripod, which was temporarily set on the north deck of the observatory. The output of the phasing harness connected through a short jumper to a VHF Design model LNA 70cm, ATF-531P8 low noise amplifier (LNA) for the 432 MHz amateur radio band. The advertised gain and noise figure of the LNA is 18 dB and 0.4 dB, respectively (I did not verify these values). The LNA noise figure probably is degraded 0.3 to 0.5 dB by implementation losses (mostly connector and jumper cable losses). The LNA is installed in a shop-built weatherproof enclosure and mounted to the tripod mast with saddle clamps. Power to the LNA was supplied from the observatory 12 Vdc station power system via a packaged bias-tee described at {Reeve18-3}.

Figure 8 ~ Temporary setup of the Yagi antenna array for attempted reception of 432 MHz transmissions via FAIS. The antennas were pointed toward the estimated spot location in the ionosphere above HAARP using an electronic level and compass. The LNA is the gray box at the top of the tripod. A short coaxial jumper connects the phasing harness to the LNA input. The setup is far from ideal due to the nearby evergreen trees. Part of the HF LPDA antenna used for the HF observations can be seen at the top-center of this image. Image © 2019 W. Reeve

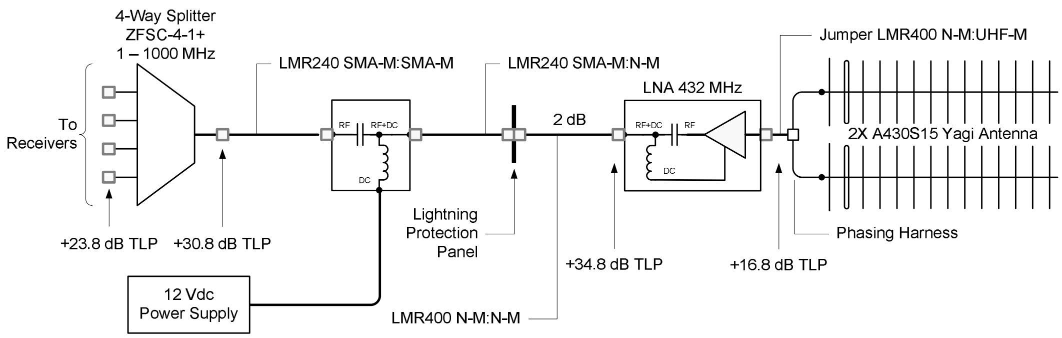


Figure 9 ~ Antenna system and low noise amplifier (right of protection panel) and bias-tee and splitter (left) used for the 432 MHz mixing and scattering experiment. The splitter allowed up to four receivers to be connected; both the NetSDR and R-8600 were temporarily repurposed from the HF observations and used for the UHF observations. Also shown are the estimated transmission level points (TLP) at locations along the transmission path. Image © 2019 W. Reeve

Although a M7.1 earthquake occurred at 1730 on 30 November only 12 km north of Anchorage, the temporary antenna array surprisingly was not disturbed. The PC monitor in the observatory was knocked off its table but it continued to operate with no apparent permanent damage. All receivers and associated equipment continued to operate without problems, and I made regular observations on the prearranged schedule.

I received the transmissions from the Anchorage transmitter station about 15 km southeast of my observatory, and these were quite strong on 432.0 MHz. I also received the HAARP transmissions at 4.5 MHz. However, I did not receive any frequency-shifted signals or any transmissions from the Fairbanks transmitter station (reception of Fairbanks was not expected). It is my understanding that there may have been one instance of success by the other participants to receive the scattered signals but I have no information on these results.

There could be several reasons for my null results: 1) Scattering and mixing did not occur as planned or were too weak for detection; 2) The transmitter or receiver antennas were not pointed correctly; 3) My receiver system was not sensitive enough; 4) All of the above. If I participate in a future similar experiment, I plant to assemble a 2x2 array of Yagi antennas and use a 4-port RF combiner instead of coaxial cable phasing harnesses.

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### 5. HF Radio Observations

Each experiment day started during local mid-afternoon before sunset and ended a few hours later after sunset. As in previous campaigns I monitored the Twitter tweets by HAARP's chief scientists, Dr. Chris Fallen, and also followed his more detailed posts in *Slack*, an online collaboration software tool used to coordinate HAARP IRI settings. I was a member of the preassigned Slack channel for the HAARP campaign and found the information provided there very useful for keeping track of the transmission schedules.

Transmitted carrier frequencies varied from the high end of the MF band at 2.8 MHz to the low end of the HF band. The highest frequency I observed was 5.4 MHz but most transmissions took place close to 2.8 and 3.0 MHz (near $2f_{ce}$).

Sometimes the HAARP transmit frequencies would change at the last minute based on ionospheric conditions. I occasionally missed these changes and did not receive the expected transmit frequency. At these times, I setup the SDR receiver software to display a wide frequency span from 2.5 to 10.5 MHz (corresponding to the full IRI frequency range) as an aid in finding the transmissions. On the other hand, when the frequency was known I set the software to display a narrower span of 100 kHz or less depending on how much detail I wanted to view in the received spectra.

There were several experiment sessions with very interesting chirp-type modulations. I did not learn the purpose of these experiments but I snapped numerous screenshots of the spectra. These screenshots and screenshots from other sessions and ionograms make up the rest of this section; all are shown in chronological order. The ionograms are labeled *Gakona* and are produced by the Digisonde located at the HAARP facility. Archives at about 8 min intervals are available at {GKNIono}.

In many cases, I provide spectrograms for the R-8600 receiver at about the same time as for the RFSpace receivers, which allow easy comparison. In some cases, it may appear that the spectrum shown in one screenshot is the same as that shown in the next; however, there usually are subtle differences worth noting such as a frequency change in a multi-carrier transmission, varying received power levels, or appearance or disappearance of sidebands.

In SpectraVue, the time of a live screenshot appears in the lower-right corner of the window; timestamps also are part of the waterfall displays. Unfortunately, the R-8600 software does not provide any form of time-stamp so I used file creation timestamps for reference. In some SpectraVue screenshots demodulation was enabled and is seen as a shaded area at or near the center of the spectrum display. The demodulation does not affect the displayed spectrum, only the audio fed to the PC soundcard.

The SpectraVue screenshots include both the Cloud-IQ and NetSDR receivers but the Cloud-IQ predominates. Screenshots from the two receivers are differentiated by the .ini filename in the title bar at the top of the window image. The Cloud-IQ indicates *Spectravue_CloudIQ* and the NetSDR indicates *Spectravue_NetSDR*. I also have included screenshots of the R-8600 receiver control software (front panel) and associated spectrum scope. The spectrum scope does not provide much information compared to SpectraVue (and other software defined radio receiver software), so a screenshot of the receiver control panel is used to record the radio settings for reference. In the future, I probably will use an alternative software with the R-8600, such as *SDR-Radio Console* or *HDSDR*.

In addition to the RF spectrograms and waterfalls discussed above, I also extracted the demodulated audio waveforms and spectrograms for some interesting cases and provide screenshots. I used the Waveform and Spectrogram views in Audacity software for all audio analyses. It should be noted that the audio bandwidth is limited by the demodulation mode selected at the recording time, typically AM (6 kHz), SSB (2.4 kHz) or CW (500 Hz) for the R-8600.

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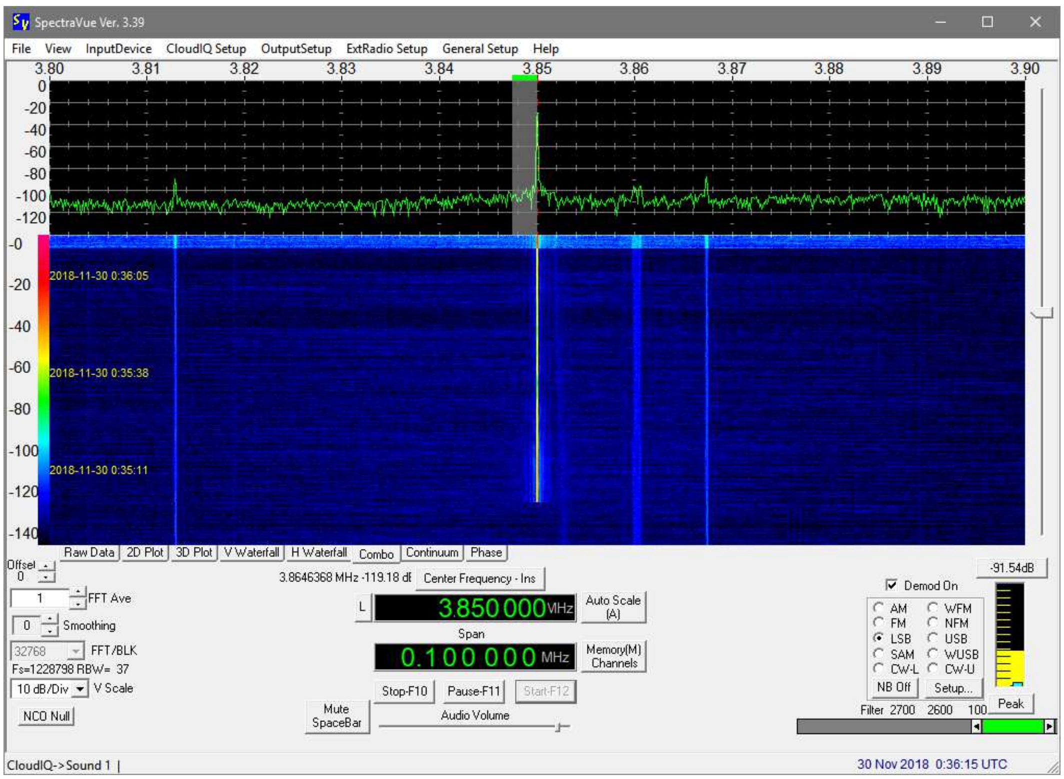
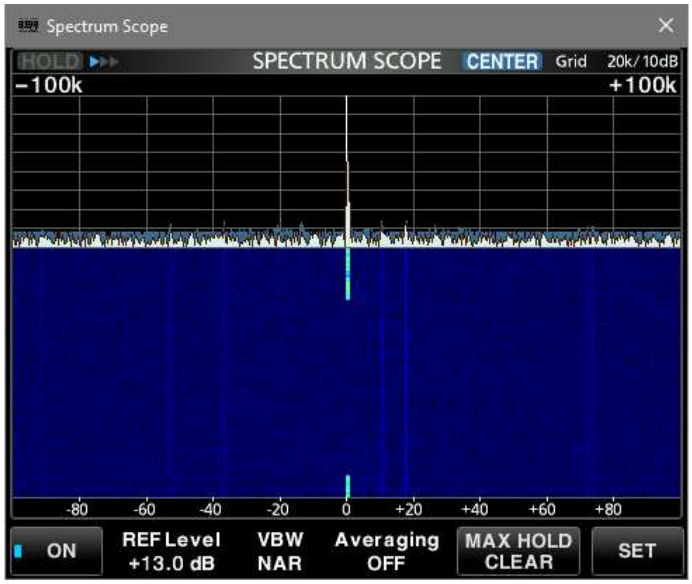
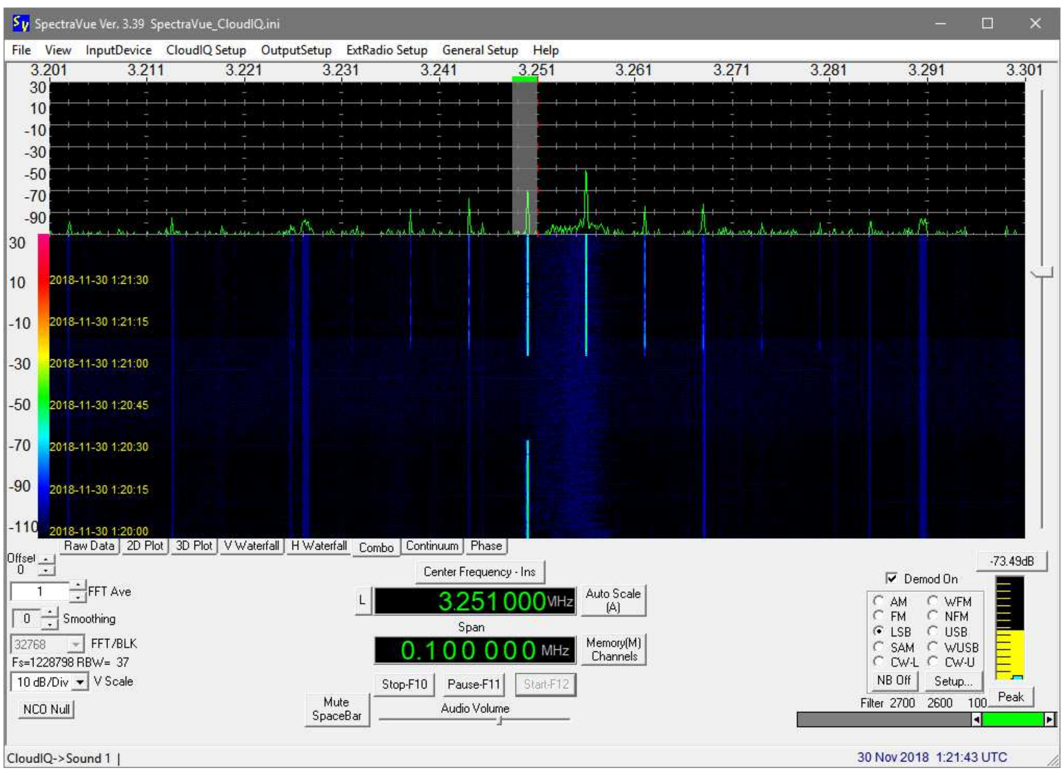
30 November 2018 (29 November local)



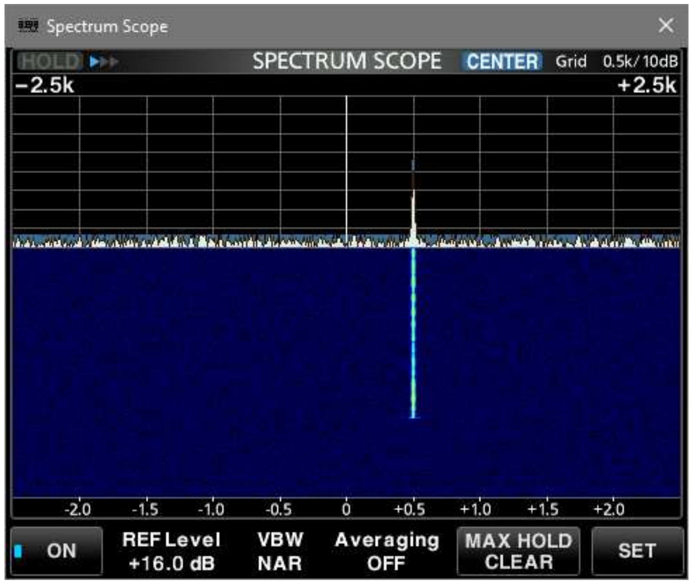

Cloud-IQ, 3.85 MHz, 100 kHz span, 30 November, 0036. Some persistent RFI is visible above and below the center frequency.



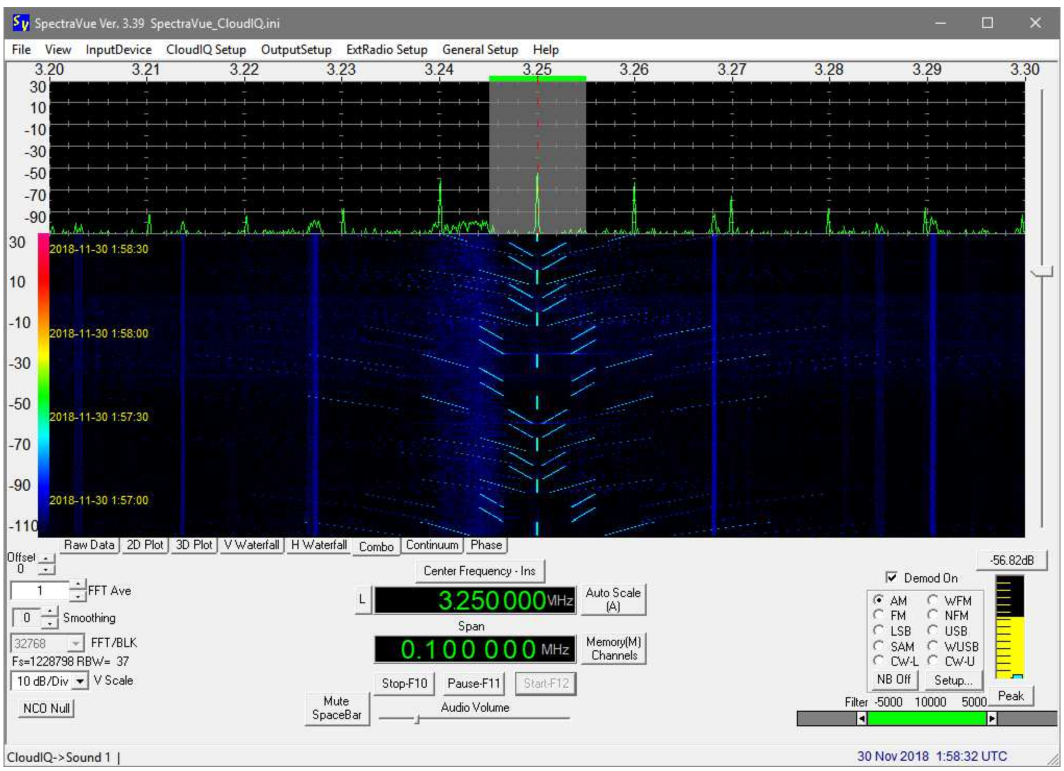

R-8600, 3.85 MHz, 200 kHz span, 30 November, 0036. The RFI clearly seen in the previous waterfall is less obvious in this one.



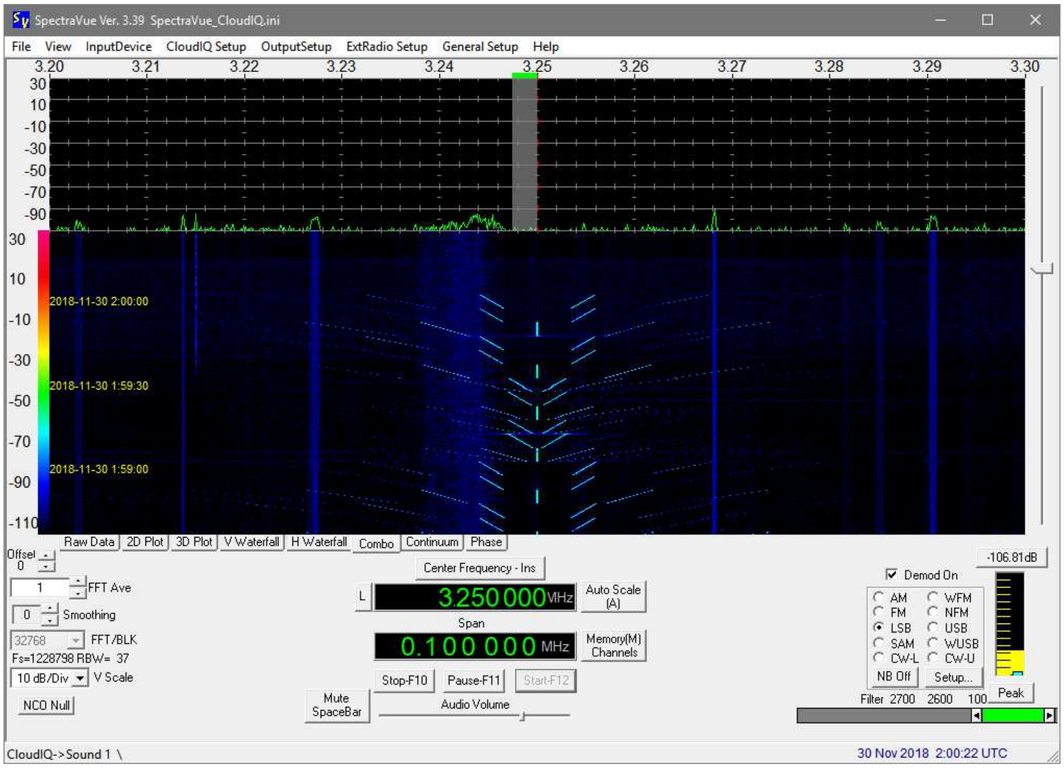

Cloud-IQ, 3.251 MHz, 100kHz span, 30 November, 0121. The strongest carrier of this multi-carrier transmission appears at 3.256 MHz with three additional carriers above and three carriers below. The carrier spacing is 6 kHz. The previous On sequence had only one carrier at 3.250 MHz.



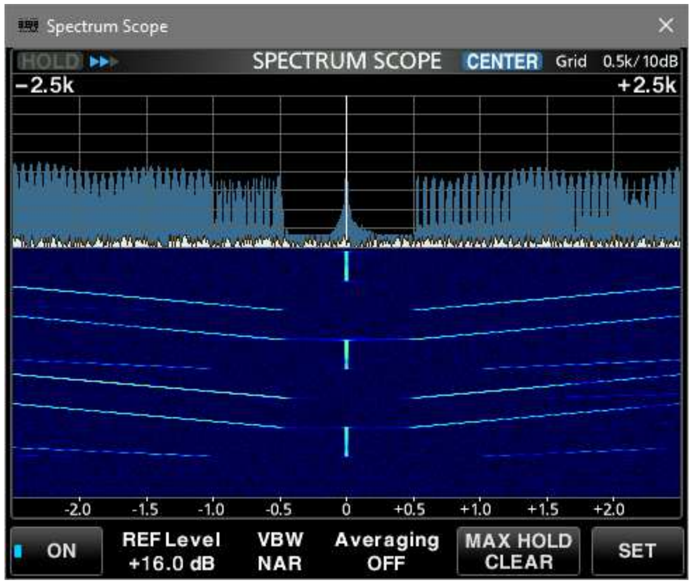

R-8600, 3.251 MHz, 5 kHz span, 30 November, 0121. Only the strongest carrier is visible in this image.



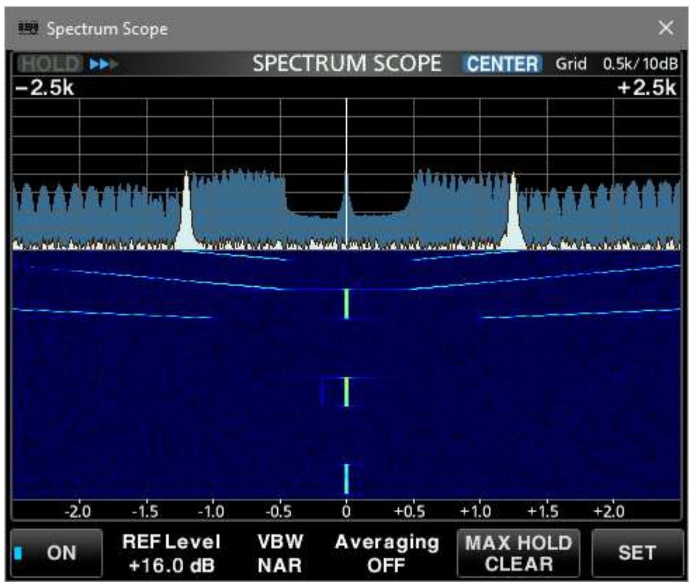

Cloud-IQ, 3.25 MHz, 100 kHz span, 30 November, 0158. Chirp modulation.



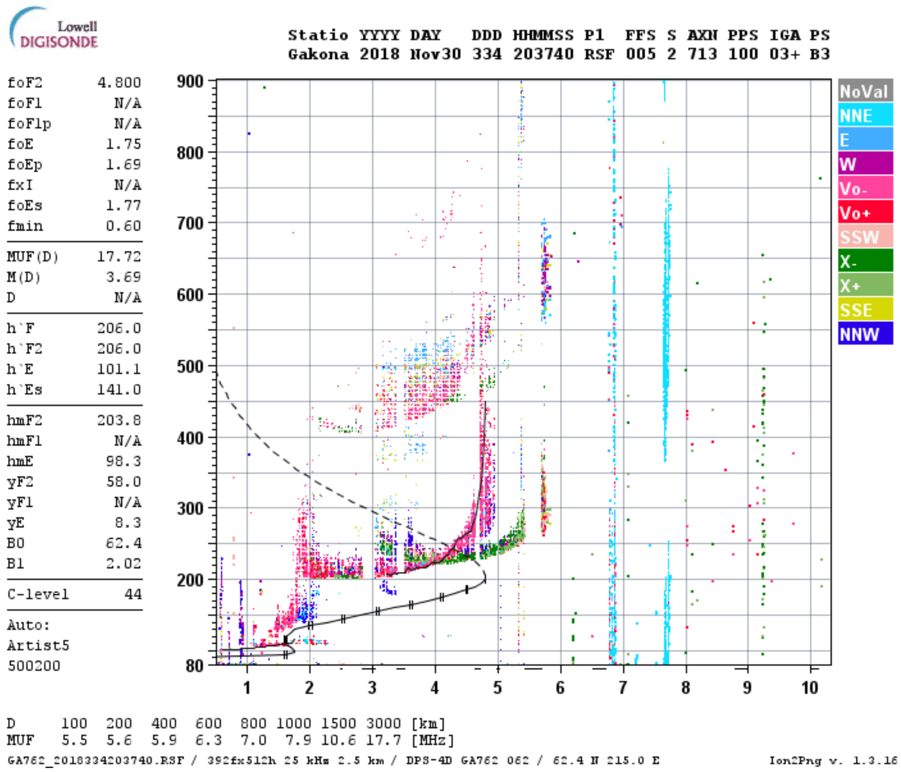

Cloud-IQ, 3.25 MHz, 100 kHz span, 30 November, 0200. Chirp modulation ends at 0200:00 in this image.




R-8600, 3.25 MHz, 5 kHz span, 30 November, 0200. Chirp modulation as shown previously except the span shown here is narrower. Note the display persistence of previous sweeps in the spectrum display.

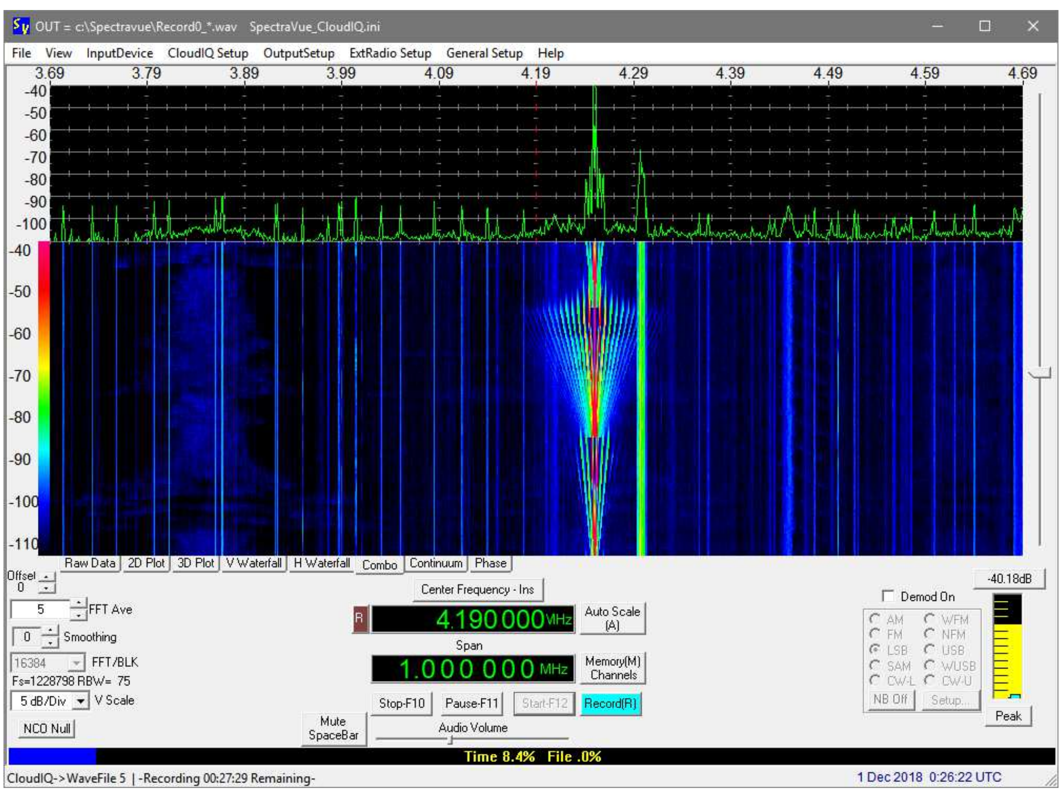



R-8600, 3.25 MHz, 5 kHz span, 30 November, 0200. Chirp modulation. Note the frequency of the current trace is indicated in the spectrum display by the white spikes.

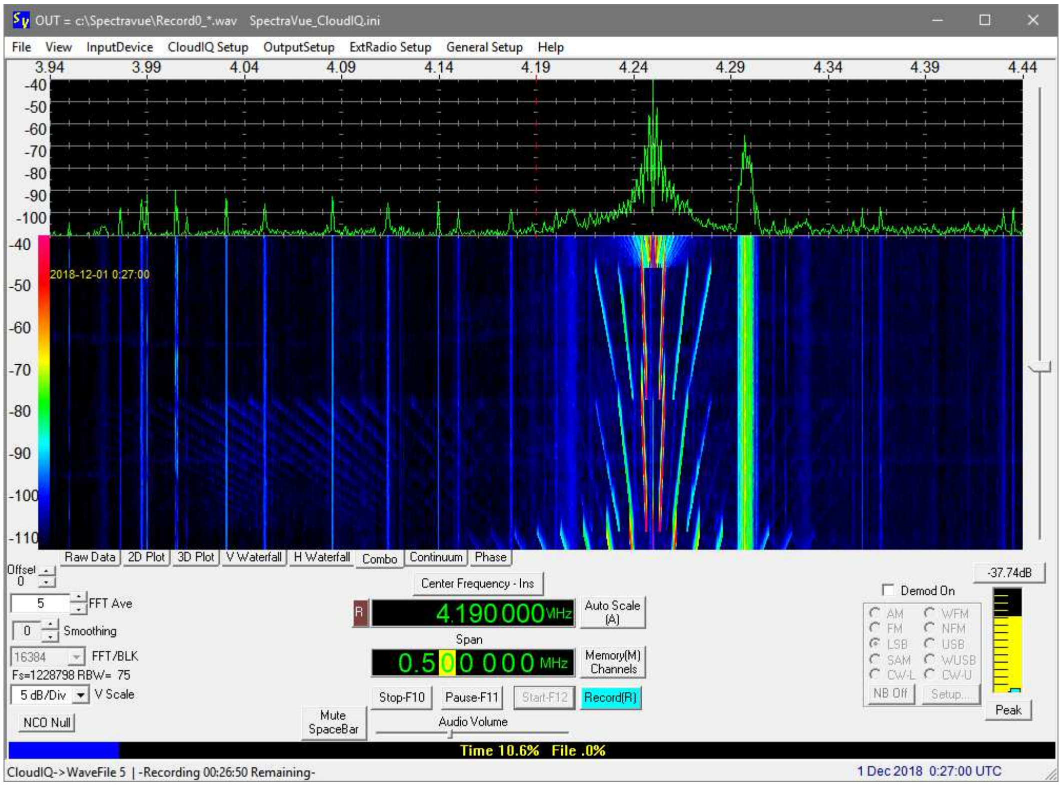



Gakona ionogram, 30 November, 2037

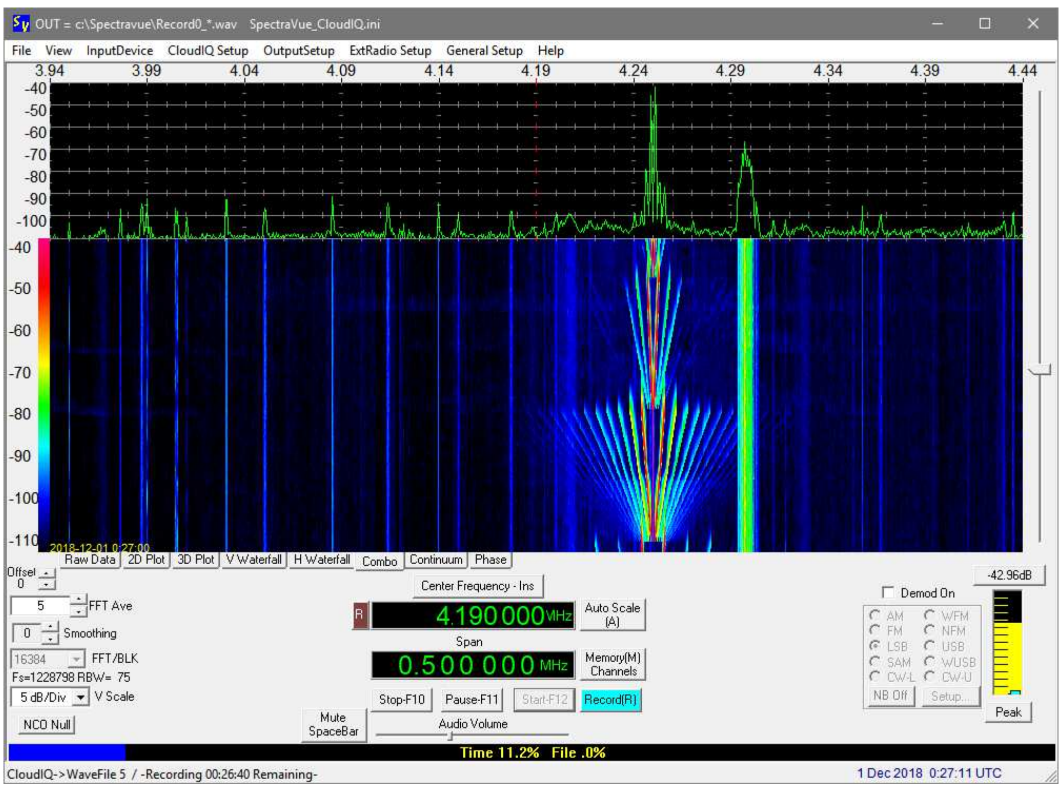
1 December 2018 (30 November local)



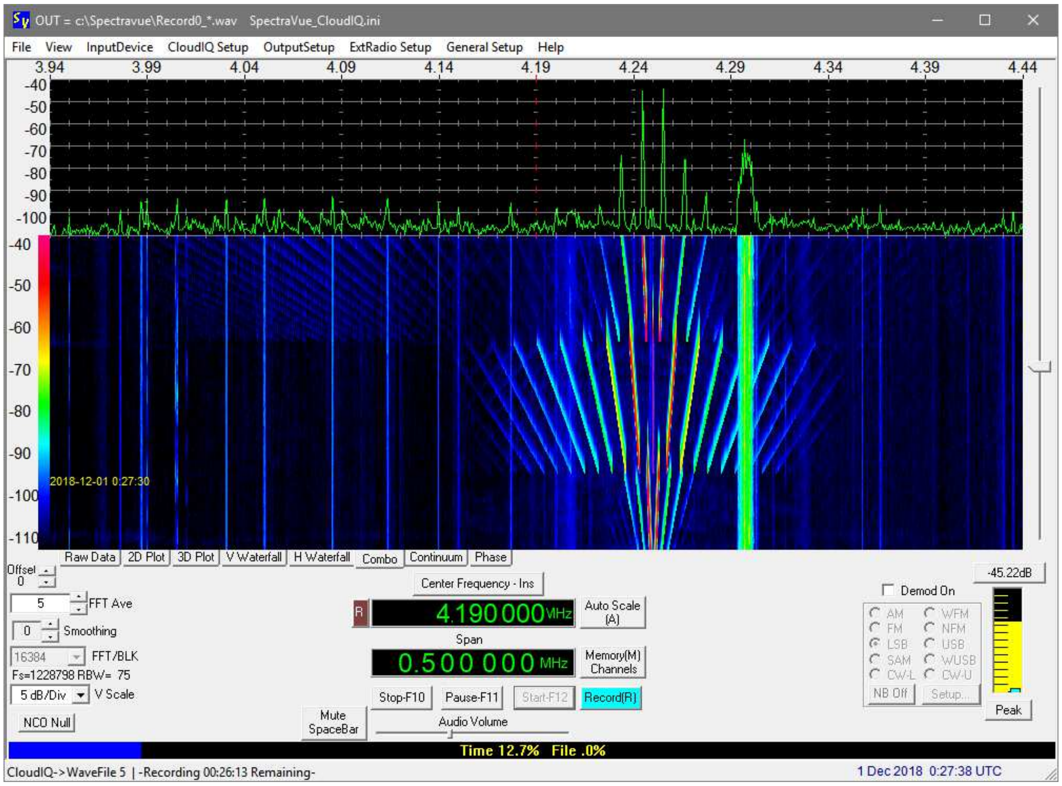

Cloud-IQ, 4.19 MHz, 1 MHz span, 1 December, 0026.Chirp modulation. Chirp modulation. RadioFax on 4.298 MHz to immediate right.



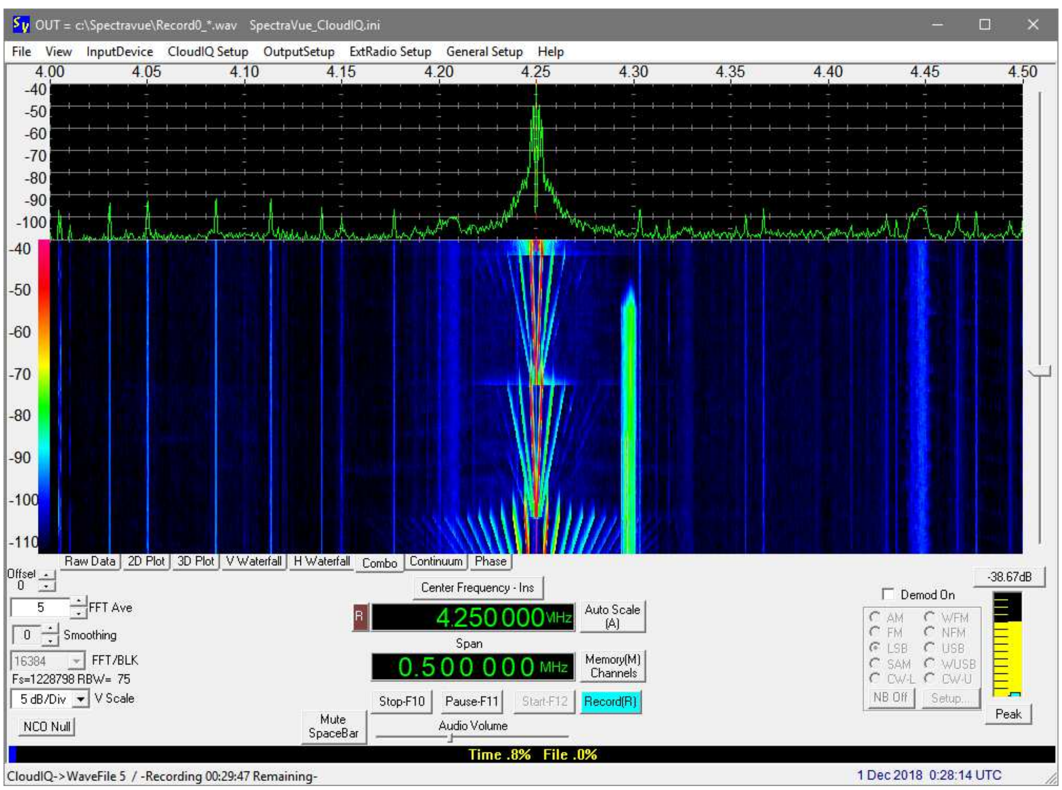

Cloud-IQ, 4.19 MHz, 500 kHz span, 1 December, 0027:00. Chirp modulation. RadioFax on 4.298 MHz to immediate right.




Cloud-IQ, 4.19 MHz, 500 kHz span, 1 December, 0027:11. Chirp modulation. RadioFax on 4.298 MHz to immediate right.

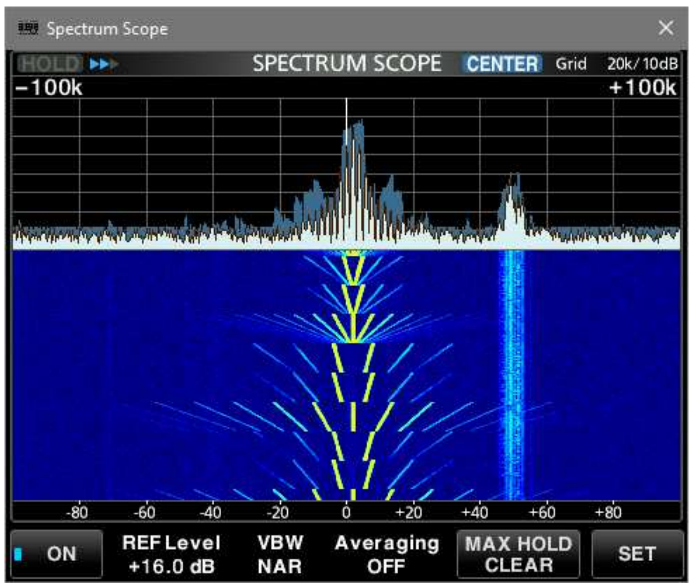



Cloud-IQ, 4.19 MHz, 500 kHz span, 1 December, 0027:38. Chirp modulation. RadioFax on 4.298 MHz to immediate right.

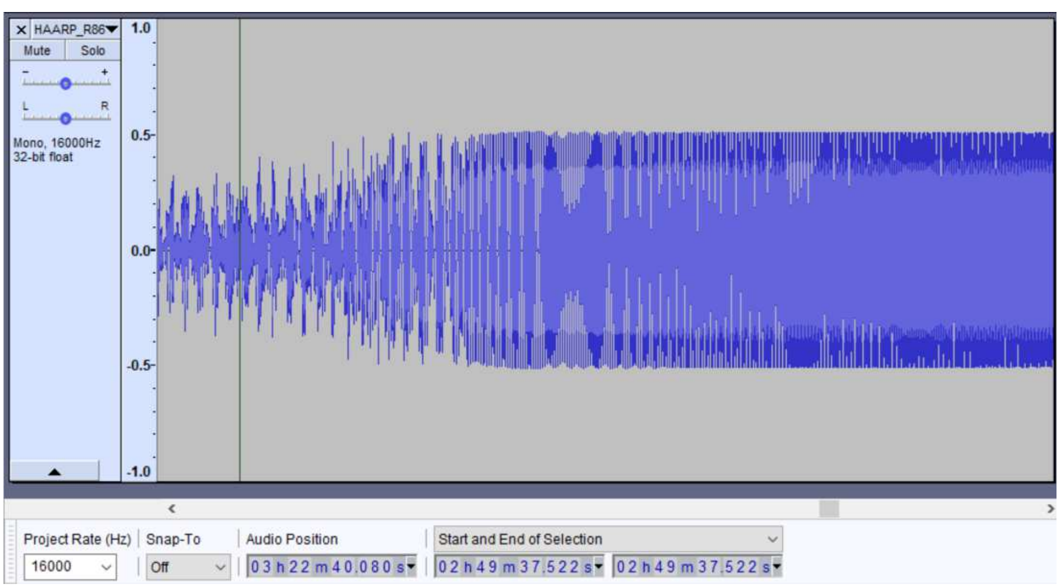



Cloud-IQ, 4.25 MHz, 500 kHz span, 1 December, 0028. Chirp modulation. Transmission of RadioFax on 4.298 MHz to immediate right ended just before this screenshot.

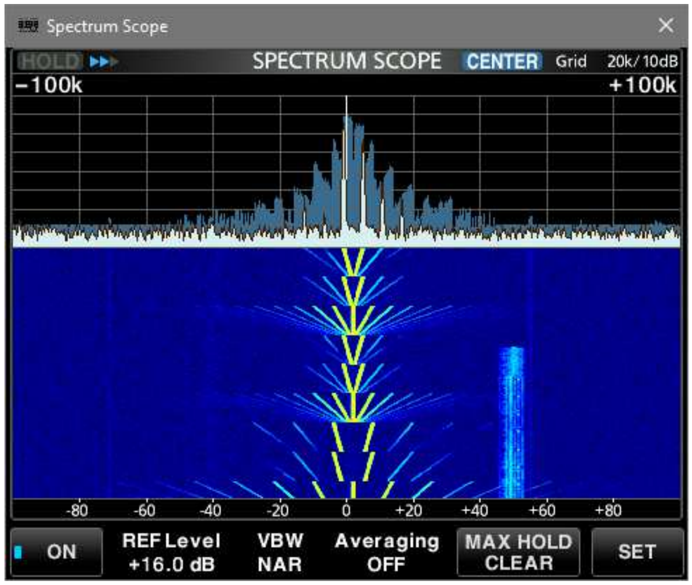

R-8600 receiver settings, 4.248 MHz front panel, 1 December, 0027.



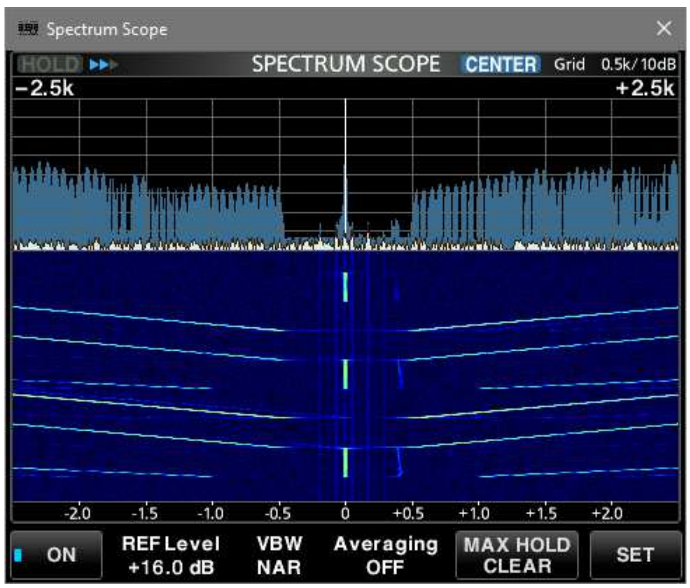

R-8600, 4.25 MHz, 200 kHz span, 1 December, 0027. Chirp modulation. RadioFax on 4.298 MHz to immediate right.




R-8600, Demodulated audio waveform corresponding approximately to the previous RF spectrogram on 1 December at 0027. The RF modulation far exceeded the audio passband of the receiver.

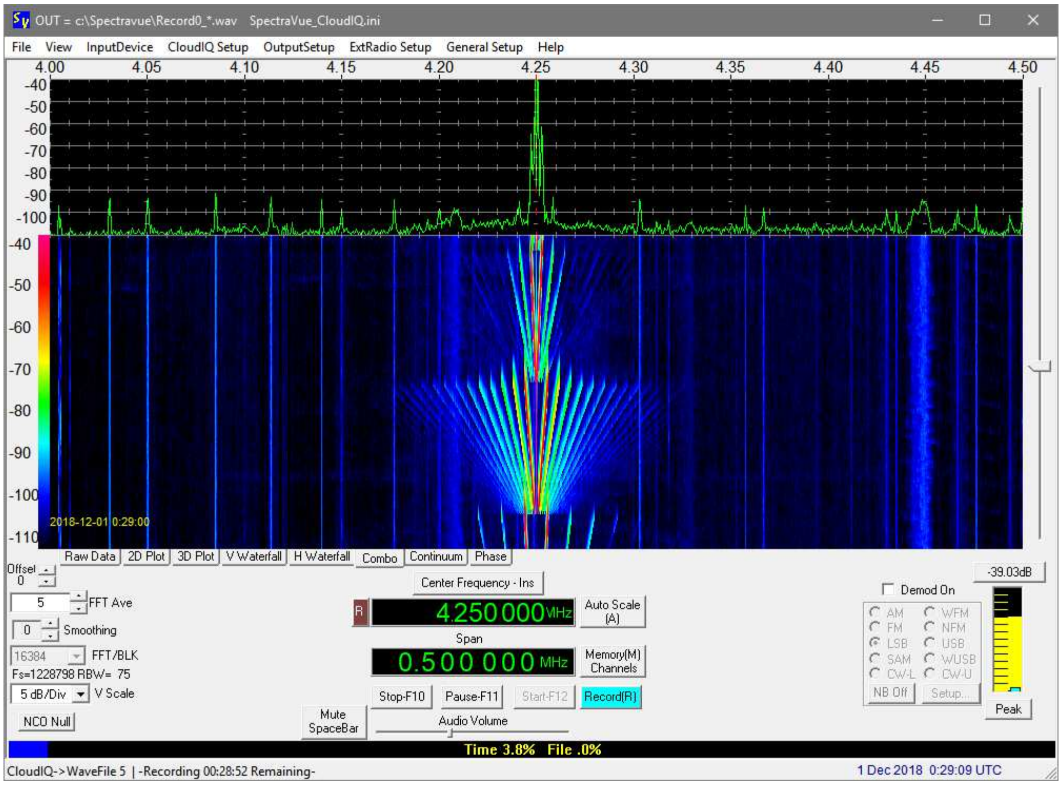



R-8600, 4.25 MHz, 200 kHz span, 1 December, 0028. Chirp modulation. RadioFax on 4.298 MHz to immediate right ended while waterfall in progress.

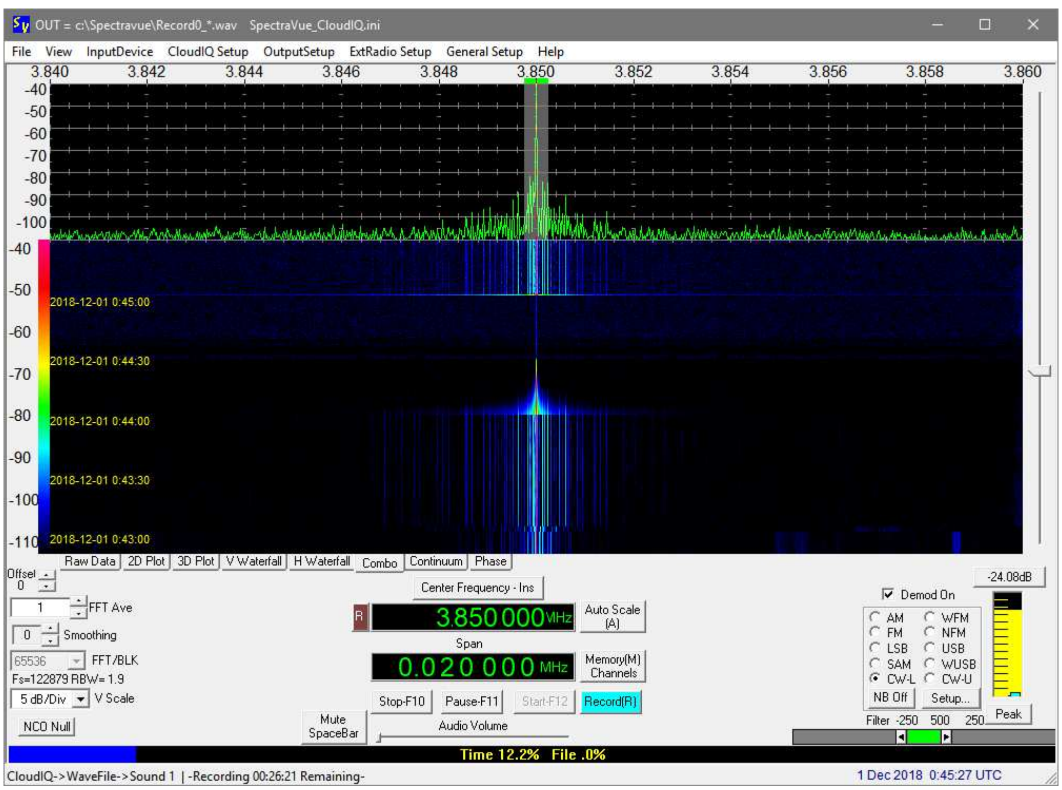



R-8600, 2.7 MHz, 5 kHz span, 1 December, 0028. Chirp modulation.

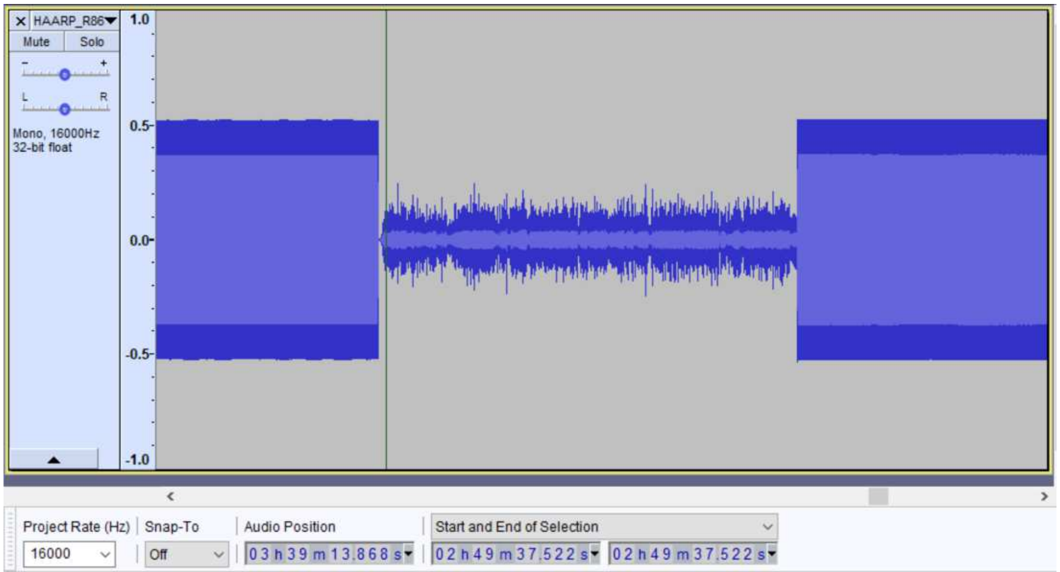
1 – 2 December 2018 (1 December local)



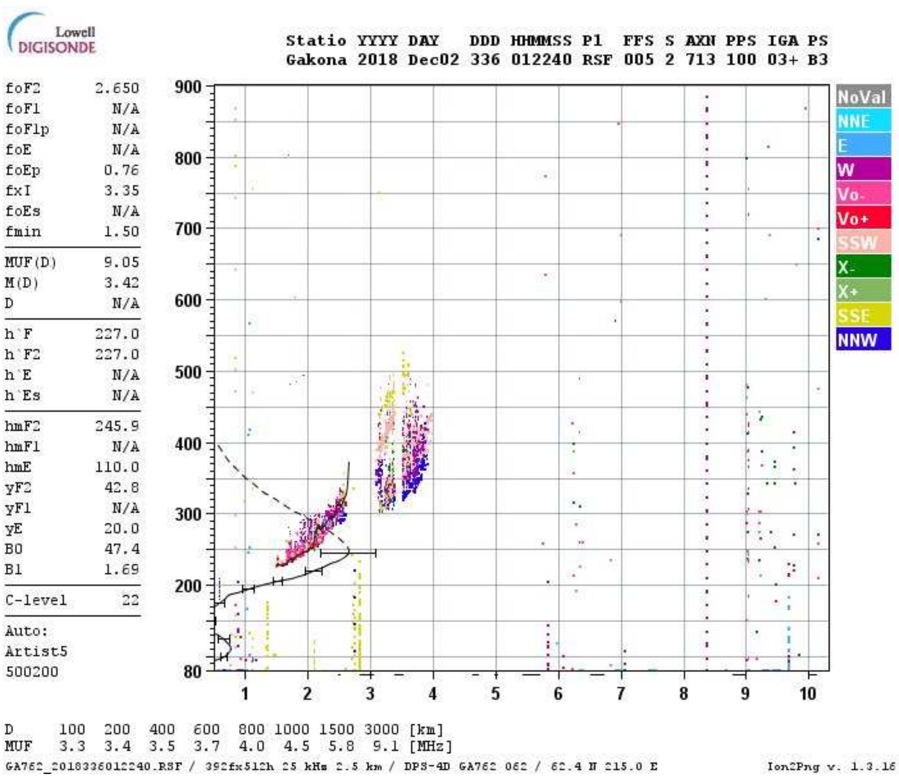

Cloud-IQ, 4.25 MHz, 500 kHz span, 1 December, 0029. Chirp modulation.



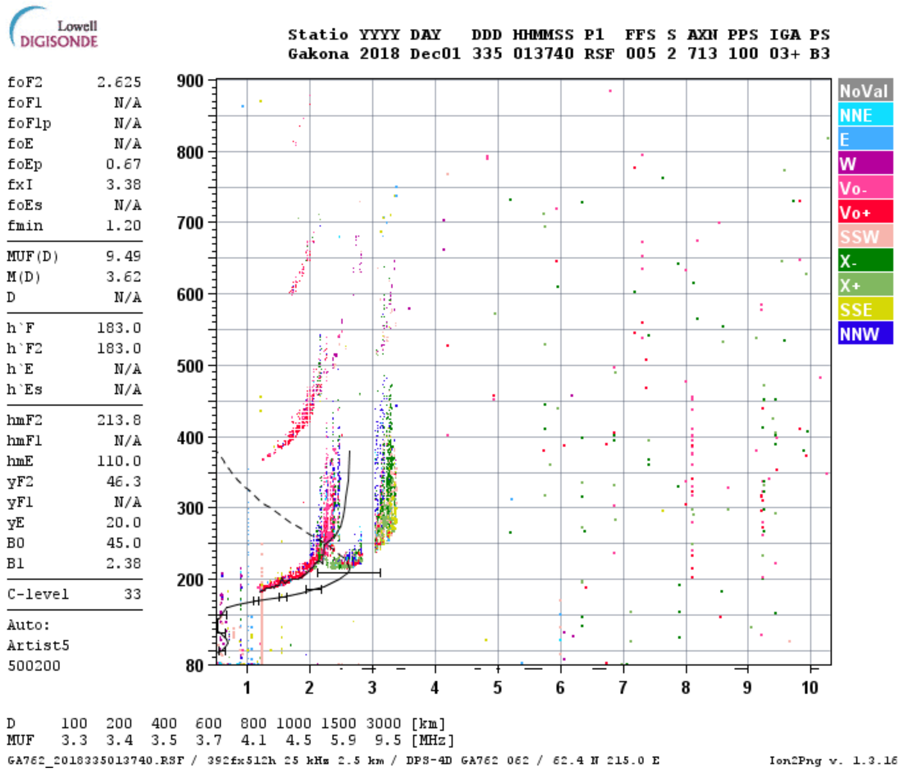

Cloud-IQ, 3.85 MHz, 20 kHz span, 1 December, 0045. Possible Stimulated Electromagnetic Emissions (SEE) but may be powerline interference modulation of HAARP transmitter.



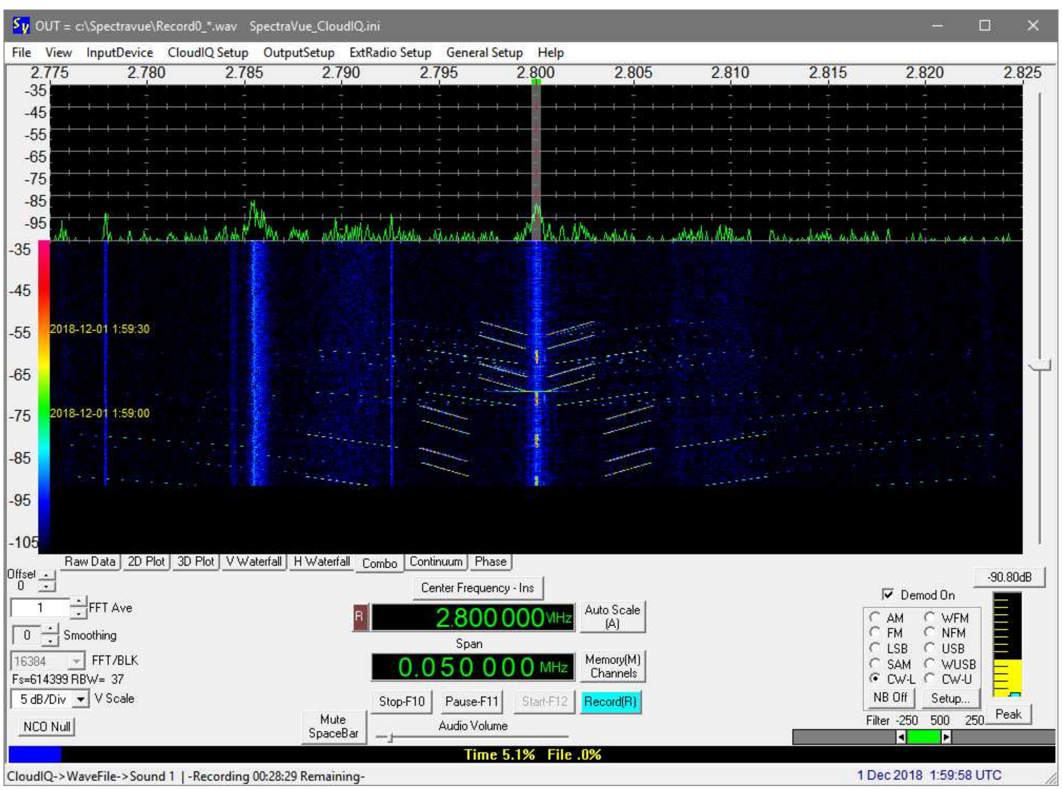

R8600 demodulated audio waveform corresponding to previous RF spectrogram on 1 December from 0043:30 to 0045:30. Note complete noise dropout immediately at the end of first section for about 1 s followed by recovery of background noise (cursor position). This probably was caused by the AGC function in the R-8600.



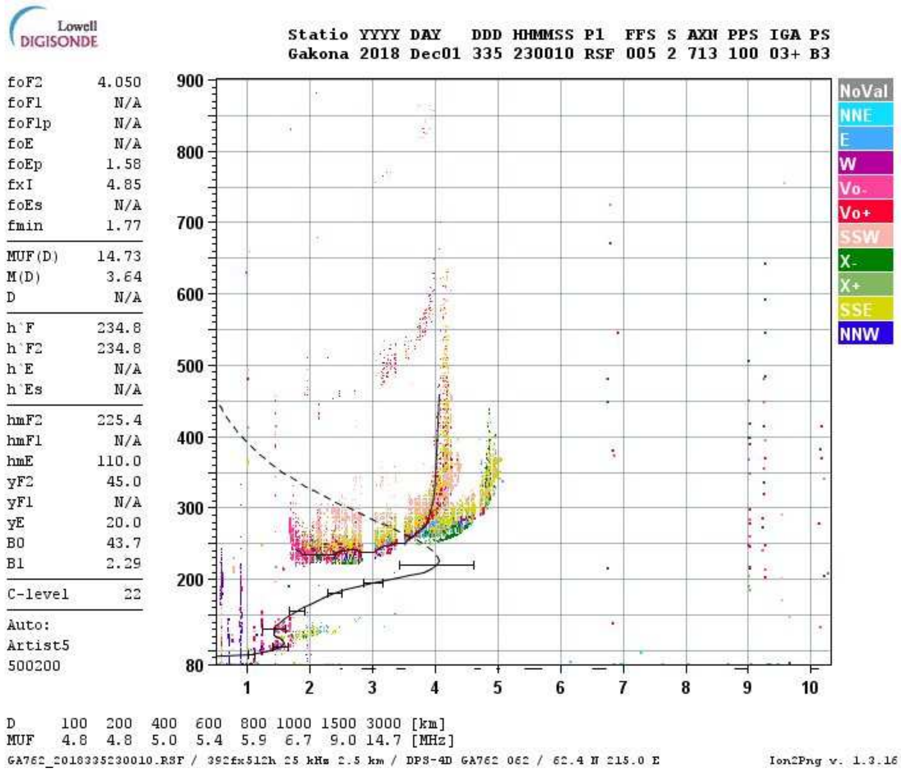

Gakona ionogram, 01 December, 0122



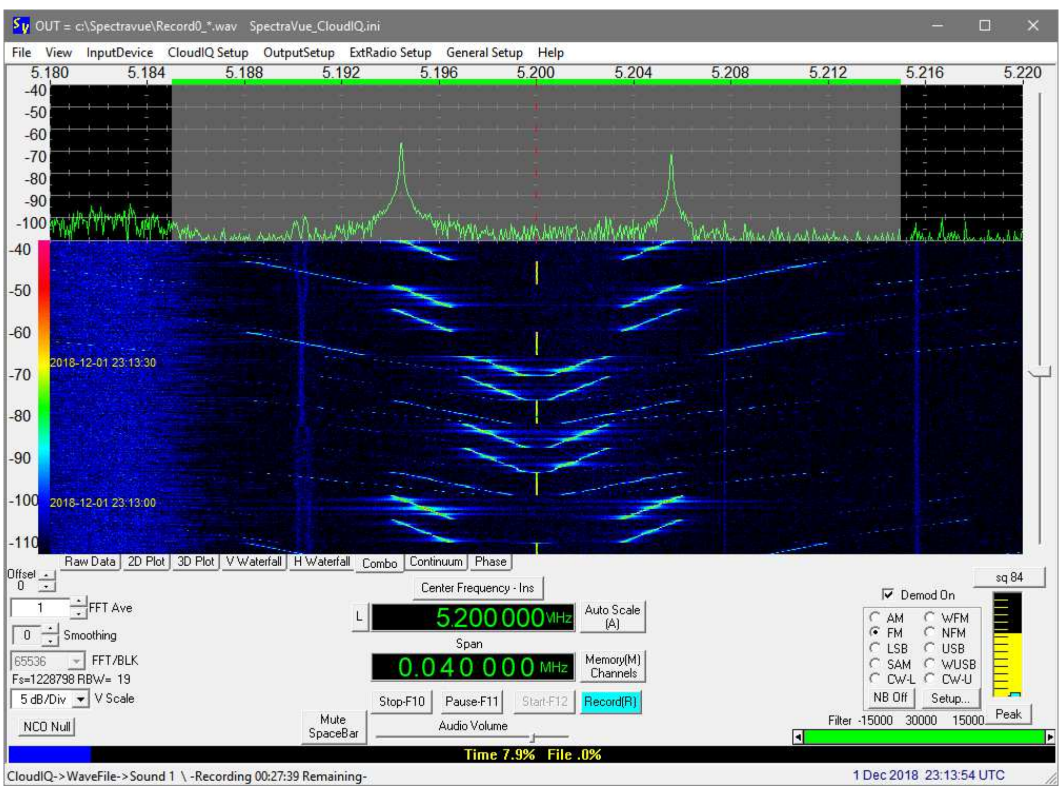

Gakona ionogram, 1 December, 0137



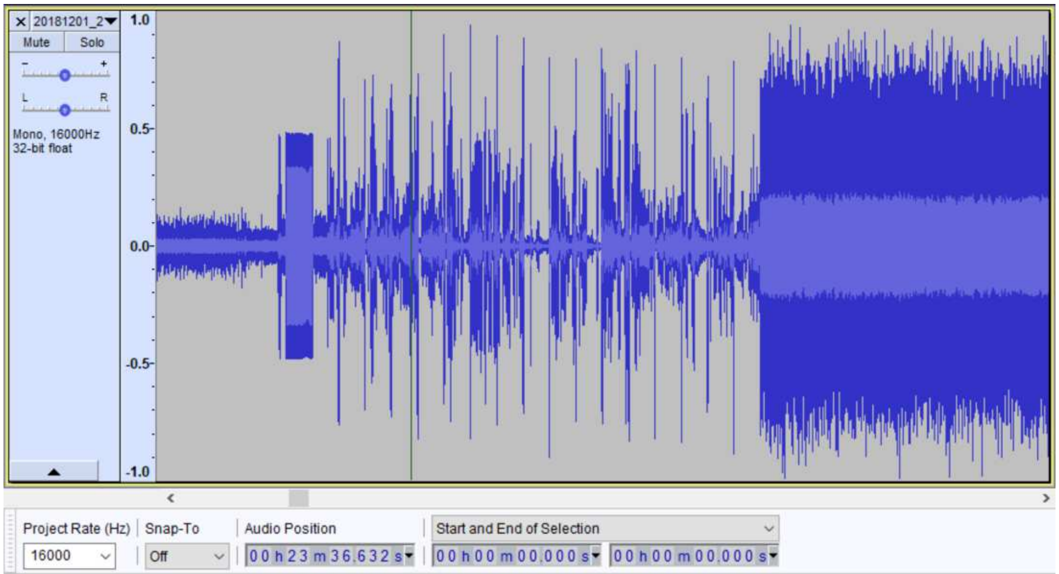

Cloud-IQ, 2.80 MHz, 50 kHz span, 1 December, 0159. Chirp modulation.



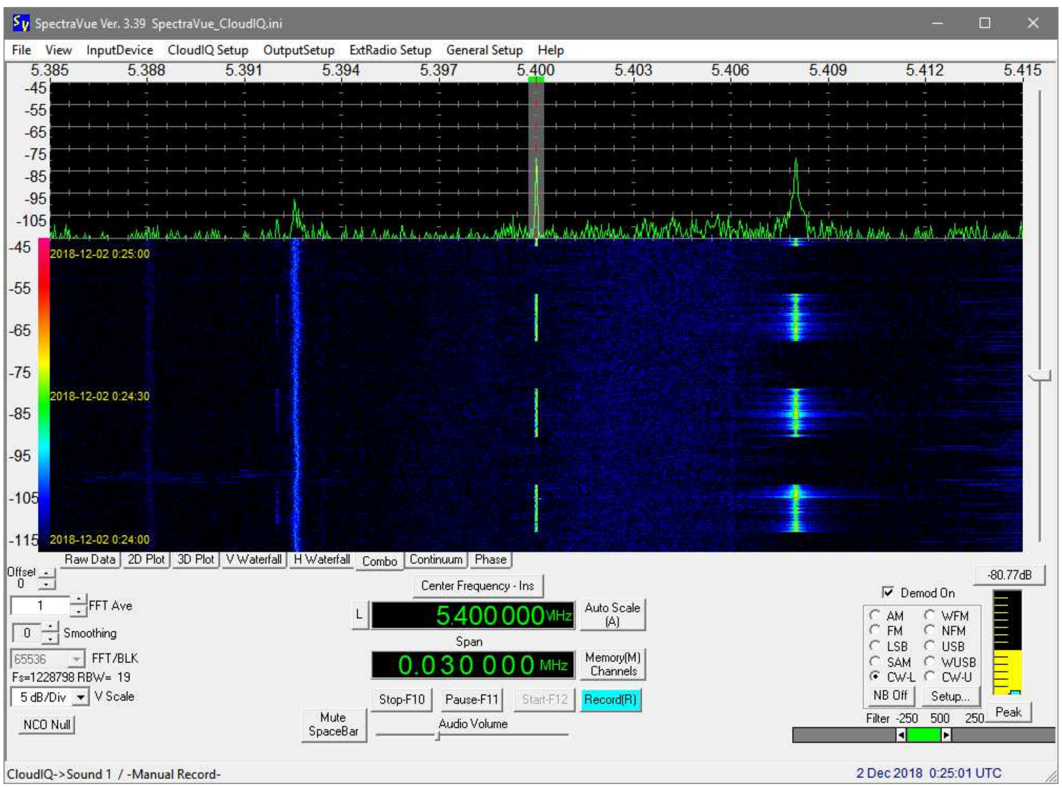

Gakona Ionogram, 1 December, 2300



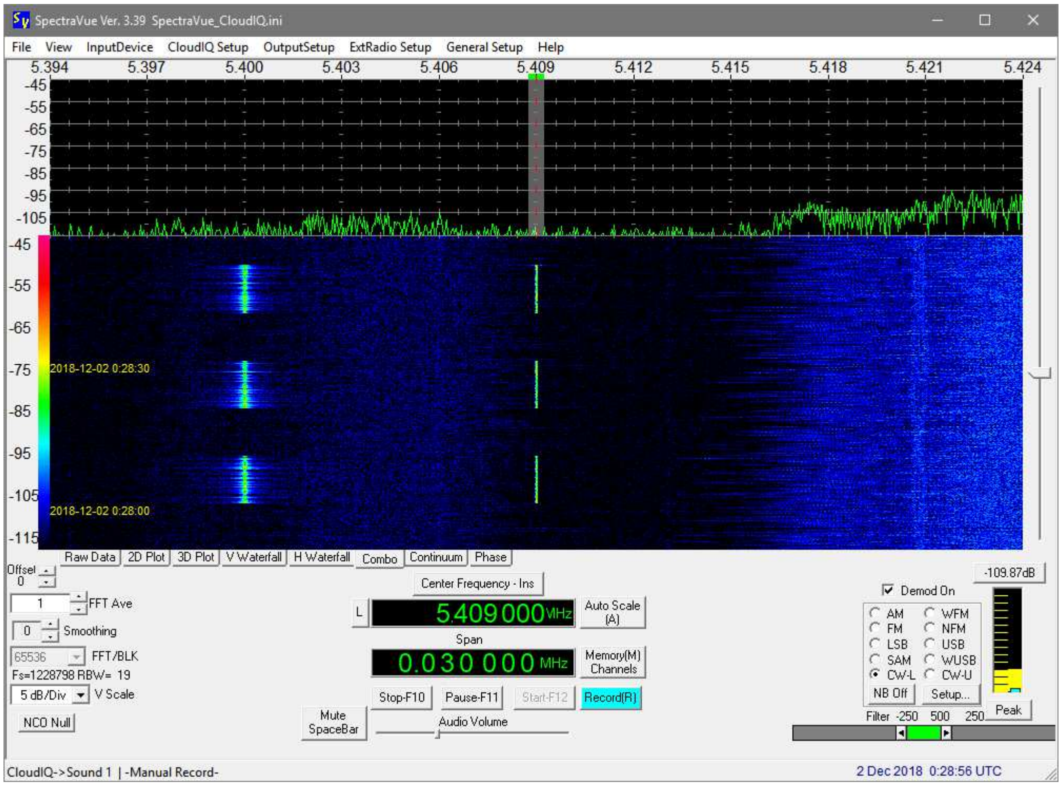

Cloud-IQ, 5.2 MHz, 400 kHz span, 1 December, 2313. Chirp modulation.



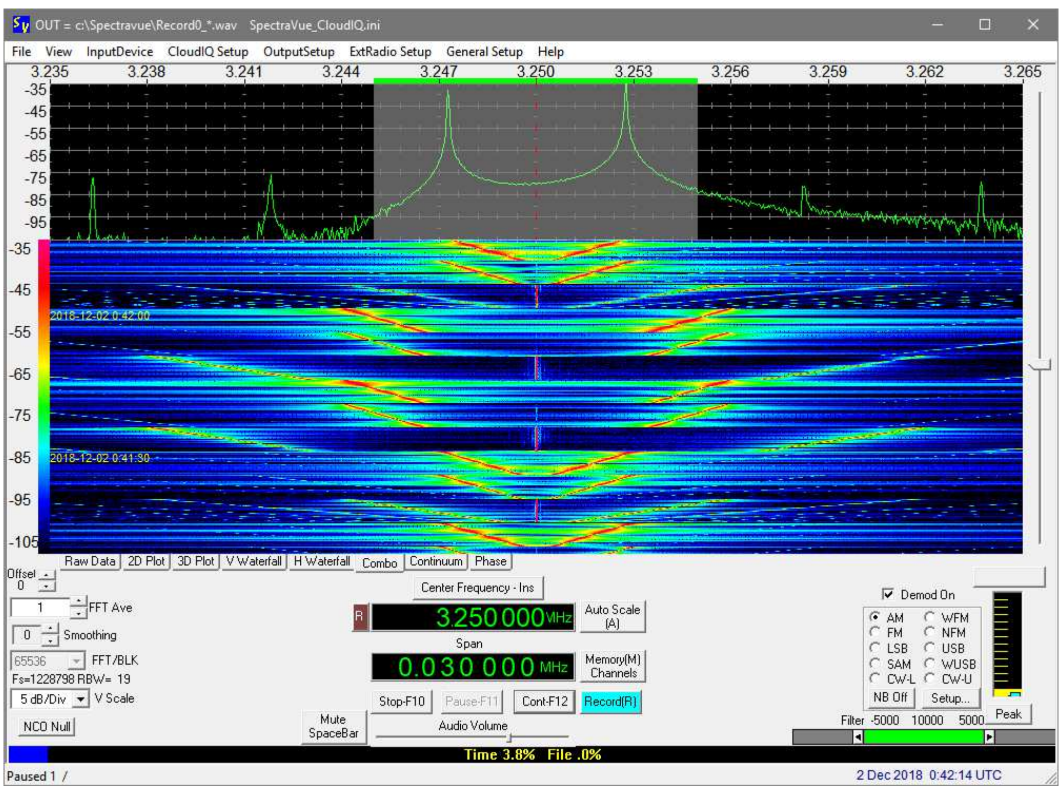

Demodulated audio waveform corresponding to previous RF spectrogram spanning about 3 min on 1 December from approximately 2300 to 2303.



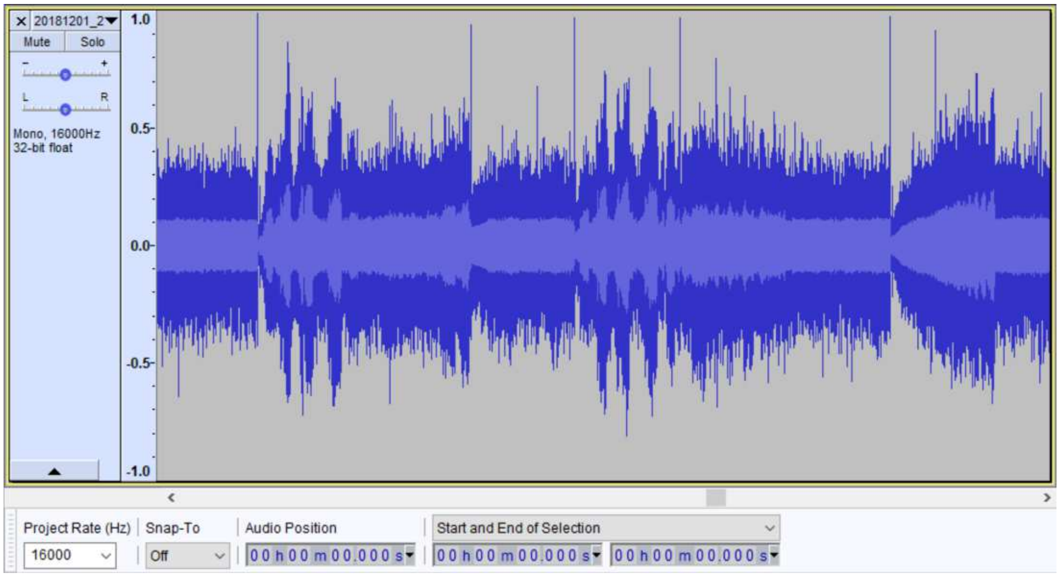

Cloud-IQ, 5.4 MHz, 30 kHz span, 2 December, 0025. A much stronger carrier at 5.408 MHz is visible but it may be signal processing artifact.



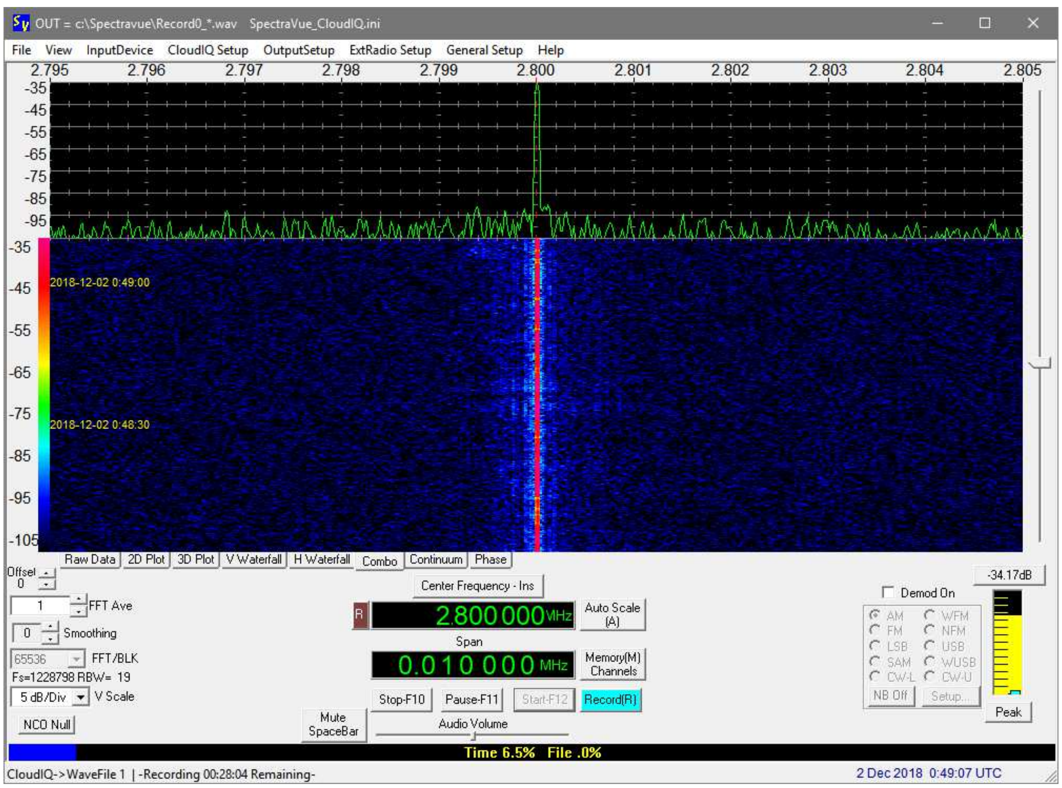

Cloud-IQ, 5.409 MHz, 300 kHz span, 2 December, 0028. Another carrier indication at 5.400 MHz appears to be stronger and modulated but modulation may be signal processing artifact. Note broad RFI to right.



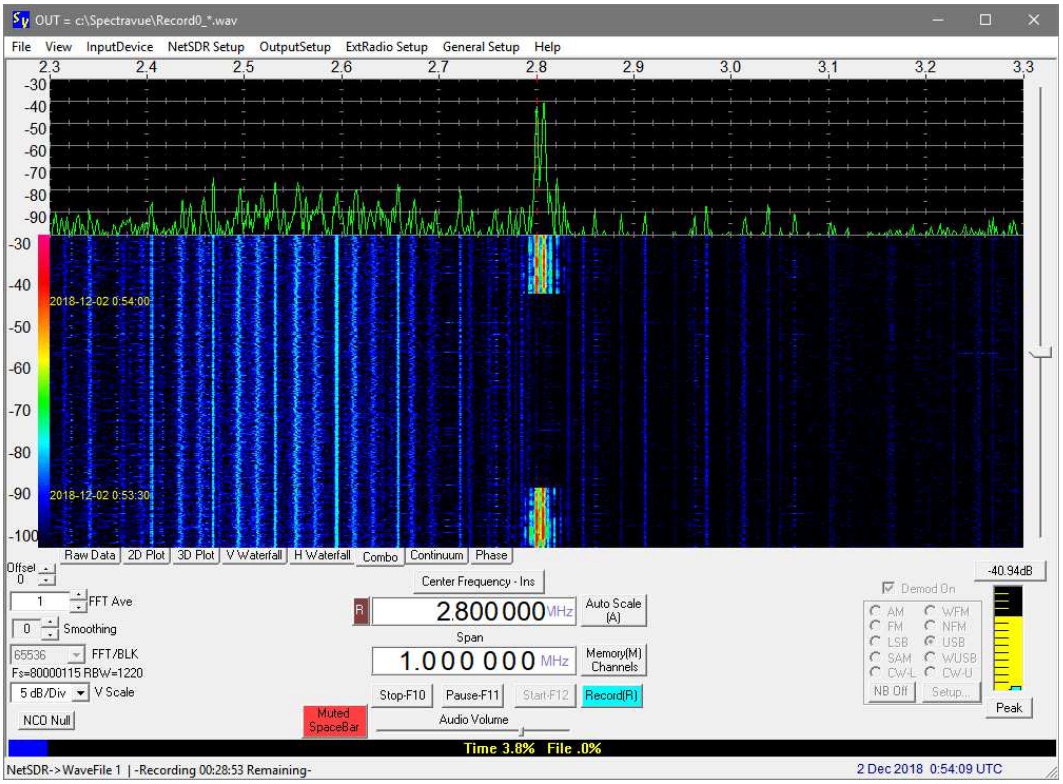

Cloud-IQ, 3.25 MHz, 30 kHz span, 2 December, 0042. Chirp modulation.



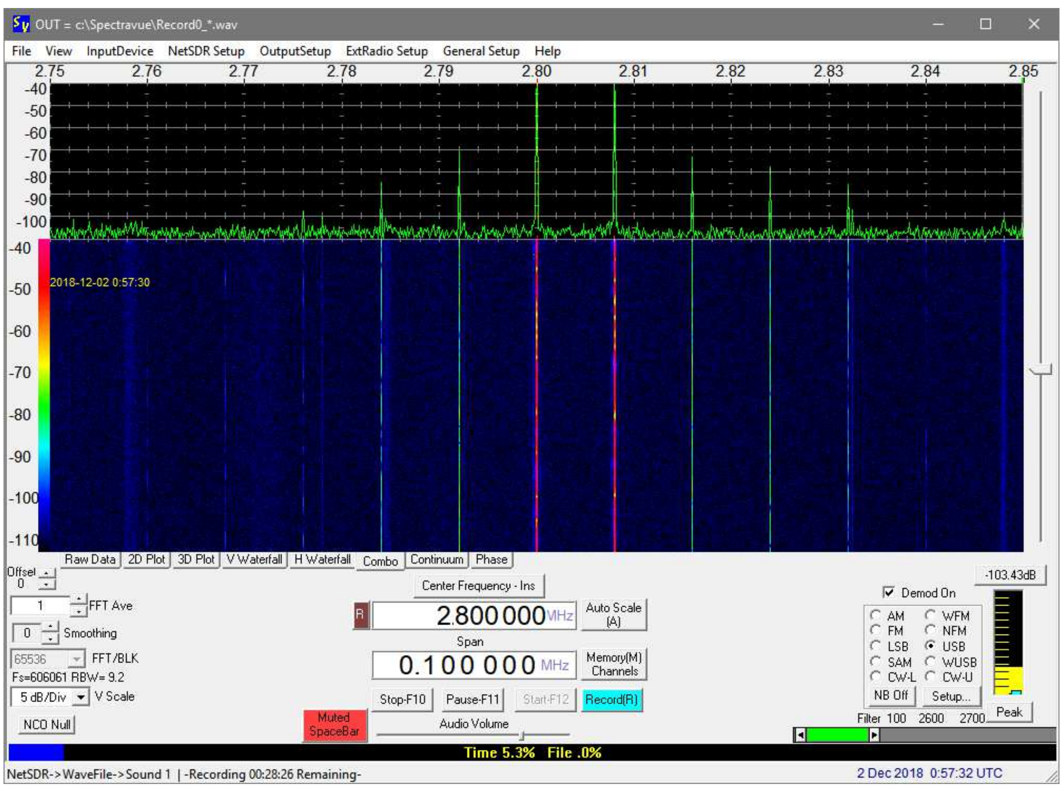

Demodulated audio waveform corresponding to previous RF spectrogram spanning about 30 s on 2 December at approximately 0041:30.



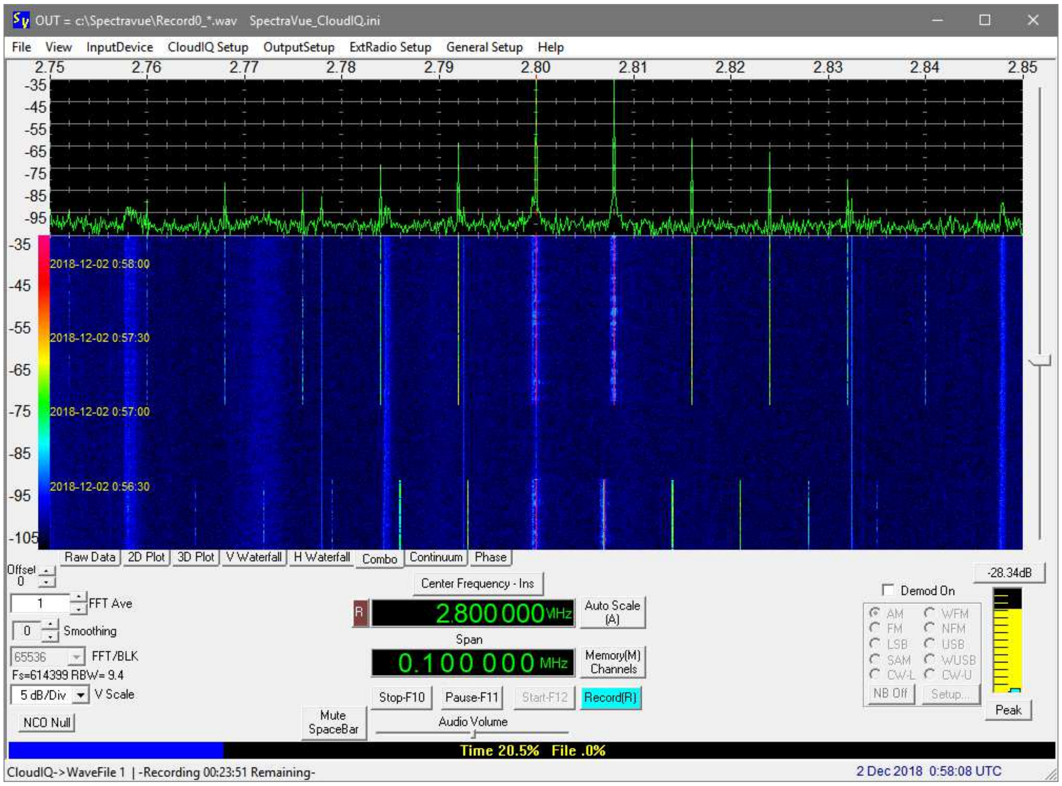

Cloud-IQ, 2.8 MHz, 10 kHz span, 2 December, 0049.



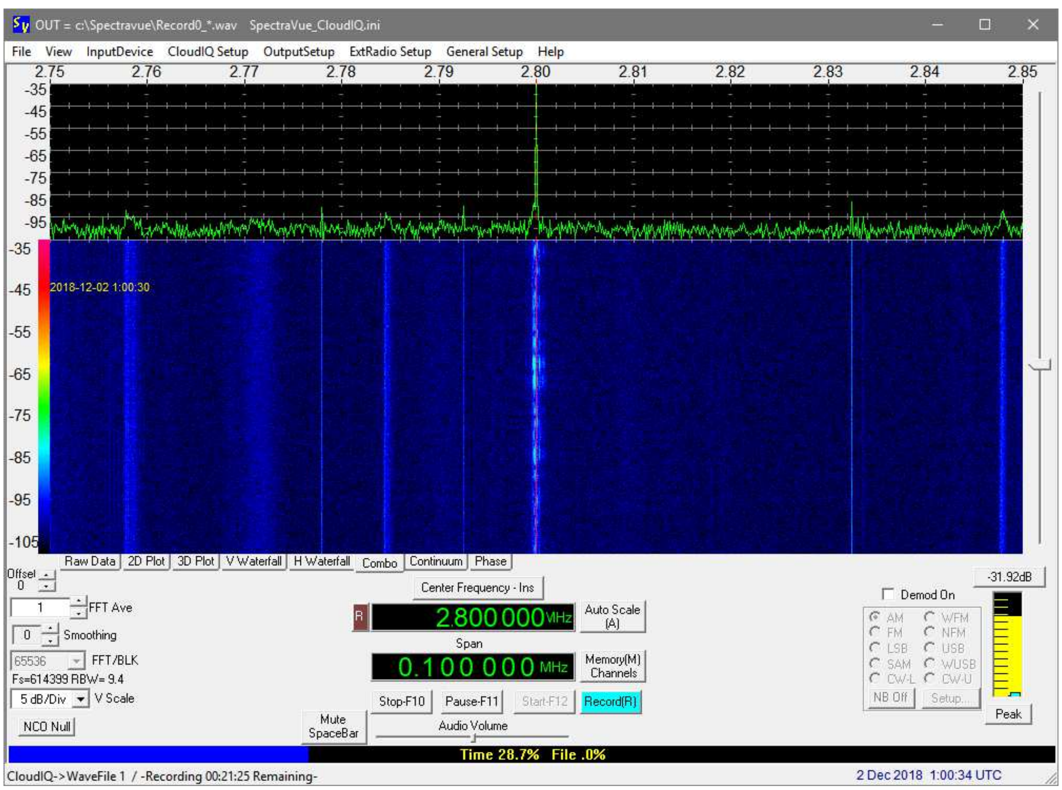

NetSDR, 2.8 MHz, 1 MHz span, 2 December, 0054. Additional carriers around the HAARP center frequency are visible along with comb-type RFI at lower frequencies.



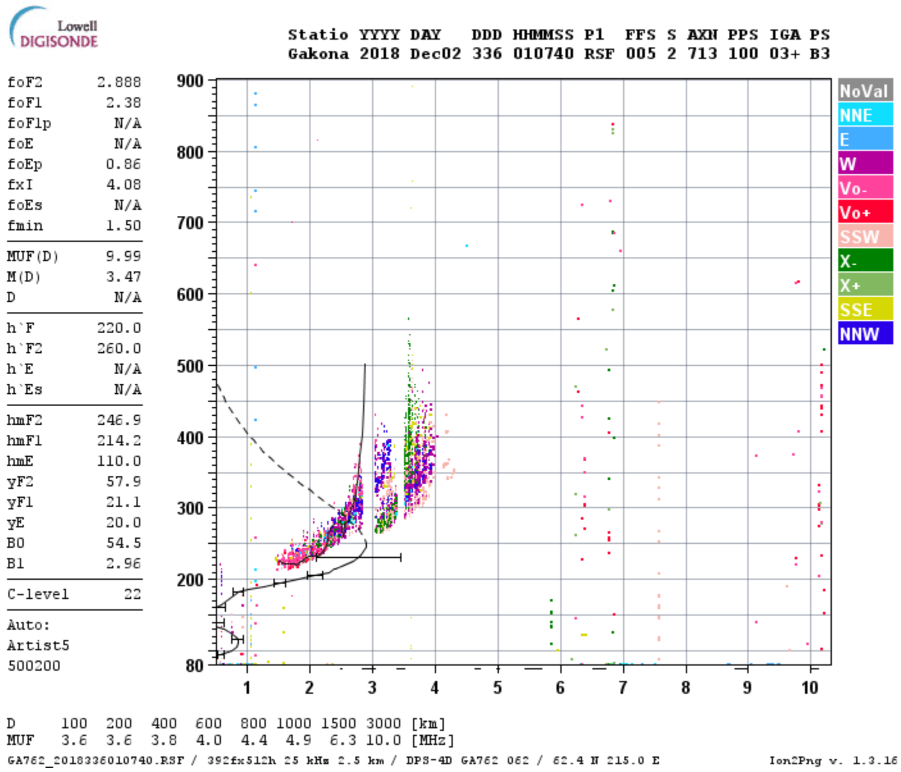

NetSDR, 2.8 MHz, 100 kHz span, 2 December, 0057. Multi-carrier with 8 kHz spacing.



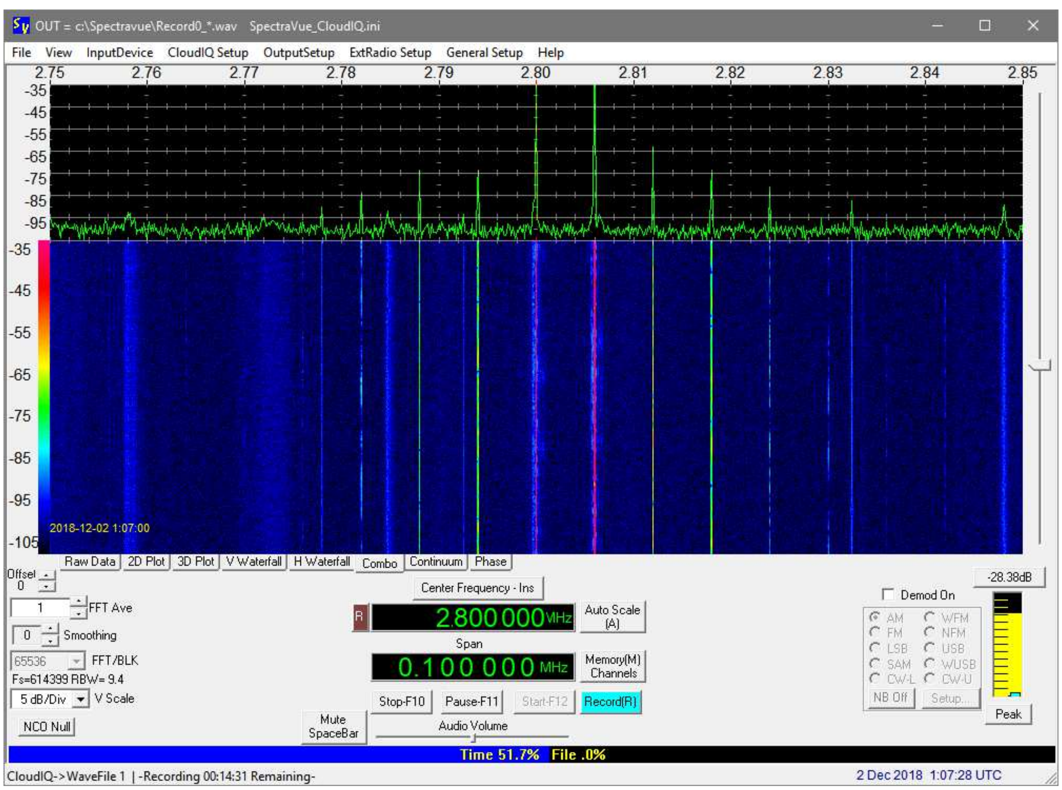

Cloud-IQ, 2.8 MHz, 100 kHz span, 2 December, 0058. Multi-carrier with 8 kHz spacing. Note shift in carrier spacing from 7 kHz spacing at 0056:30 and variable received power level at the various carrier frequencies. Some RFI also is visible.



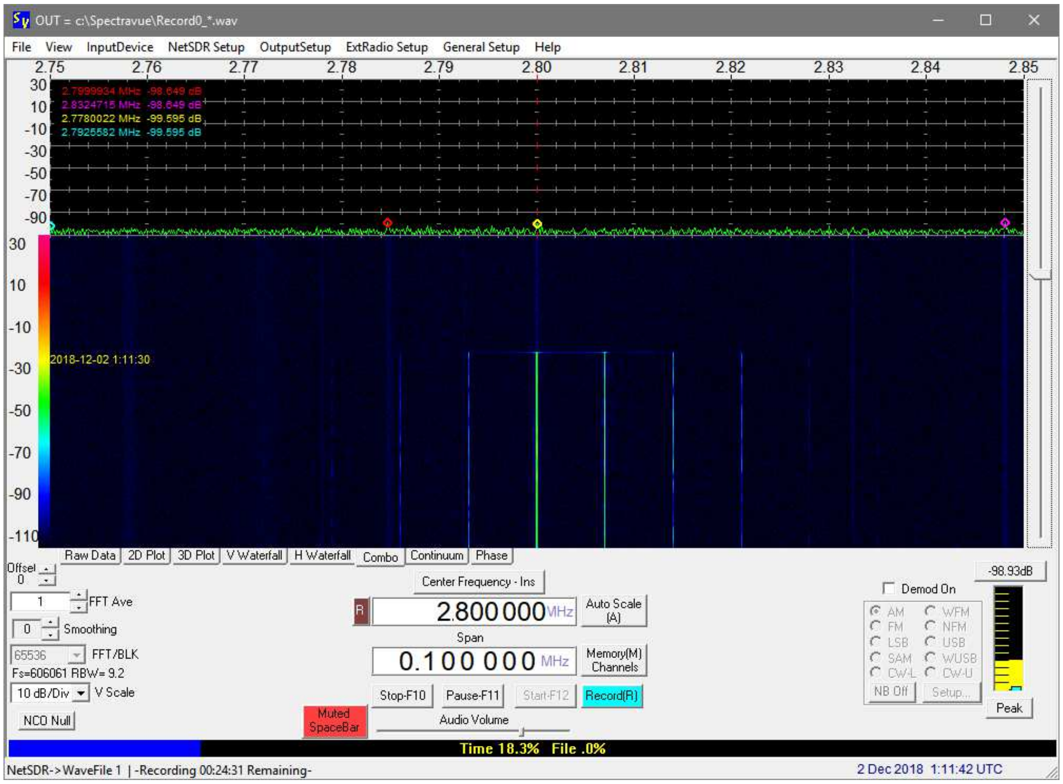

Cloud-IQ, 2.8 MHz, 100 kHz span, 2 December, 0100. Note variable intensity of received carrier.



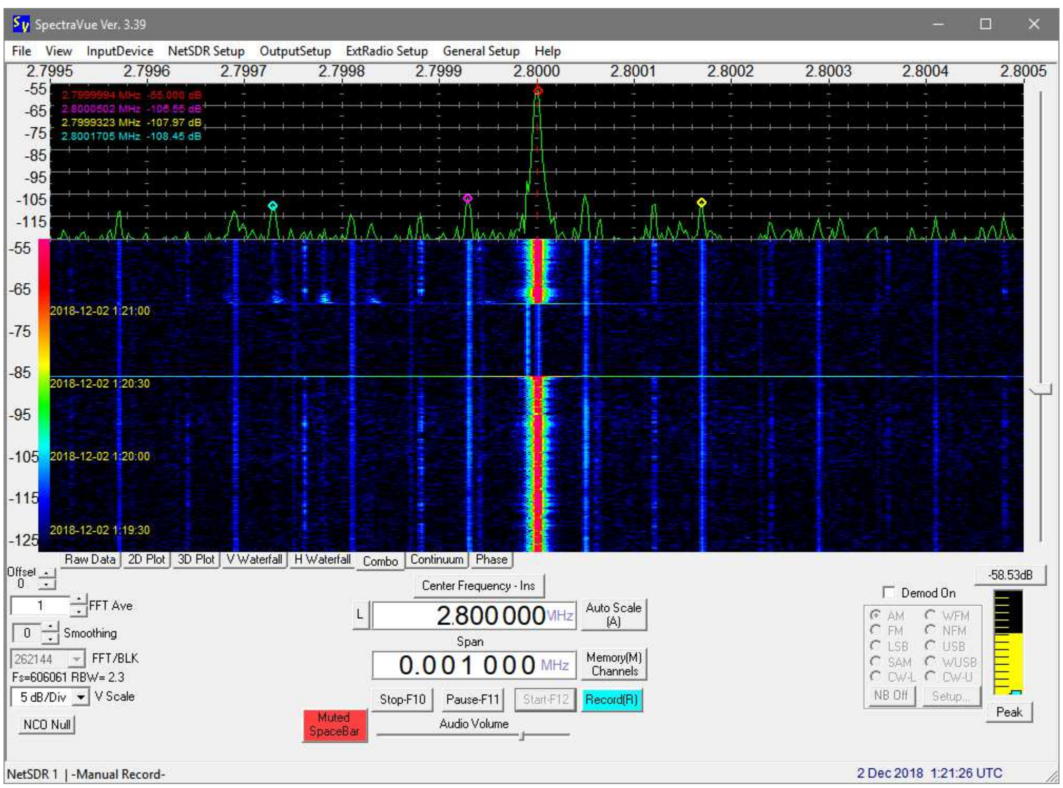
Gakona Ionogram, 02 December, 0107



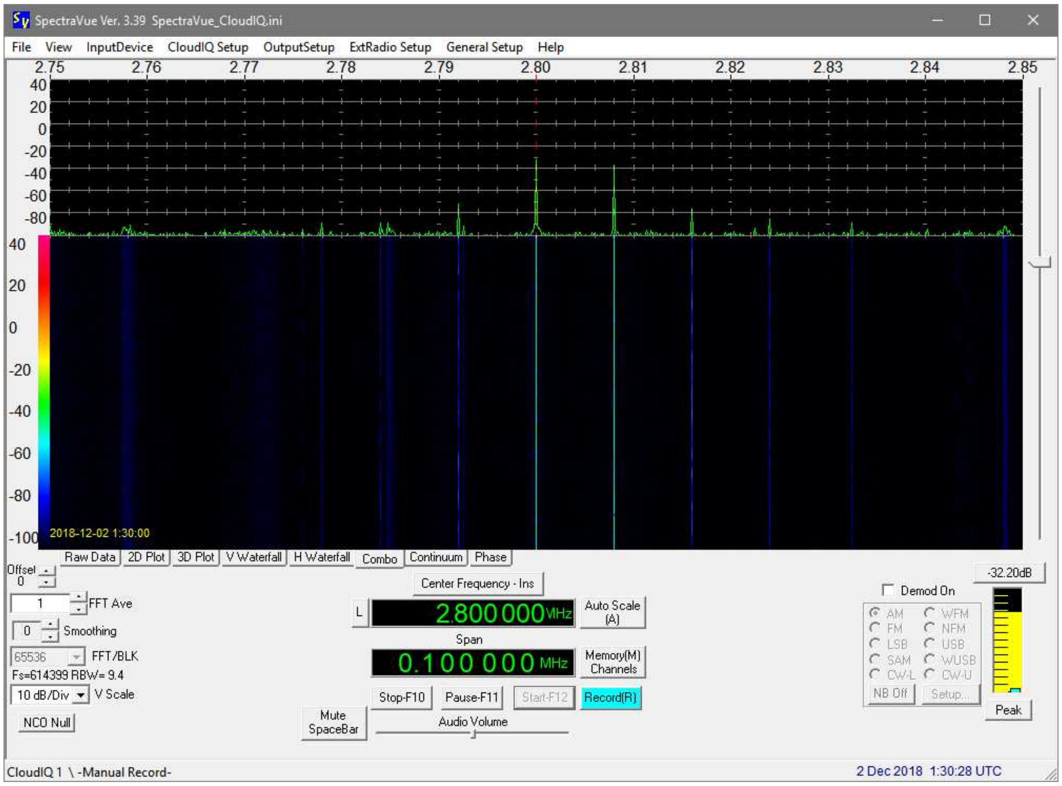
Cloud-IQ, 2.8 MHz, 100 kHz span, 2 December, 0107. Multi-carrier with 6 kHz spacing.



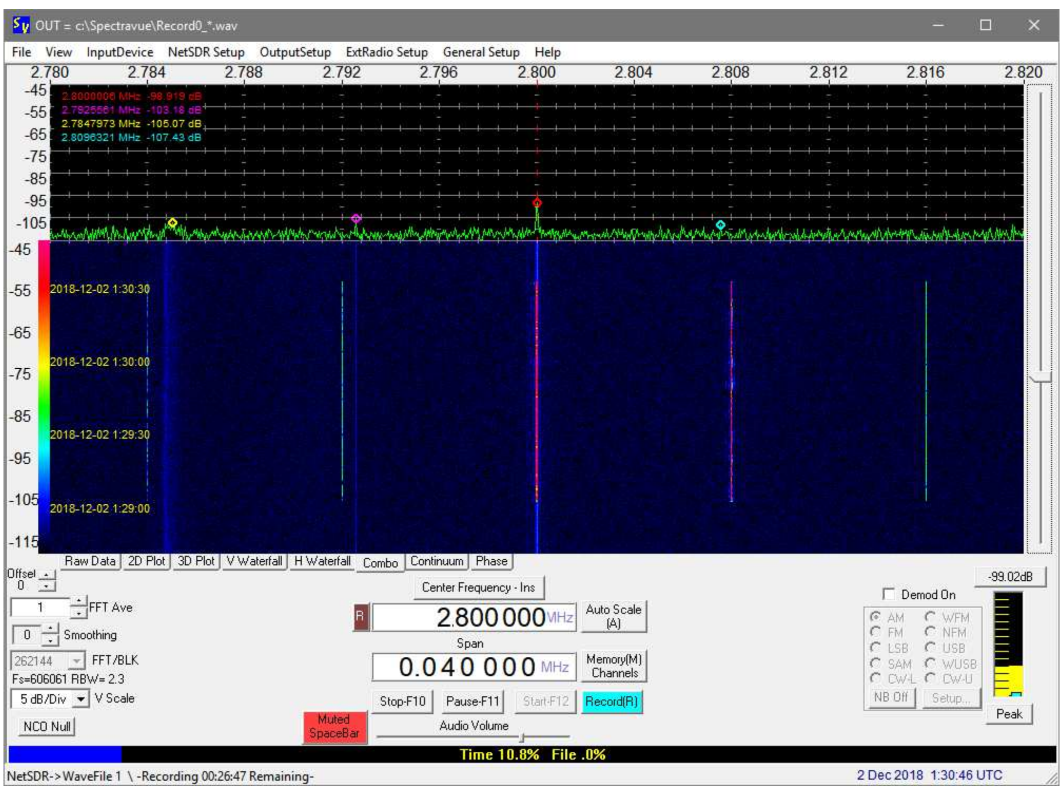

NetSDR, 2.8 MHz, 100 KHz span, 2 December, 0111. Multi-carrier with 6 kHz spacing off at 0111:30.



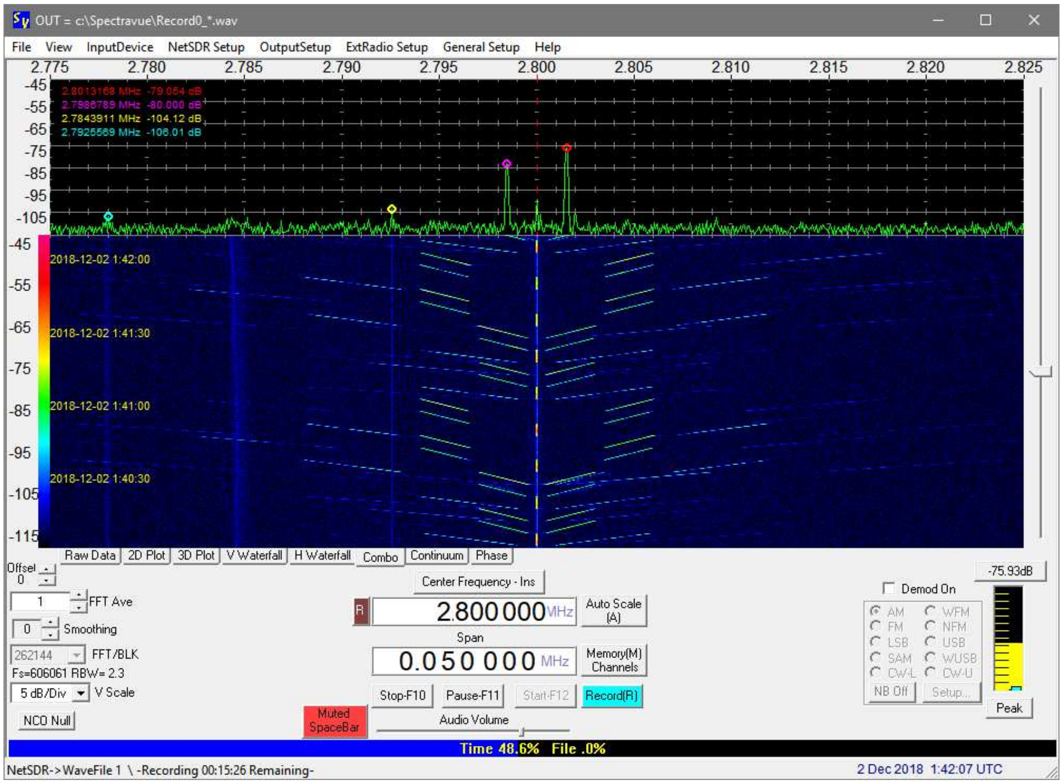

NetSDR, 2.8 MHz, 1 kHz span, 2 December, 0121. Some waterfall lines are RFI and some are multi-carriers around the primary.



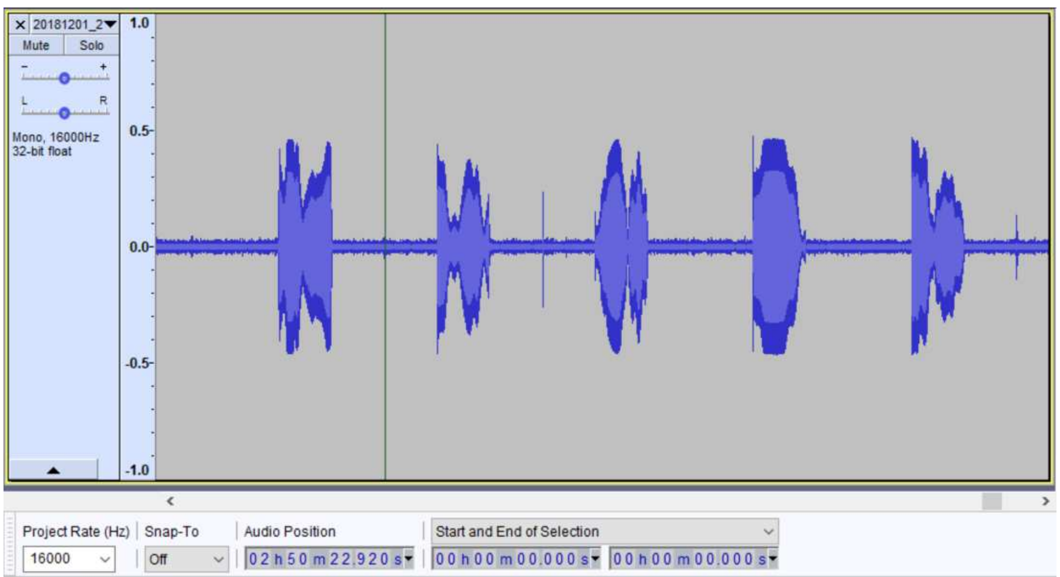

Cloud-IQ, 2.8 MHz, 100 kHz span, 2 December, 0130:28. Multi-carrier with 8 kHz spacing.



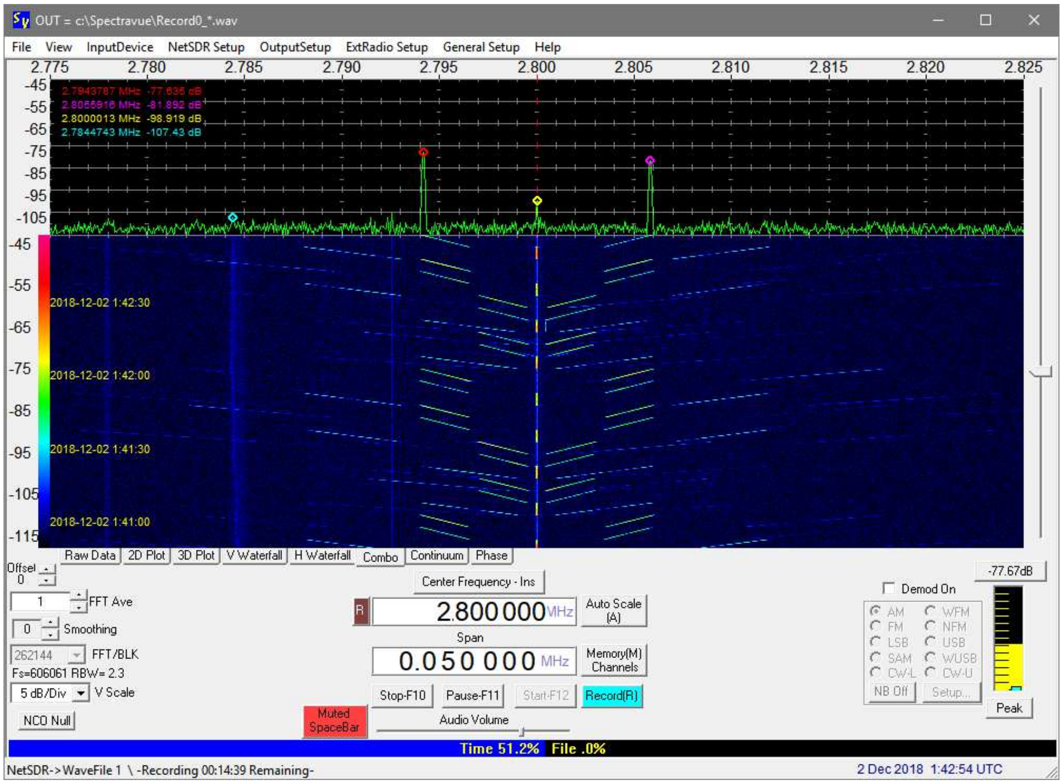

NetSDR, 2.8 MHz, 40 kHz span, 2 December, 0130:46. Compare to previous, which has wide span.



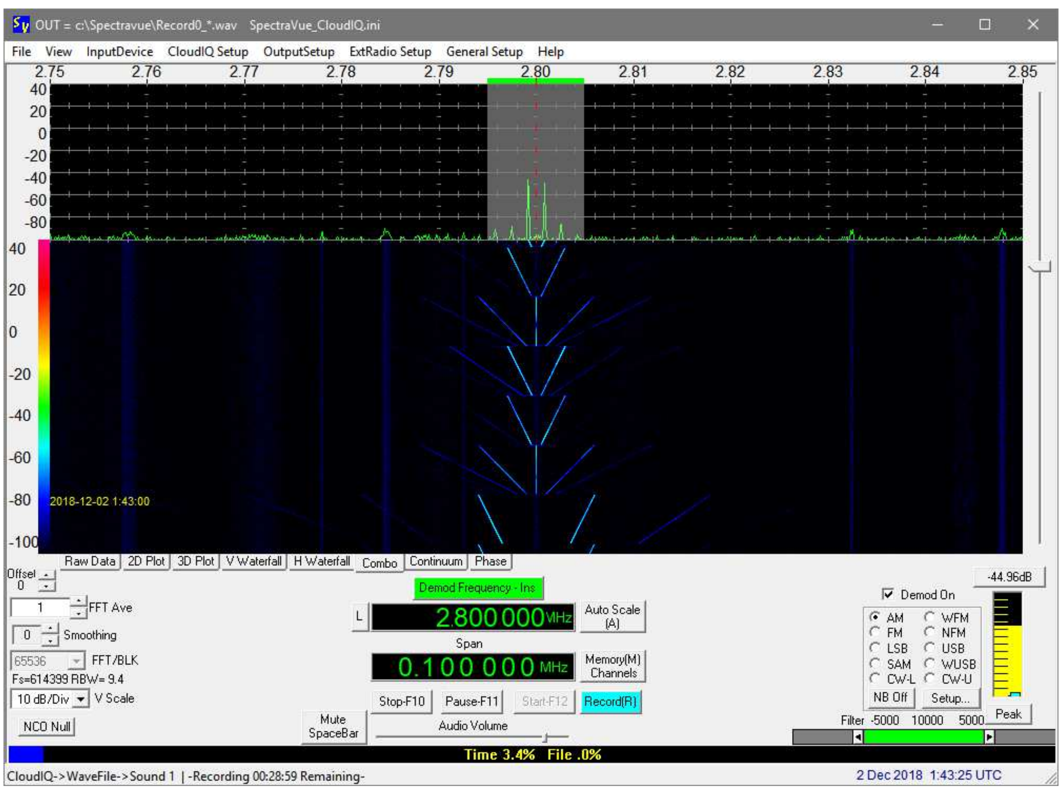

NetSDR, 2.8 MHz, 50 kHz span, 2 December, 0142:07. Chirp modulation.



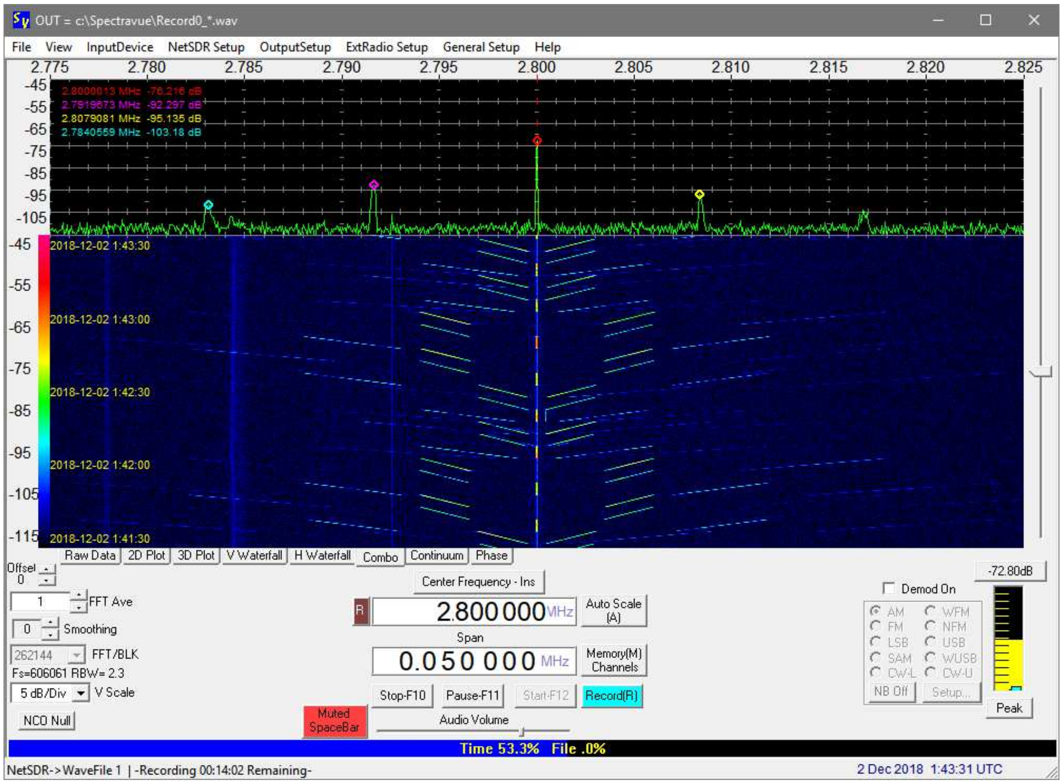

Demodulated audio waveform corresponding to previous RF spectrogram spanning about 1 min on 2 December from approximately 0140.



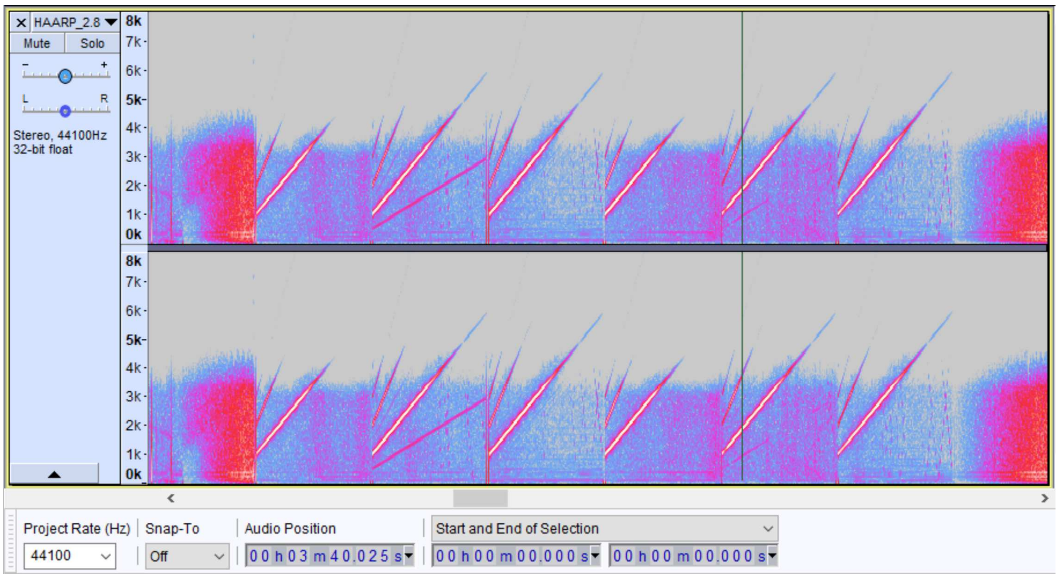
NetSDR, 2.8 MHz, 50 kHz span, 2 December, 0142:54. Chirp modulation.



Cloud-IQ, 2.8 MHz, 100 kHz span, 2 December, 0143:25. Chirp modulation.

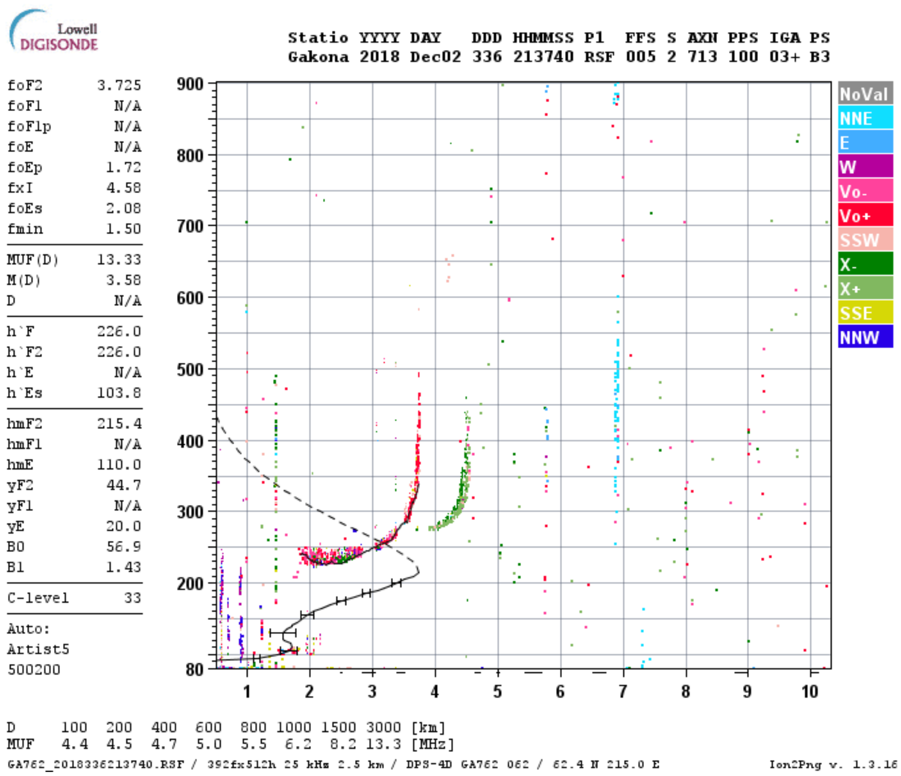



NetSDR, 2.8 MHz, 50 kHz span, 2 December, 0143:31. Compare to previous. Chirp modulation.

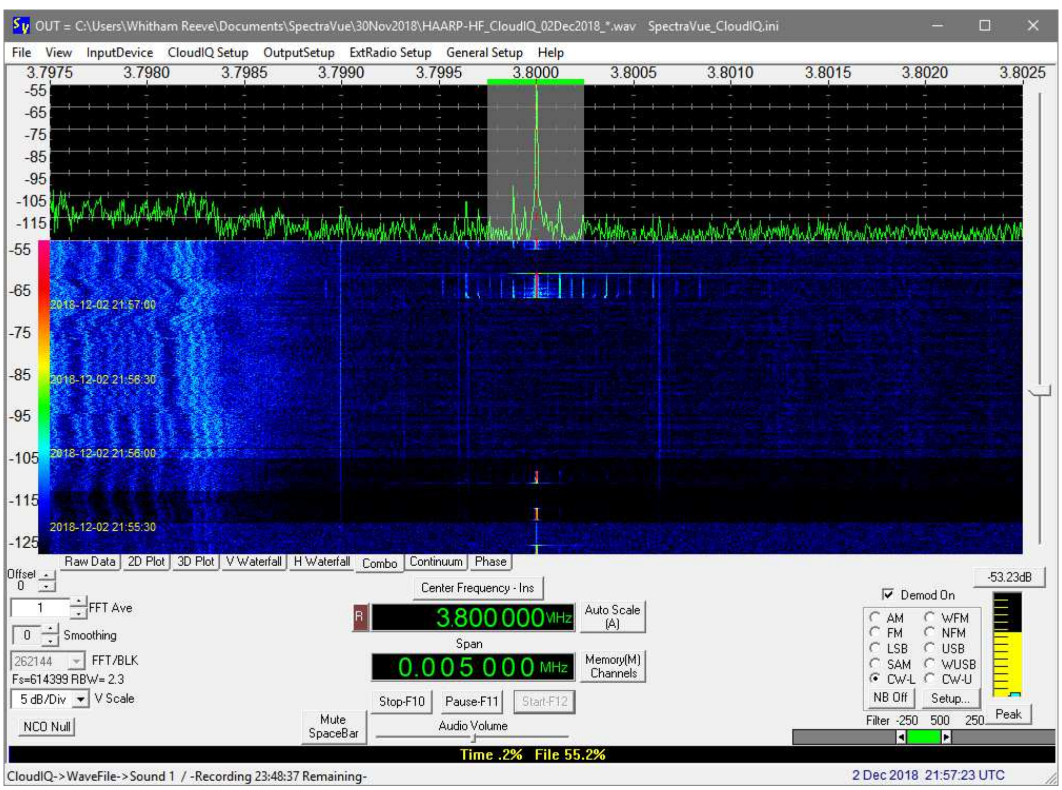



Demodulated audio spectrogram corresponding to previous RF spectrogram spanning slightly less than 40 s on 2 December. Although stereo spectrograms are shown, both channels were taken from the same receiver monaural output.

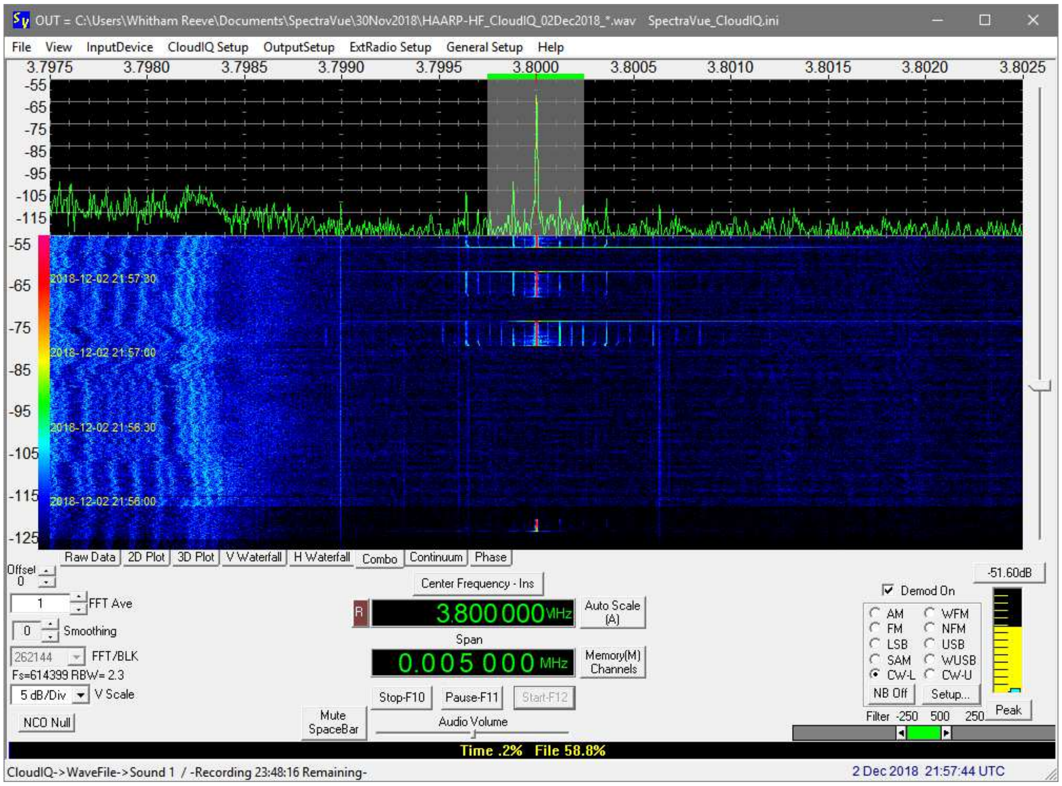
2 – 3 December 2018 (2 December local)



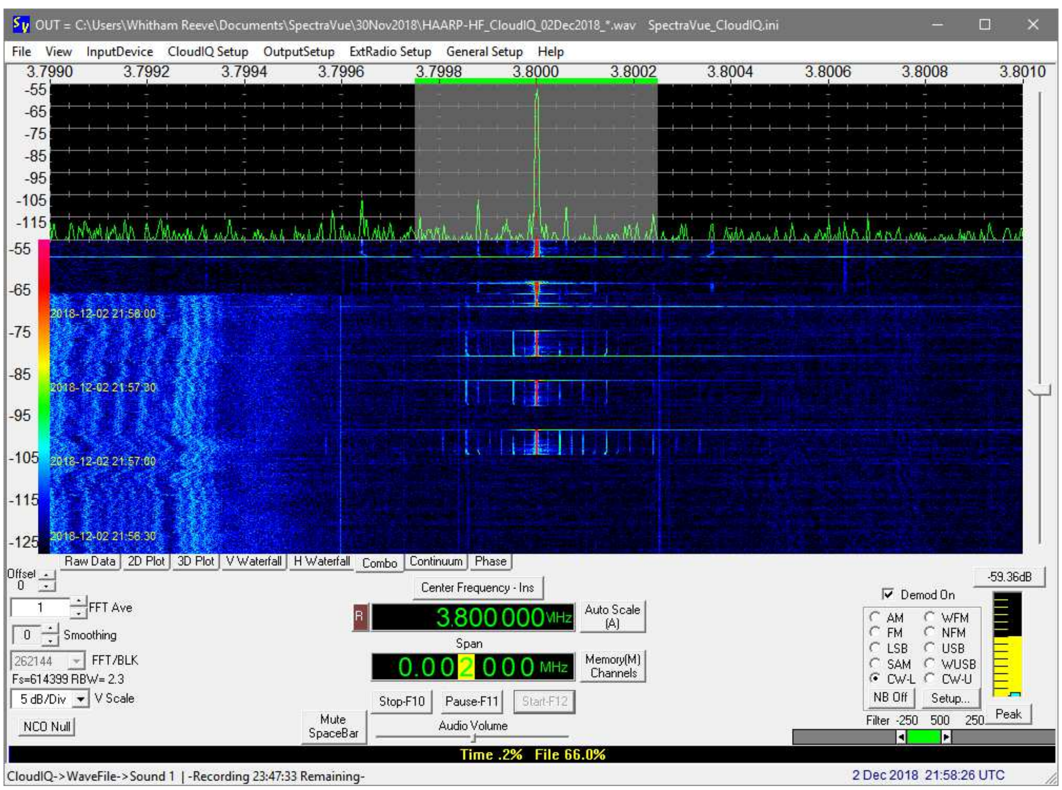
Gakona Ionogram, 02 December, 2137



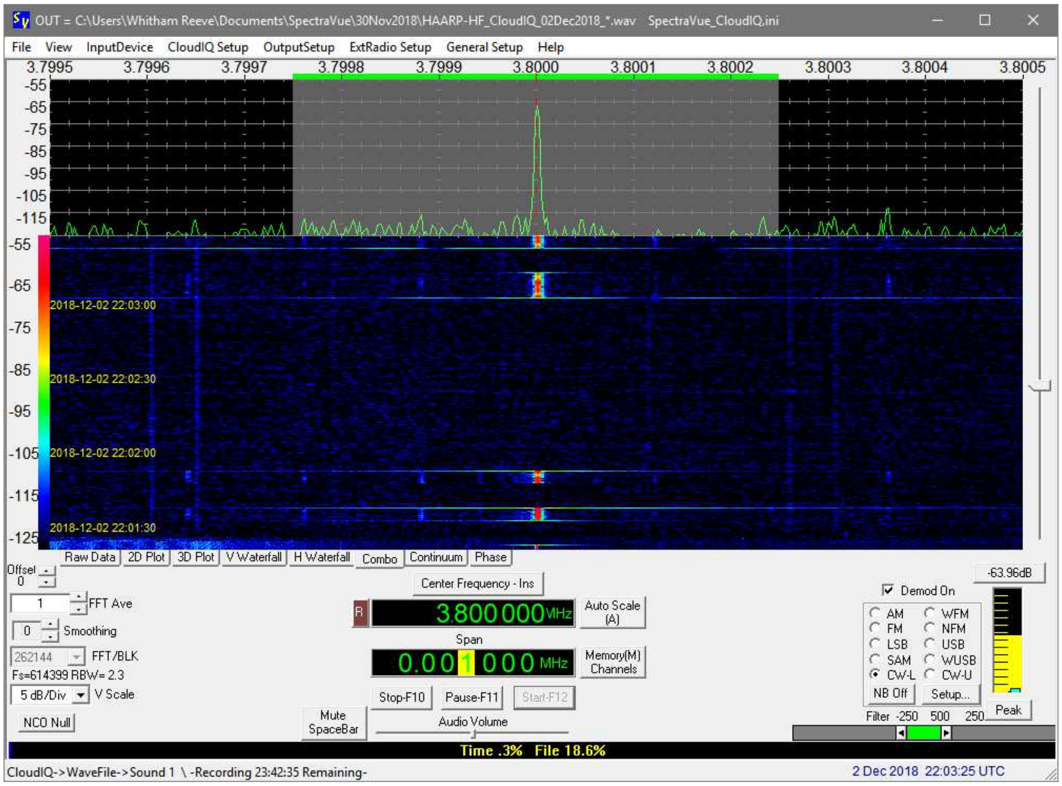
Cloud-IQ, 3.8 MHz, 5 kHz span, 2 December, 2157:23. Apparent powerline interference modulation of HAARP carrier. Note broad RFI to left.



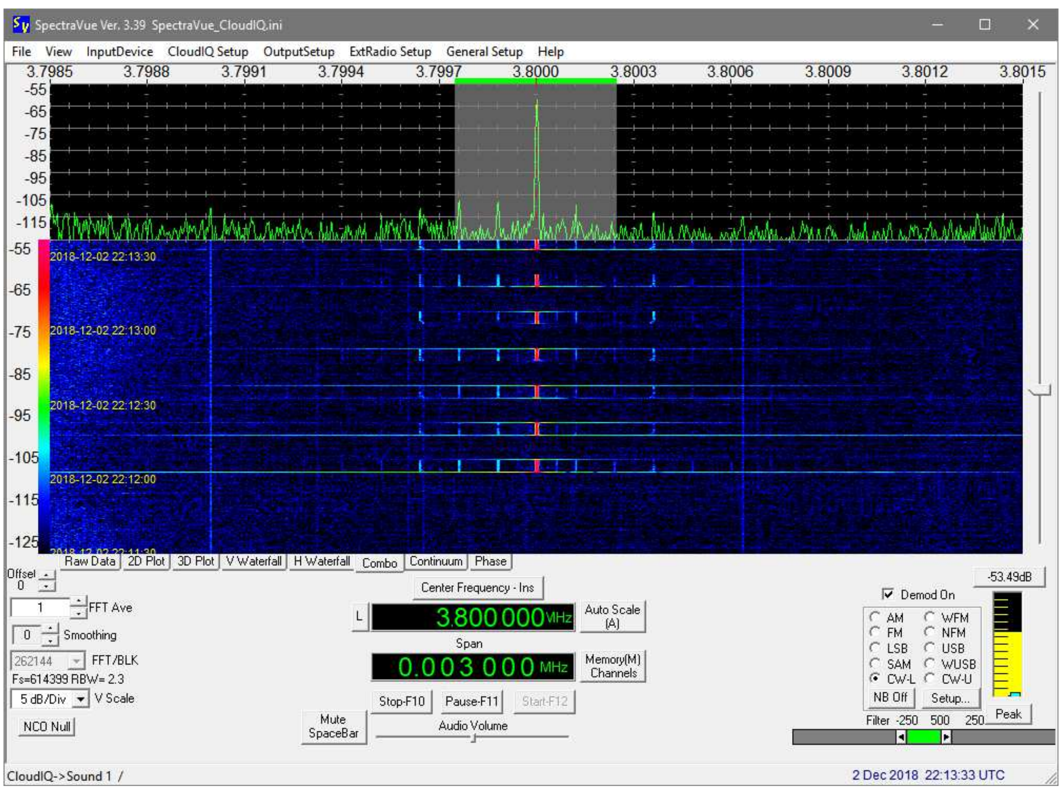

Cloud-IQ, 3.8 MHz, 5 kHz span, 2 December, 2157:44. Same as previous.



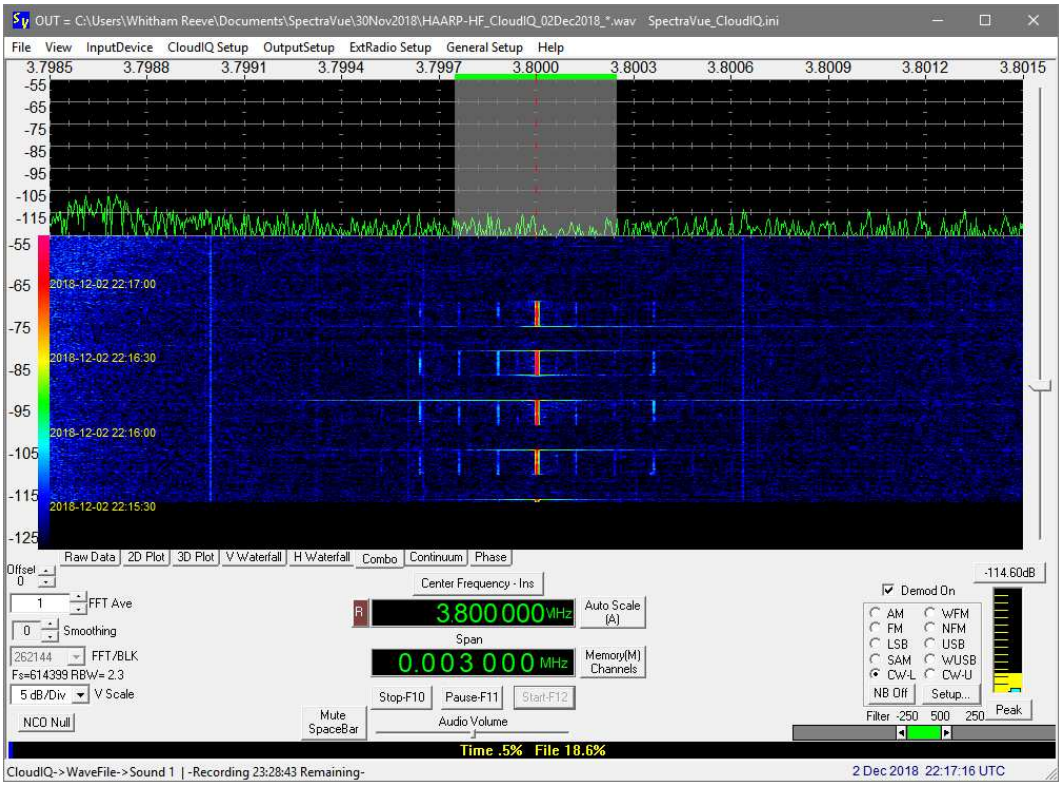

Cloud-IQ, 3.8 MHz, 2 kHz span, 2 December, 2158. Same as previous.



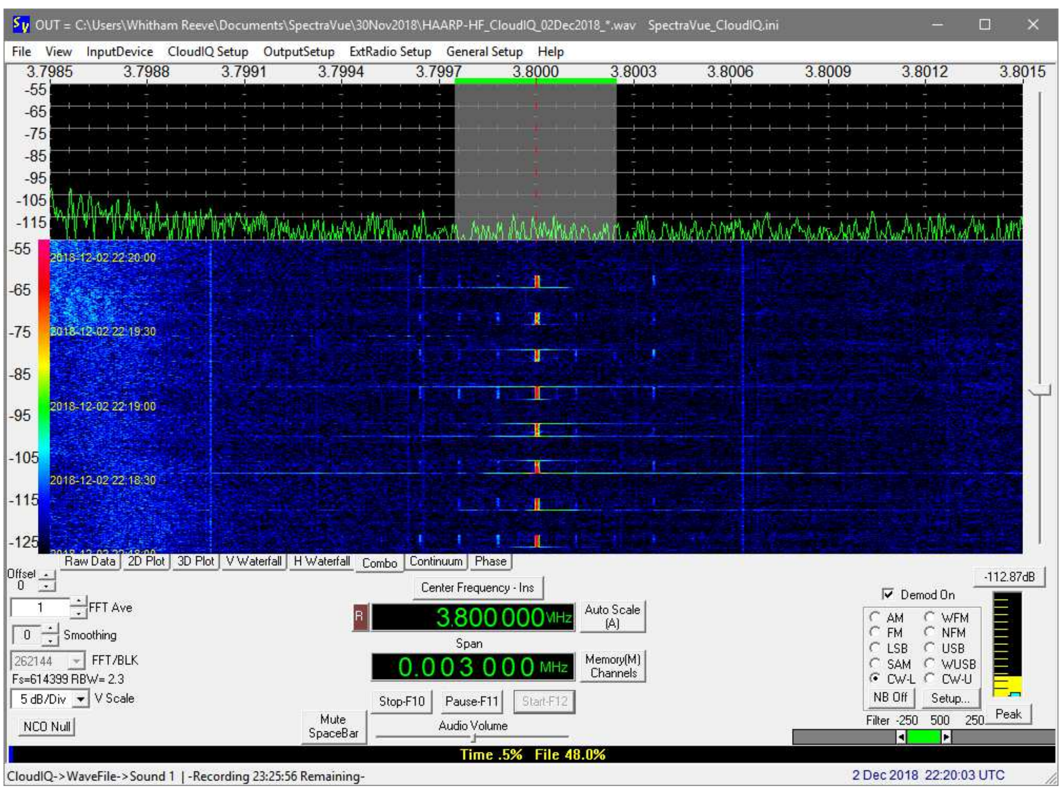

Cloud-IQ, 3.8 MHz, 1 kHz span, 2 December, 2203.



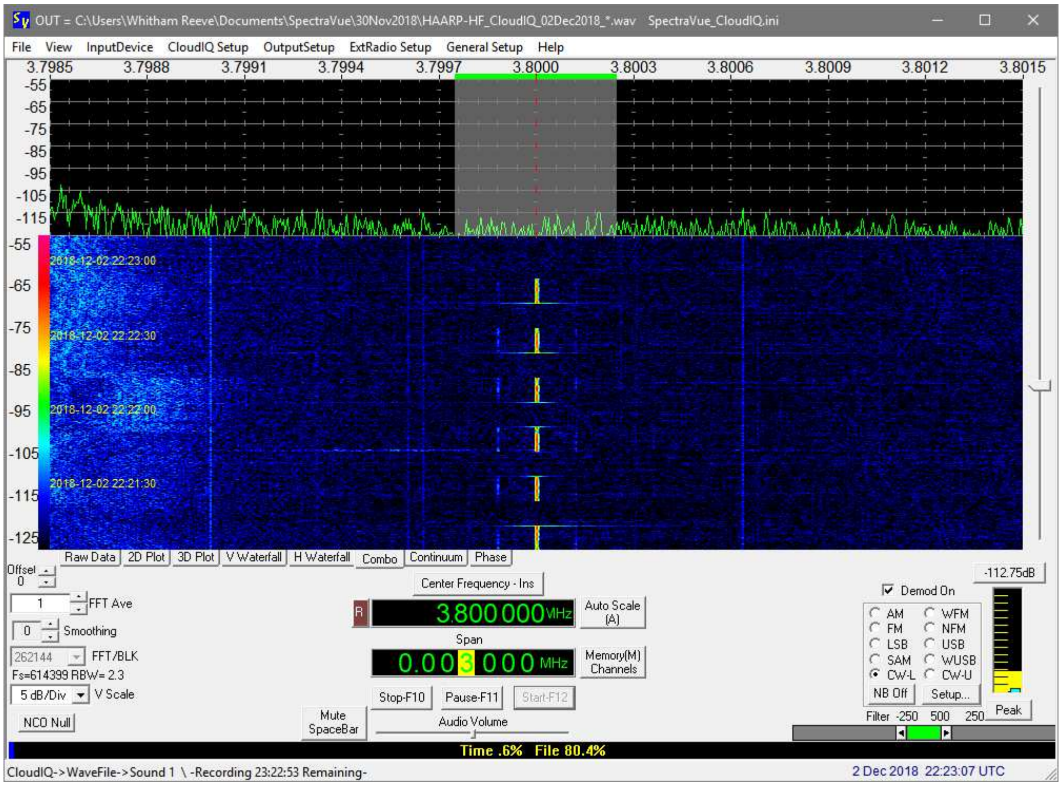

Cloud-IQ, 3.8 MHz, 3 kHz span, 2 December, 2213. Multi-carrier with narrow 120 Hz spacing. Suspect modulation by 60 Hz power system interference.



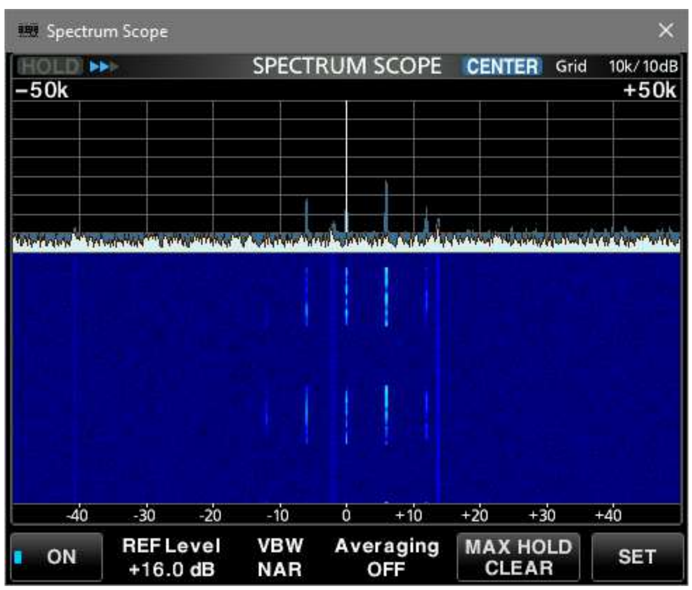

Cloud-IQ, 3.8 MHz, 3 kHz span, 2 December, 2217. Same as previous.



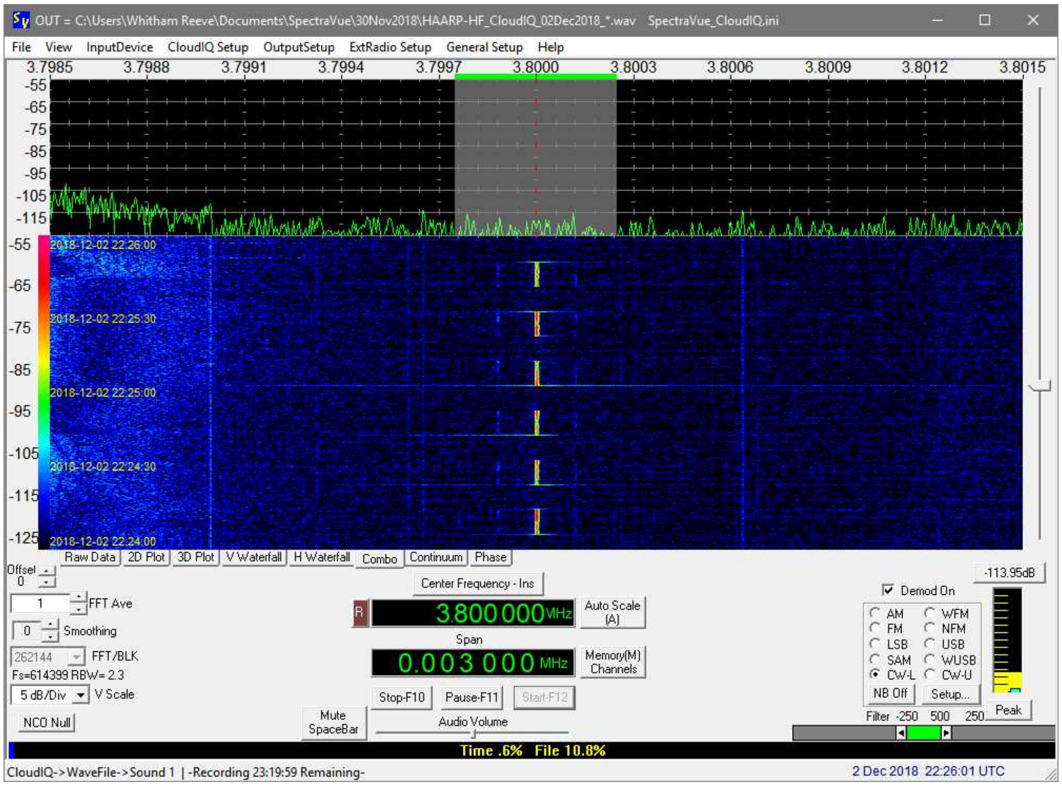

Cloud-IQ, 3.8 MHz, 3 kHz span, 2 December, 2220. Same as previous.



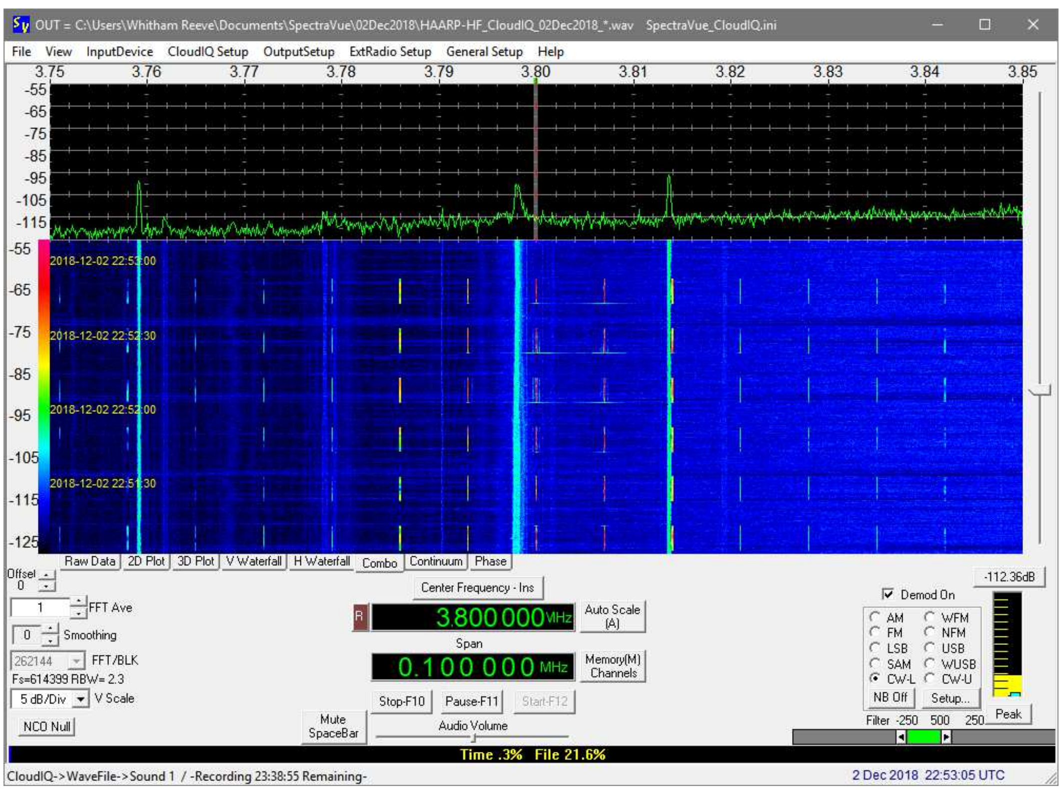

Cloud-IQ, 3.8 MHz, 3 kHz span, 2 December, 2223. Same as previous but not as many harmonics of the interference.



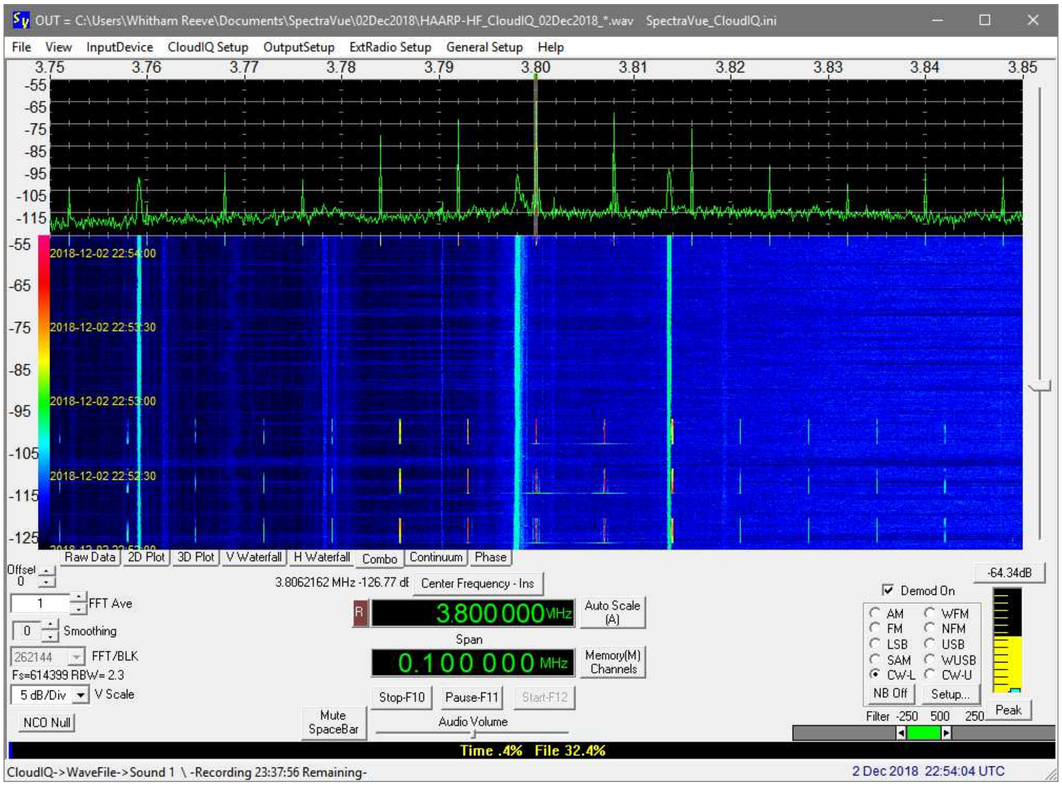

R-8600, 3.80 MHz, 100 kHz span, 2 December, 2223. Apparent multi-carrier transmission.



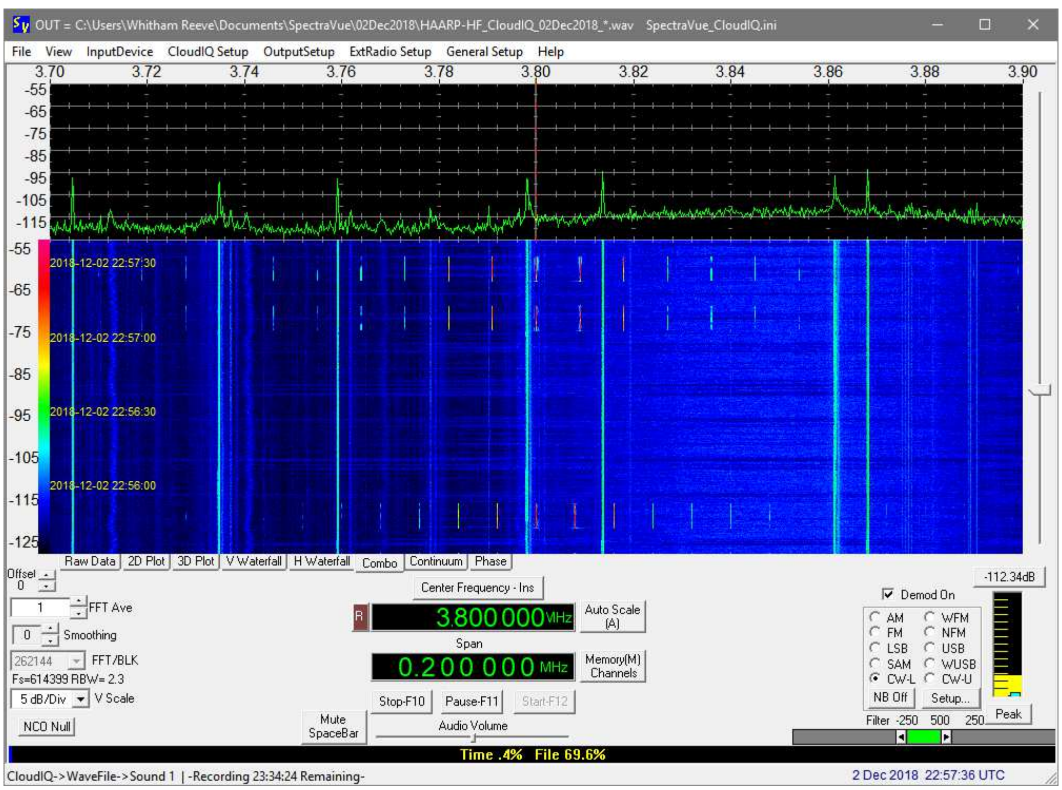

Cloud-IQ, 3.8 MHz, 3 kHz span, 2 December, 2226. Wideband radio frequency interference (RFI) can be seen on the left side of the spectrum and waterfall.



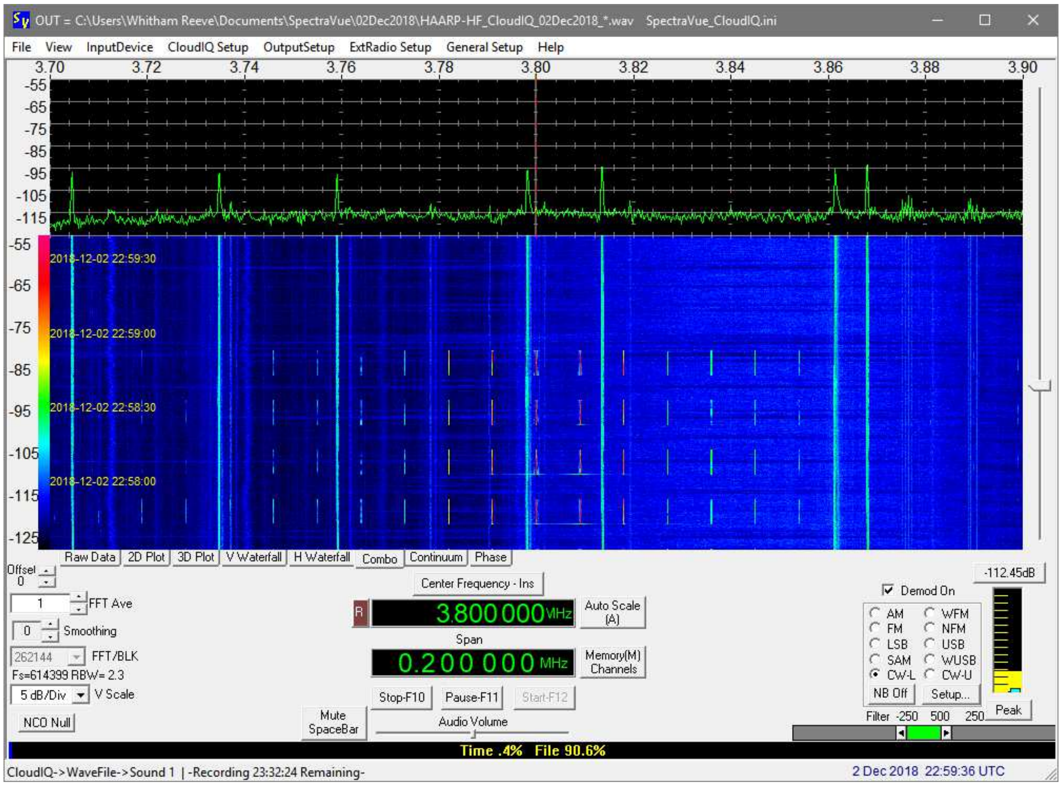

Cloud-IQ, 3.8 MHz, 100 kHz span, 2 December, 2253. Multi-carrier transmissions with 7 kHz spacing. The thicker lines in the waterfall are RFI.



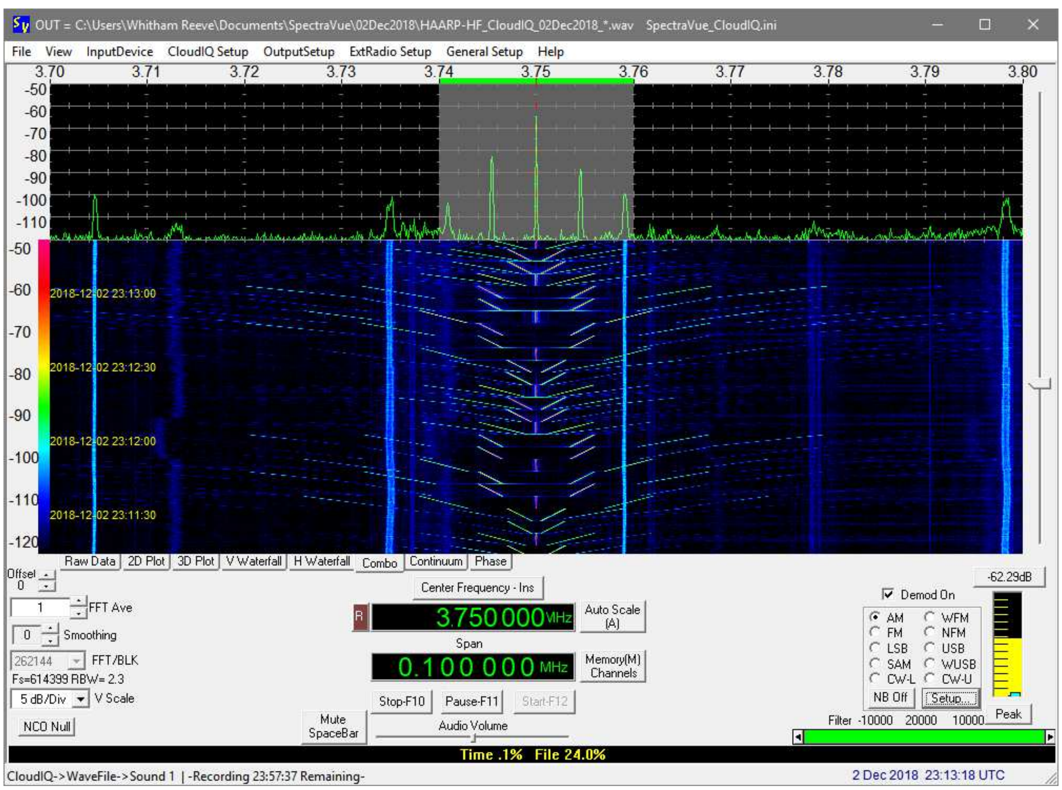
Cloud-IQ, 3.8 MHz, 100 kHz span, 2 December, 2254. Multi-carrier transmission with 8 kHz spacing; note change from previous session that had 7 kHz spacing. The thicker lines in the waterfall are RFI.



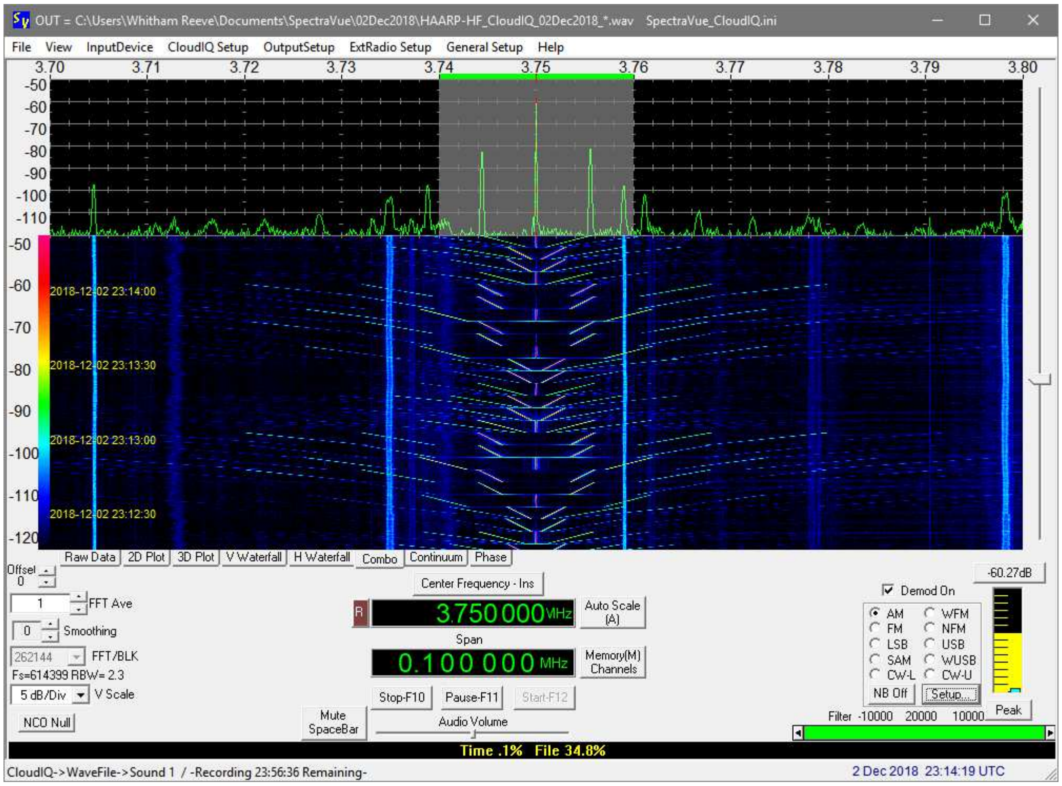
Cloud-IQ, 3.8 MHz, 200 kHz span, 2 December, 2257. Multi-carrier with 8 kHz spacing. The thicker lines in the waterfall are RFI.



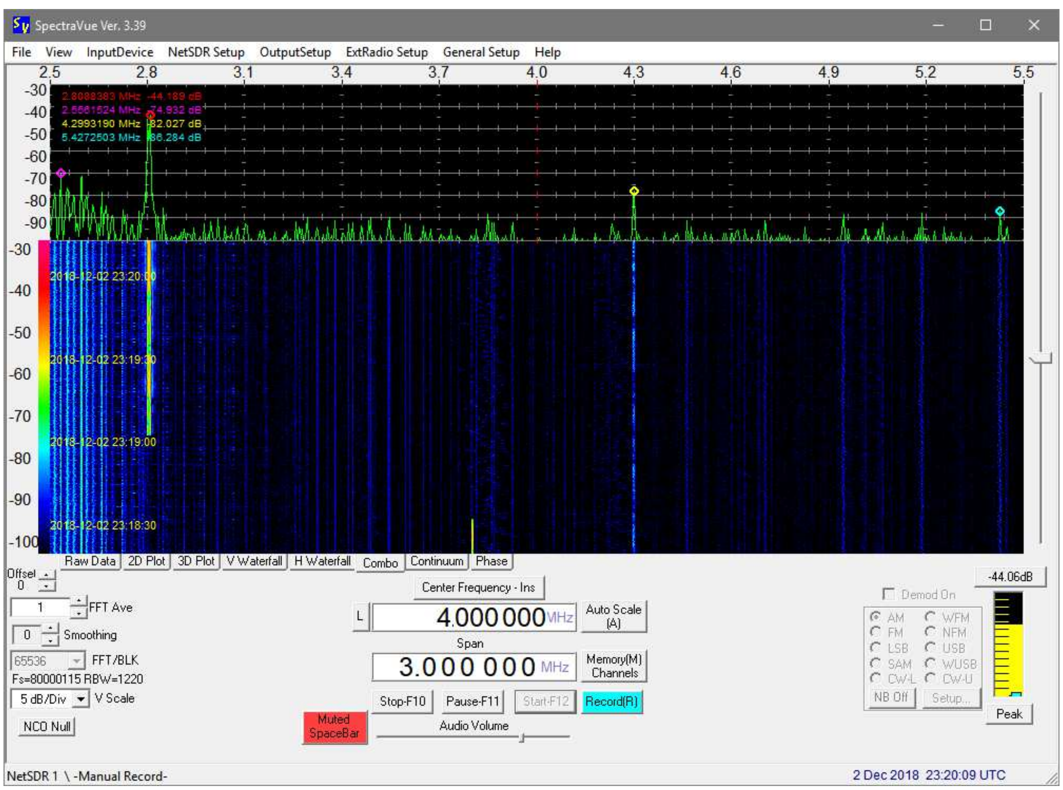

Cloud-IQ, 3.8 MHz, 200 kHz span, 2 December, 2259. Multi-carrier transmissions ended at 2259:00. The thicker lines in the waterfall are RFI.



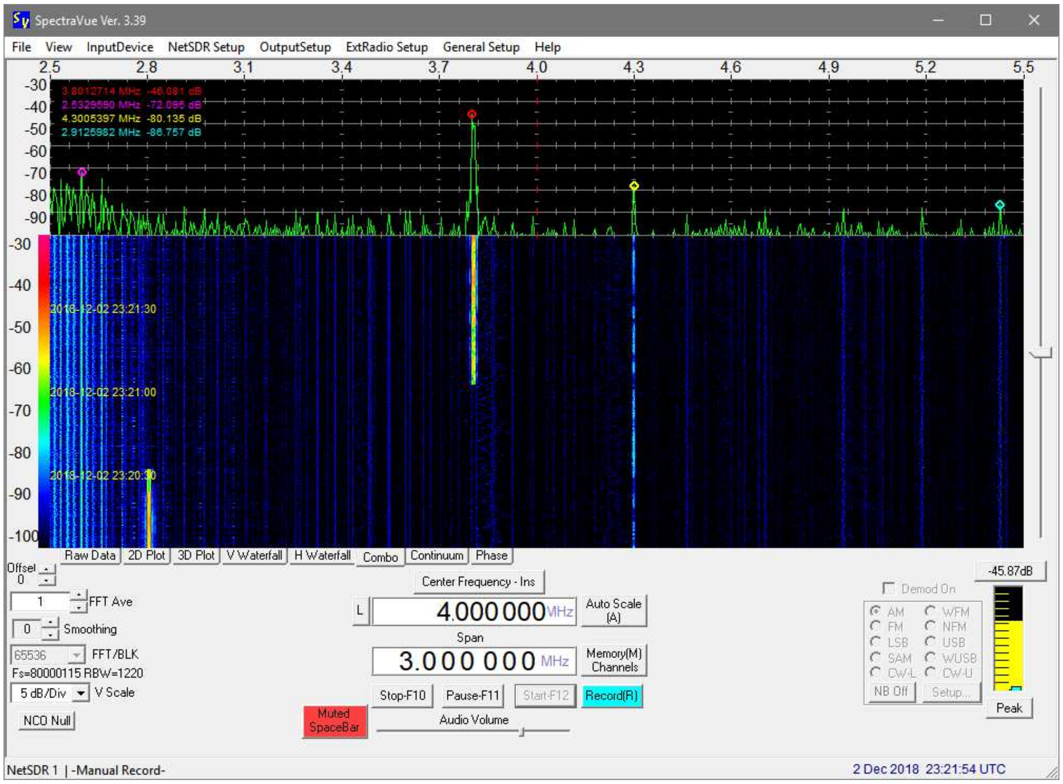

Cloud-IQ, 3.75 MHz, 100 kHz span, 2 December, 2313. Chirp modulation.



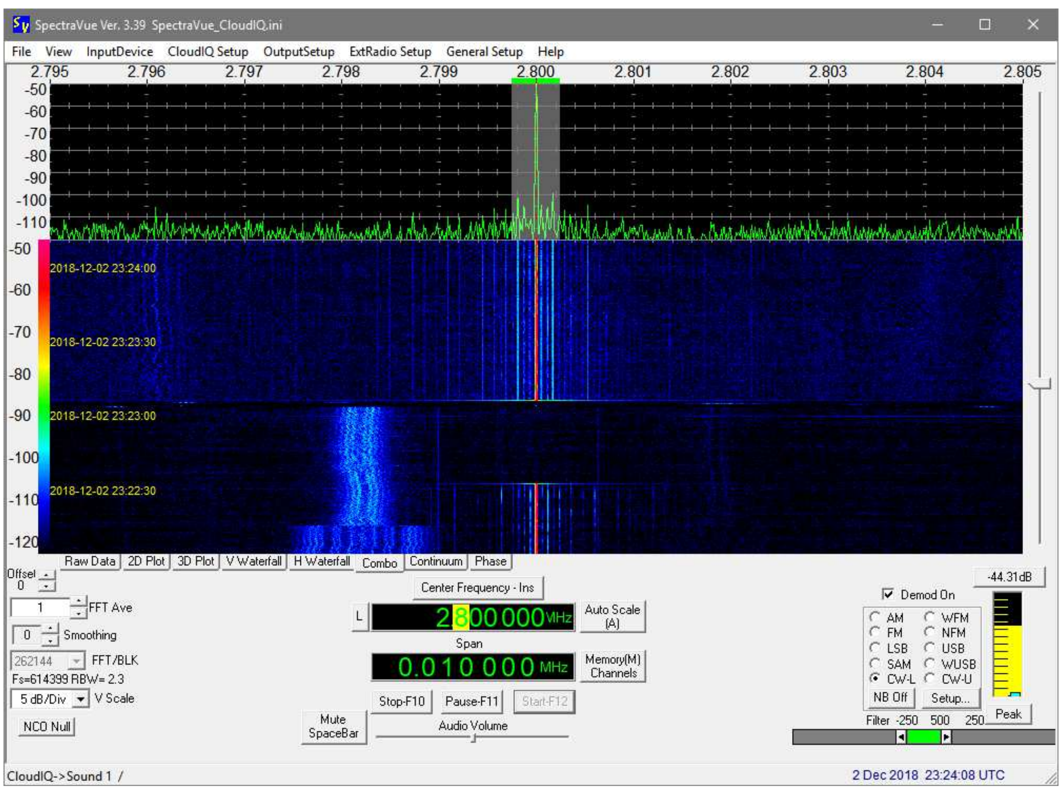

Cloud-IQ, 3.75 MHz, 100 kHz span, 2 December, 2314. Chirp modulation.



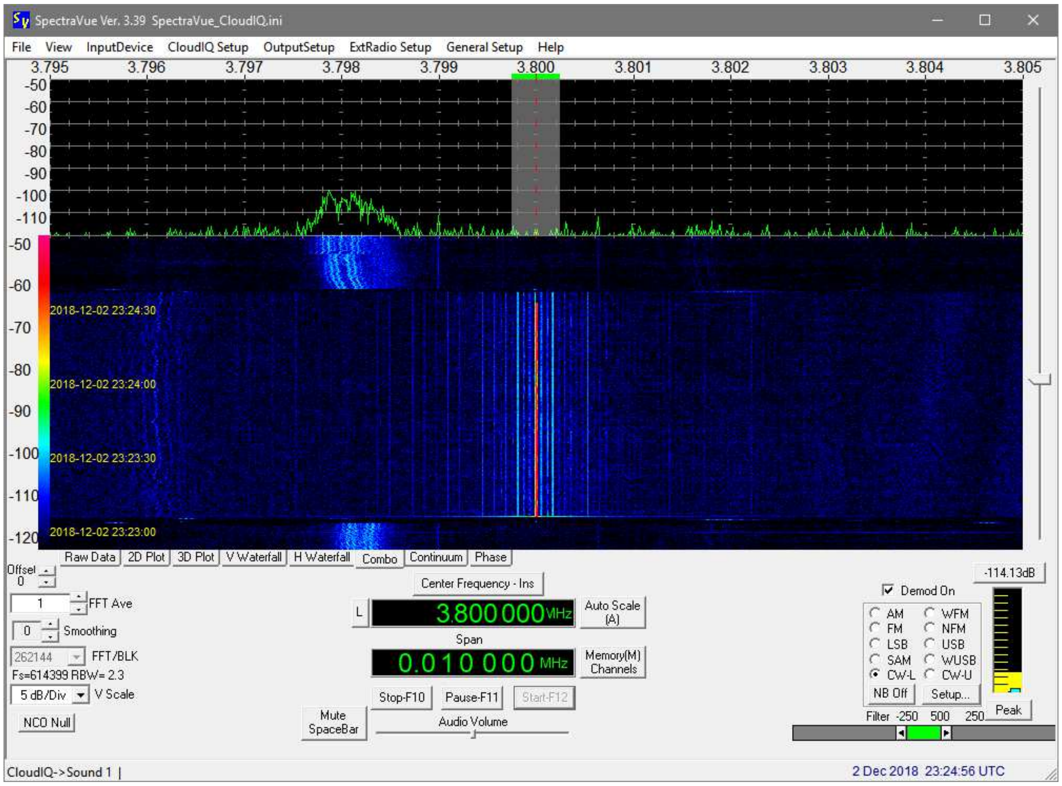

NetSDR, 4.0 MHz, 3 MHz span, 2 December, 2320. Note HAARP transmitter frequency $f_0$ = 2.8 MHz. The spectra at about 4.3 MHz is the weather fax (RadioFax) transmitted by the Kodiak Coast Guard station.



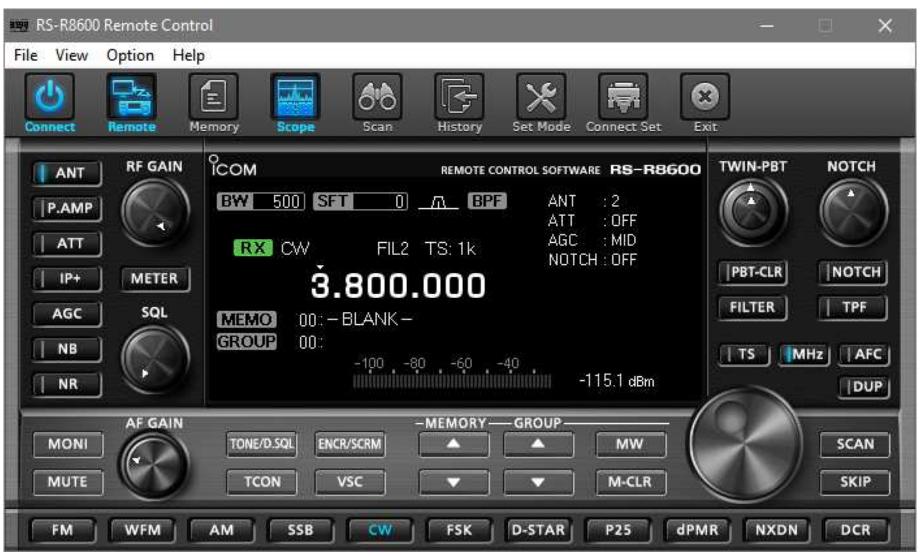

NetSDR, 3.8 MHz, 3 MHz span, 2 December, 2321. Note HAARP transmitter frequency $f_0$ = 3.8 MHz. The spectra at about 4.3 MHz is the weather fax at the Kodiak Coast Guard station.



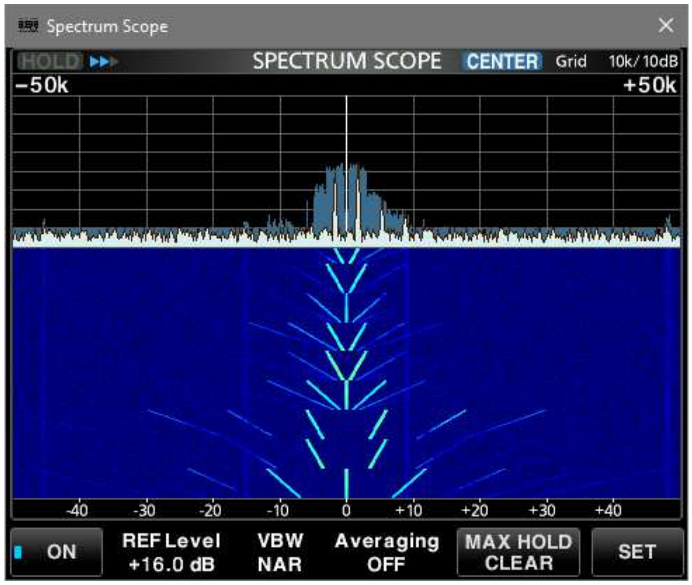

Cloud-IQ, 2.8 MHz, 10 kHz span, 2 December, 2324:08. Possible Stimulated Electromagnetic Emissions (SEE) around the HAARP carrier.



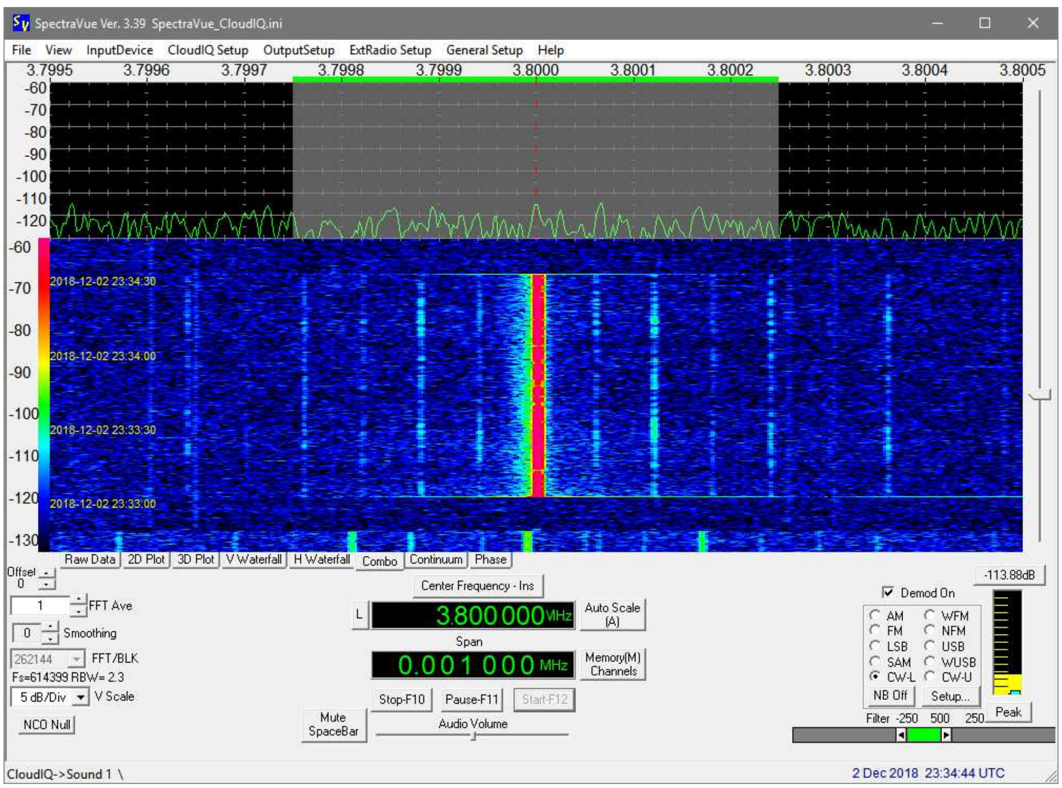

Cloud-IQ, 3.8 MHz, 10 kHz span, 2 December, 2354:58. Compare to previous.



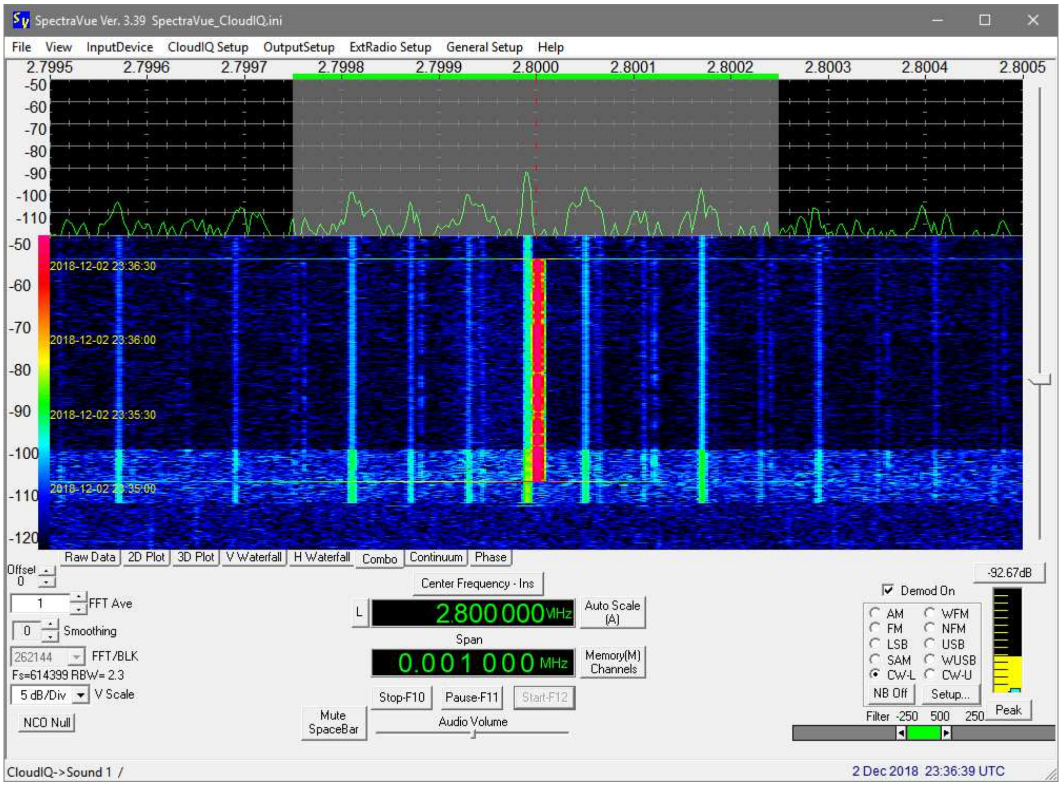

R-8600 receiver settings, 3.8 MHz, 2 December, 2330.



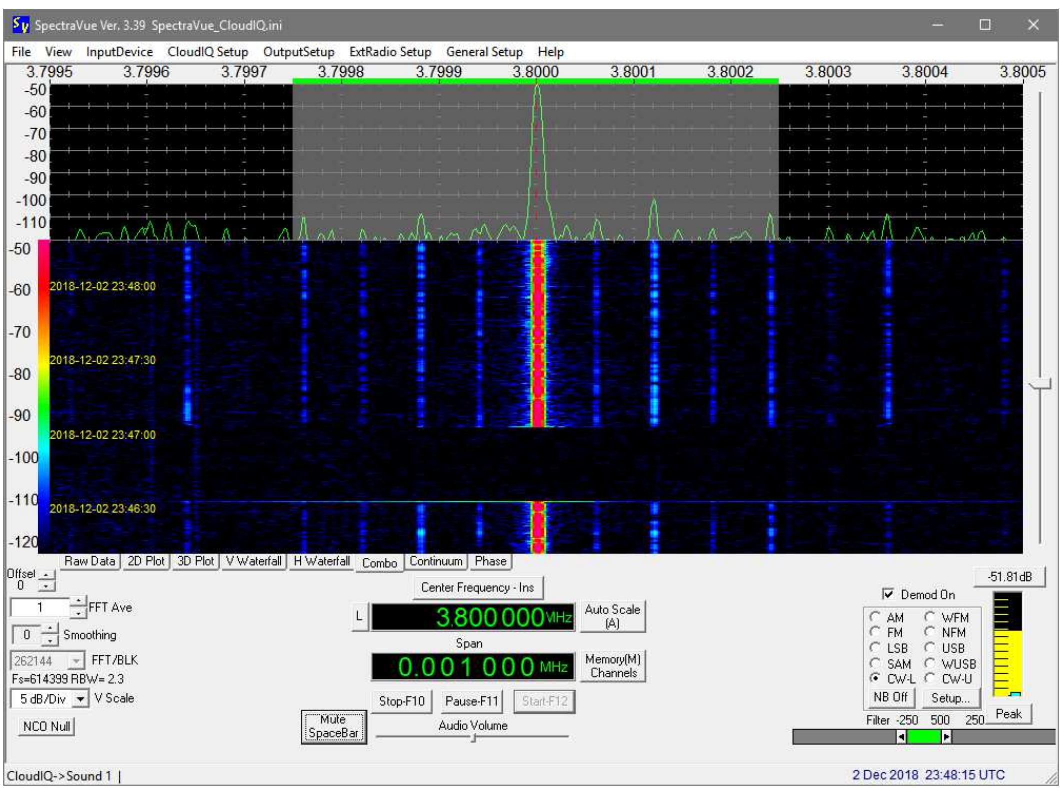

R-8600, 3.8 MHz, 100 kHz span, 2 December, 2330. Chirp modulation.



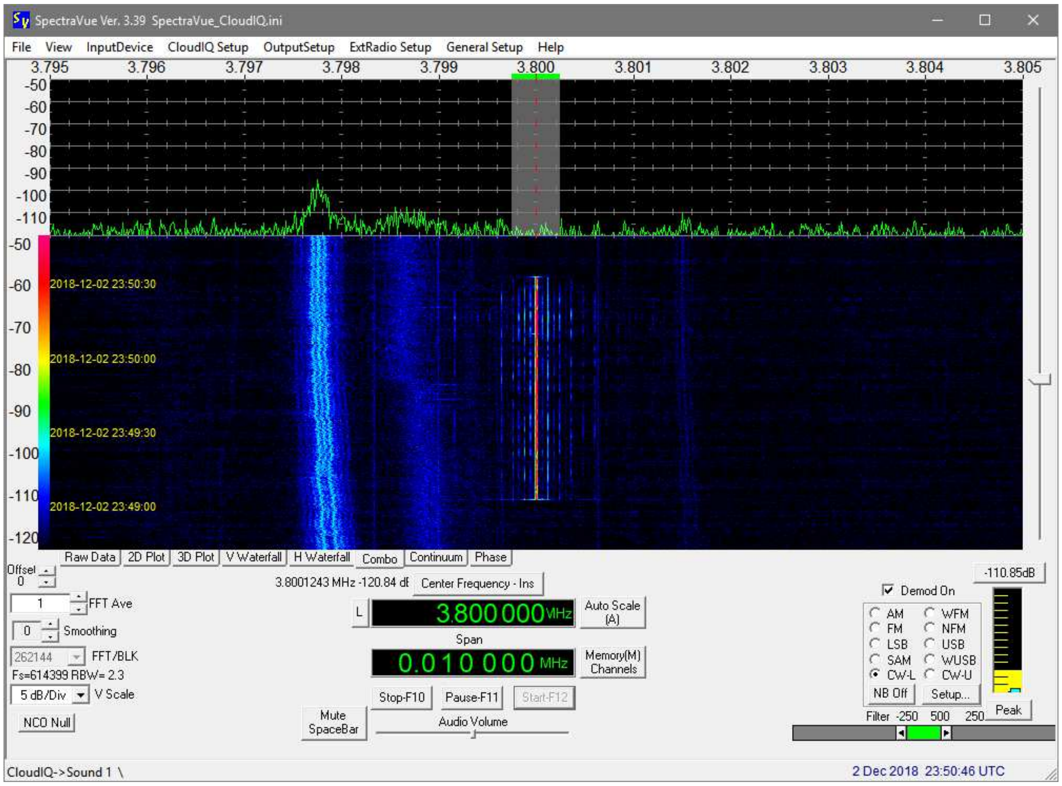

Cloud-IQ, 3.8 MHz, 1 kHz span, 2 December, 2334. Carriers with 60 Hz spacing may be inadvertent modulation of the primary carrier by the power system.



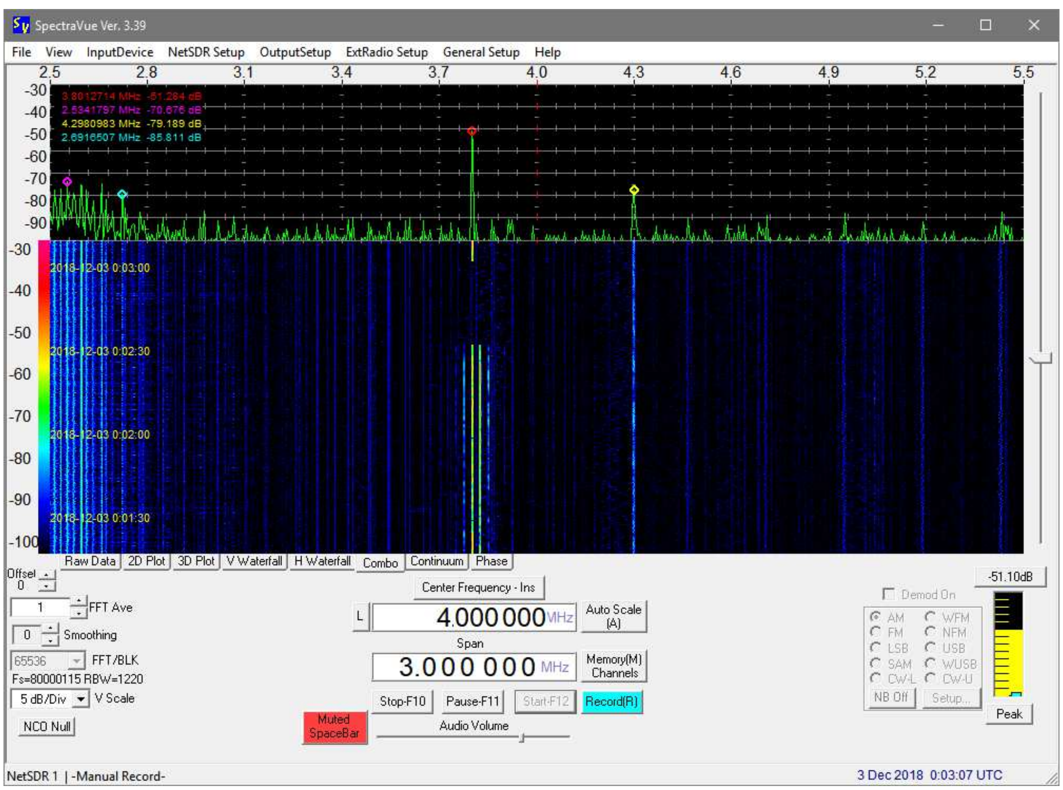

Cloud-IQ, 2.8 MHz, 1 kHz span, 2 December, 2336. Same as previous.



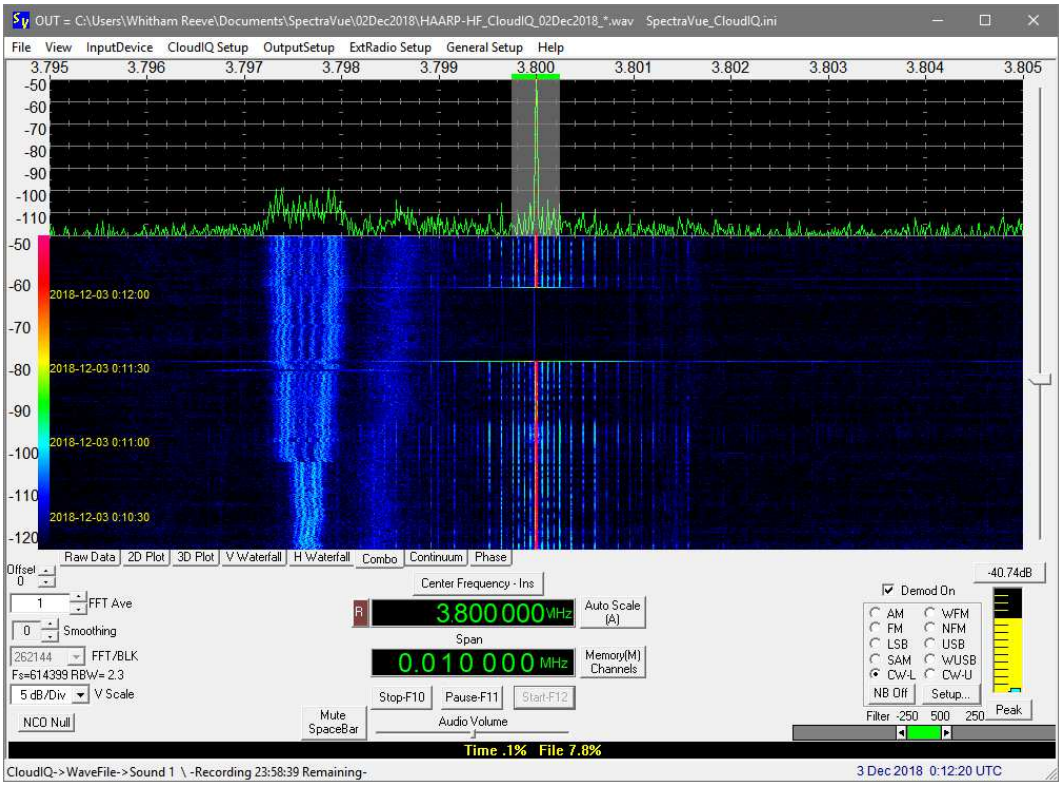

Cloud-IQ, 3.8 MHz, 1 kHz span, 2 December, 2348. Same as previous.



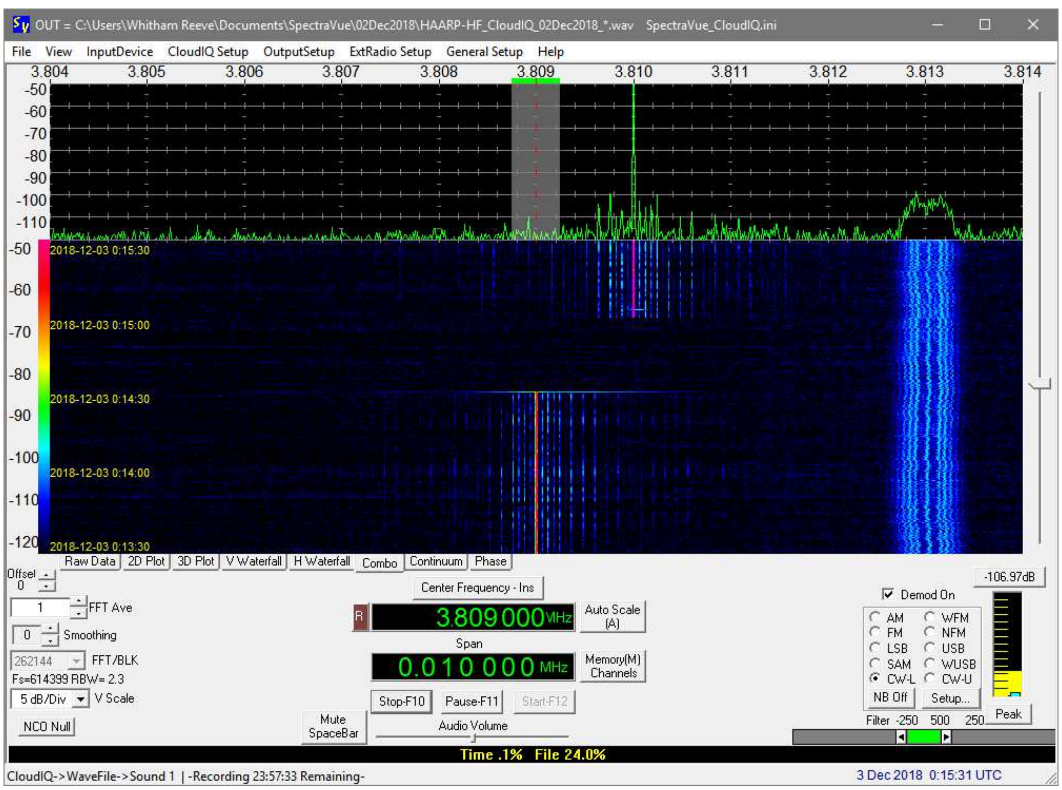

Cloud-IQ, 3.8 MHz, 1 kHz span, 2 December, 2350. Note drifting RFI between 3.797 and 3.798 MHz.



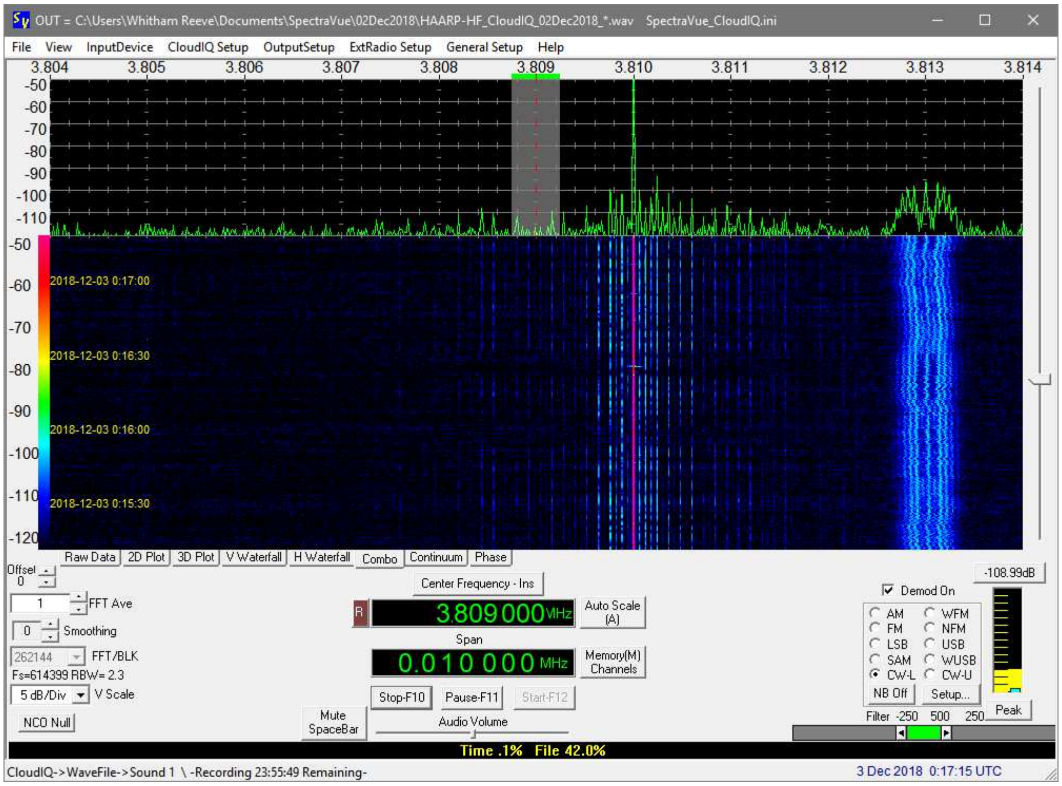

Cloud-IQ, 3.8 MHz, 3 MHz span, 3 December, 0003. Carrier near 4.3 MHz is weather fax transmitted by the Coast Guard station at Kodiak.



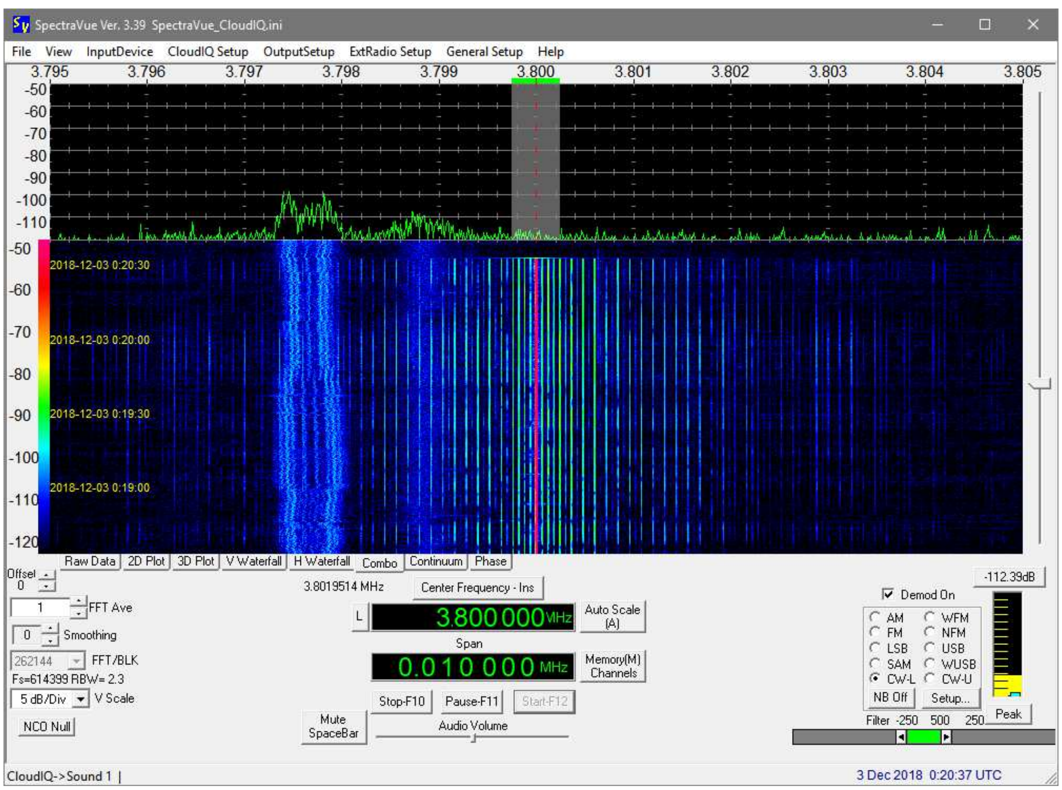
Cloud-IQ, 3.8 MHz, 10 kHz span, 3 December, 0012. Note RFI between 3.797 and 3.798 MHz. Evenly spaced carriers may be unintended modulation by power system.



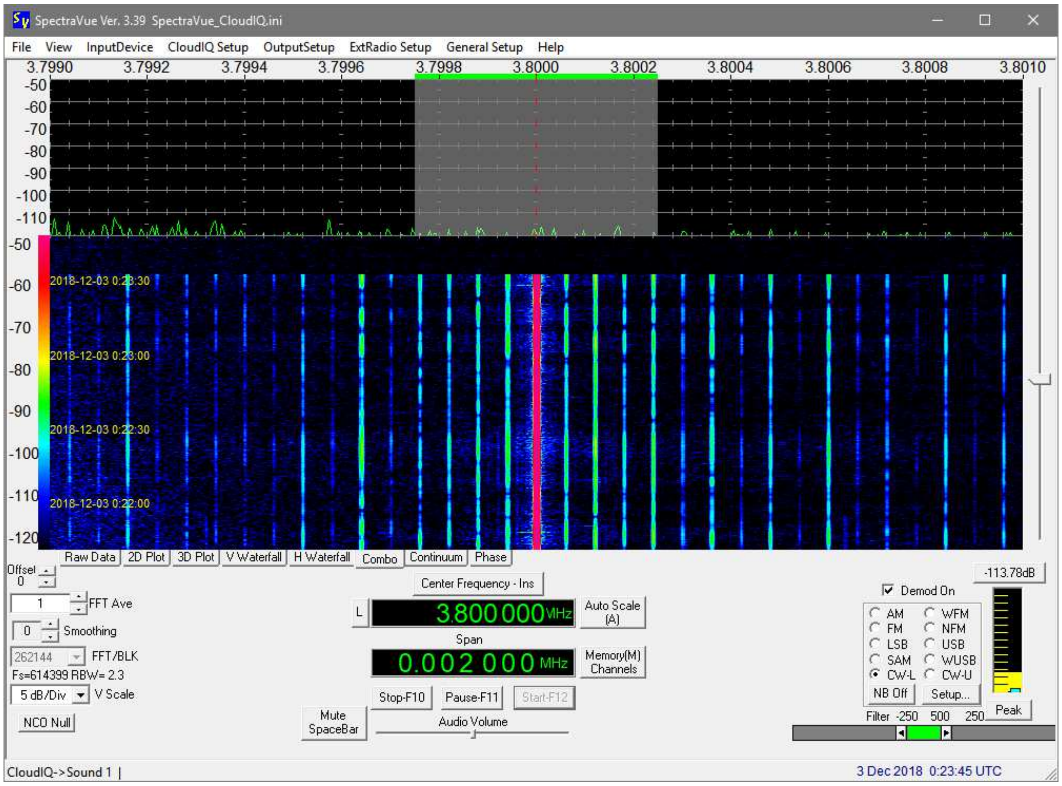
Cloud-IQ, 3.8 MHz, 10 kHz span, 3 December, 0015. Compare to previous. Note wobbly RFI at 3.813 MHz, possibly from a switchmode power supply.



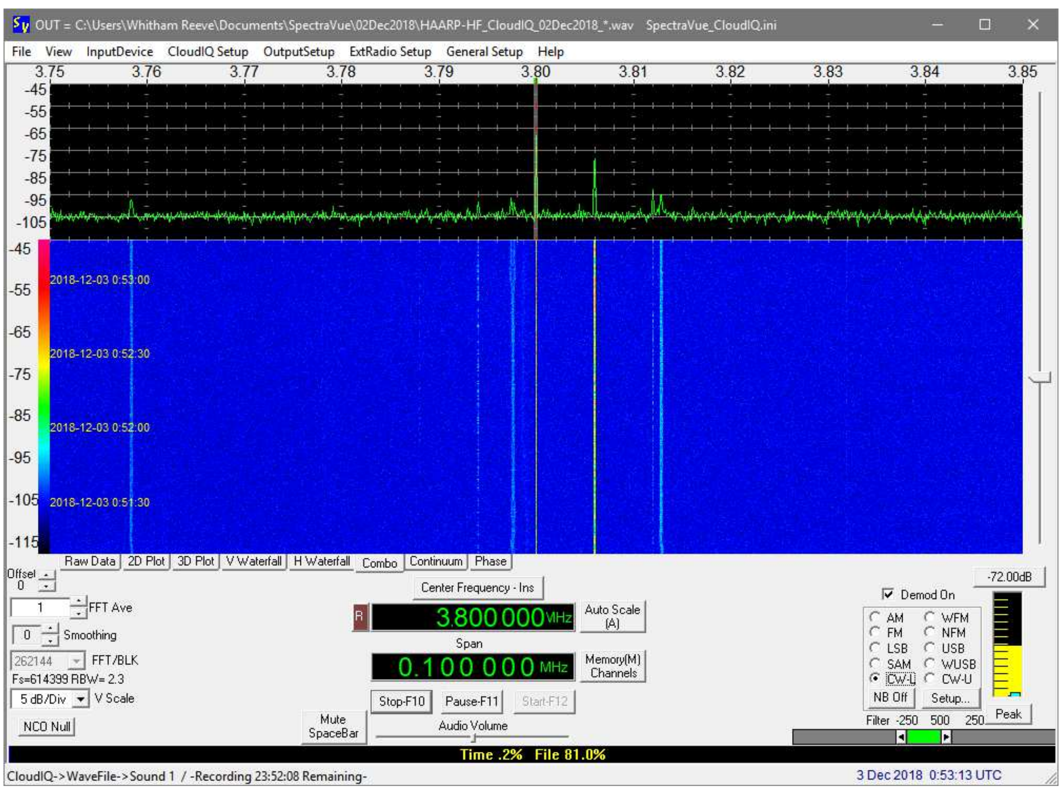

Cloud-IQ, 3.809 MHz, 10 kHz span, 3 December, 0017. Compare to previous. Note RFI at 3.813 MHz.



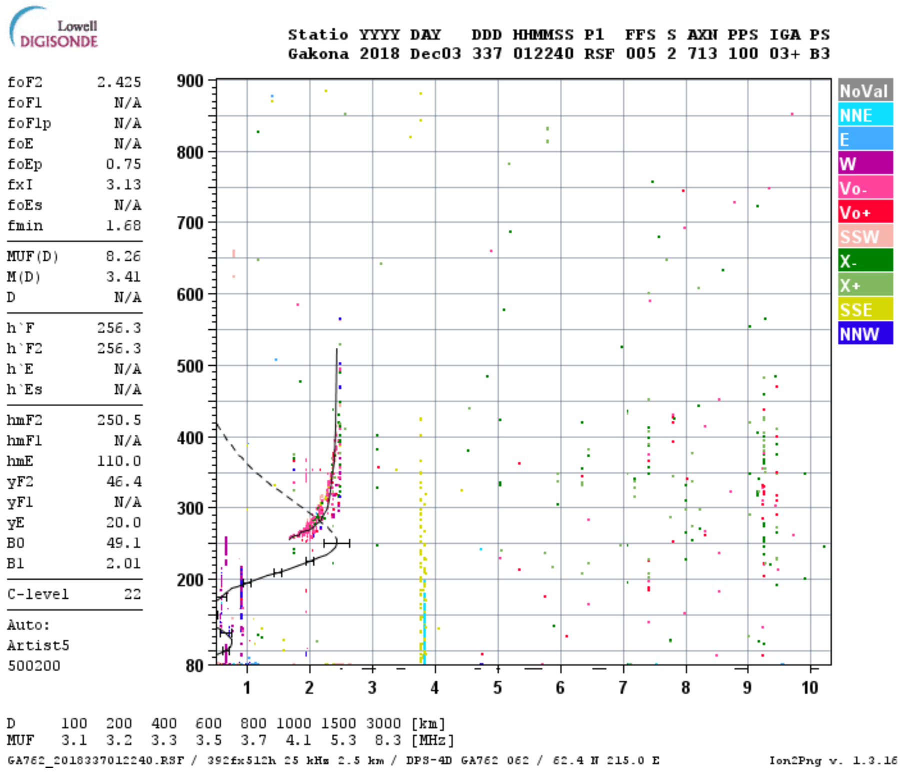

Cloud-IQ, 3.8 MHz, 10 kHz span, 3 December, 0020. Many powerline harmonics?



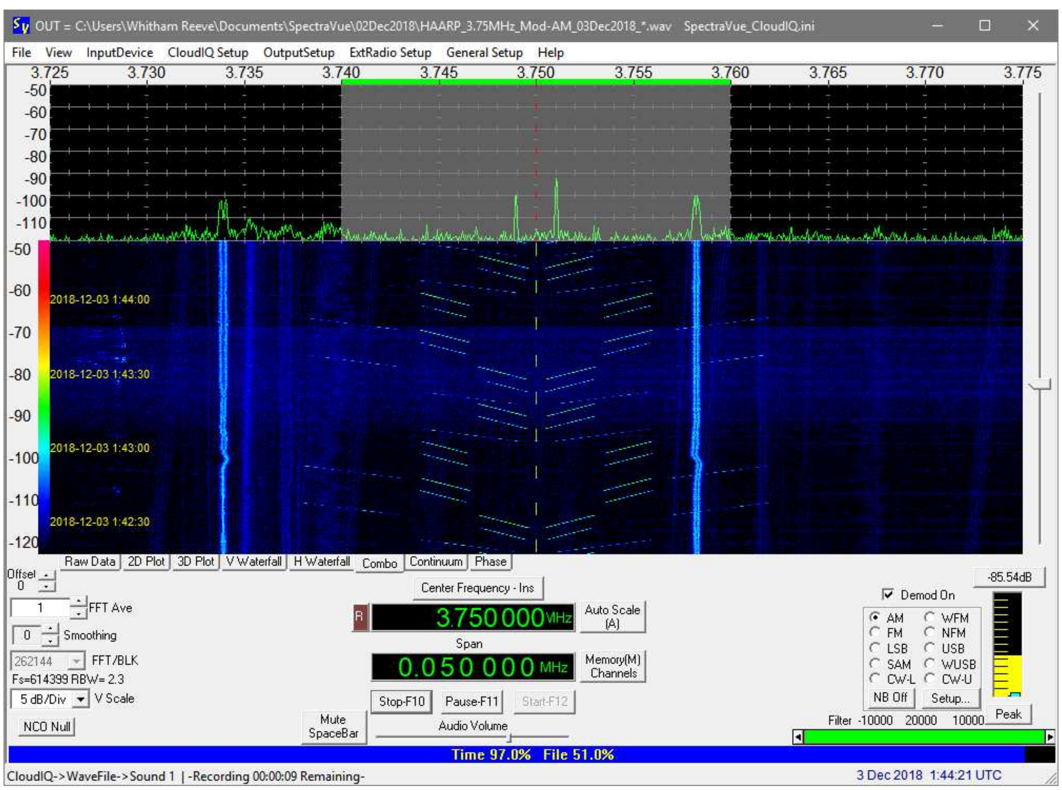
Cloud-IQ, 3.8 MHz, 2 kHz span, 3 December, 0023. Powerline harmonics?



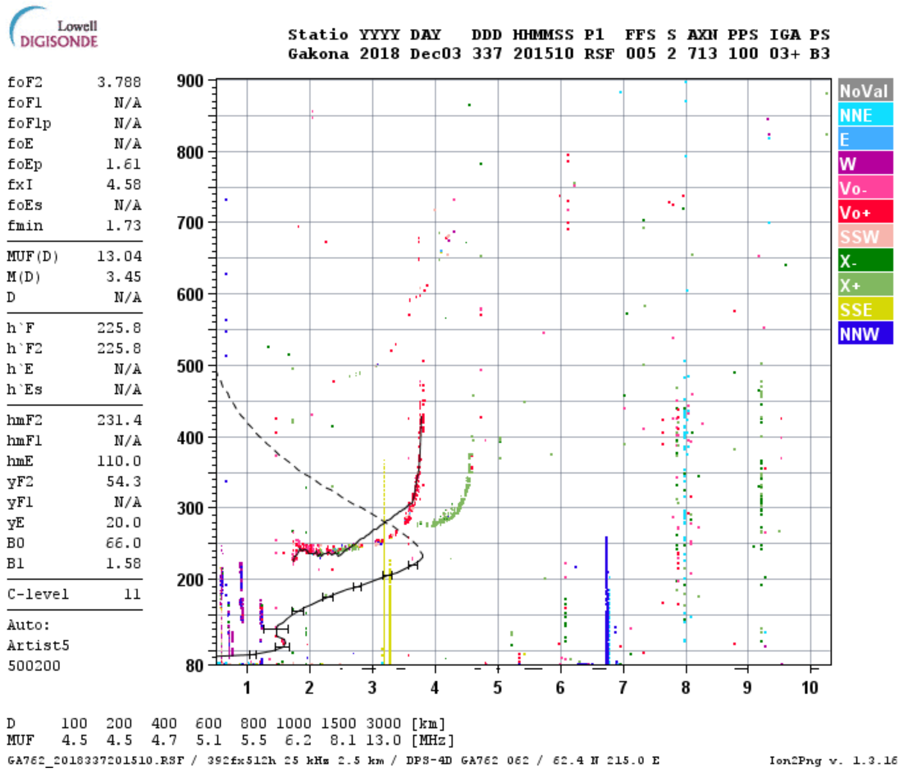
Cloud-IQ, 3.8 MHz, 100 kHz span, 3 December, 0053. Carriers visible at 3.806 and 3.812 MHz along with some RFI.



Gakona Ionogram, 03 December, 0122

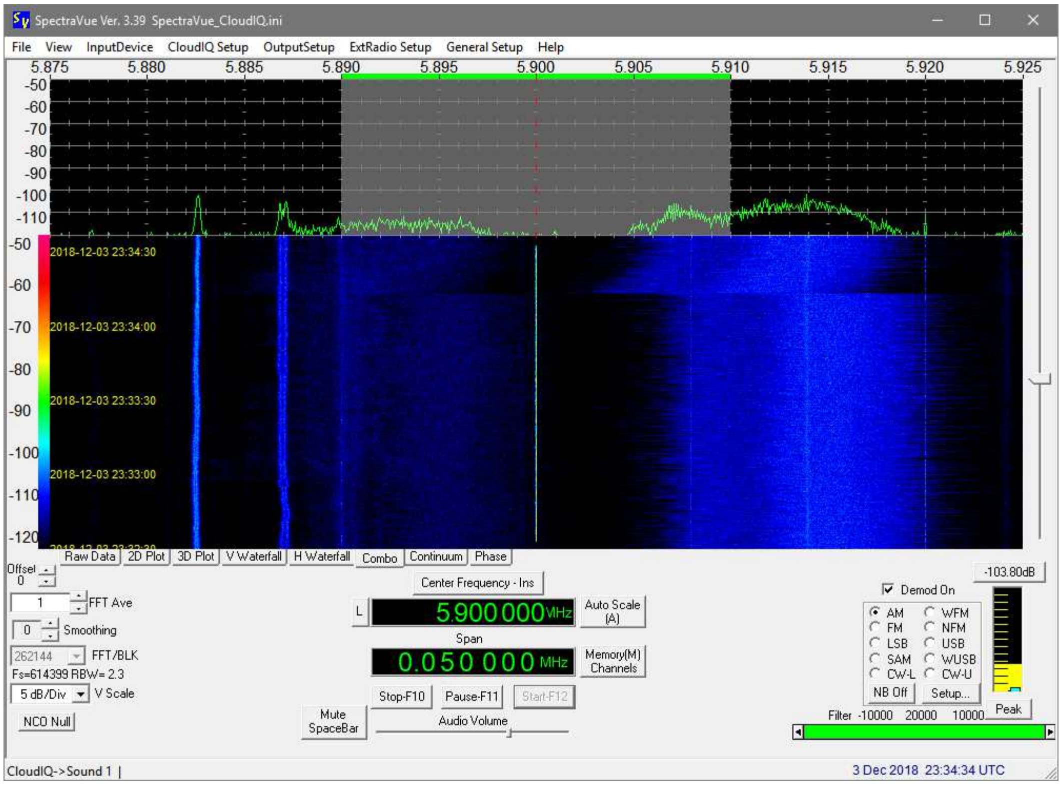


Cloud-IQ, 3.75 MHz, 50 kHz span, 3 December, 0144. Chirp modulation along with RFI (broad lines in waterfall).

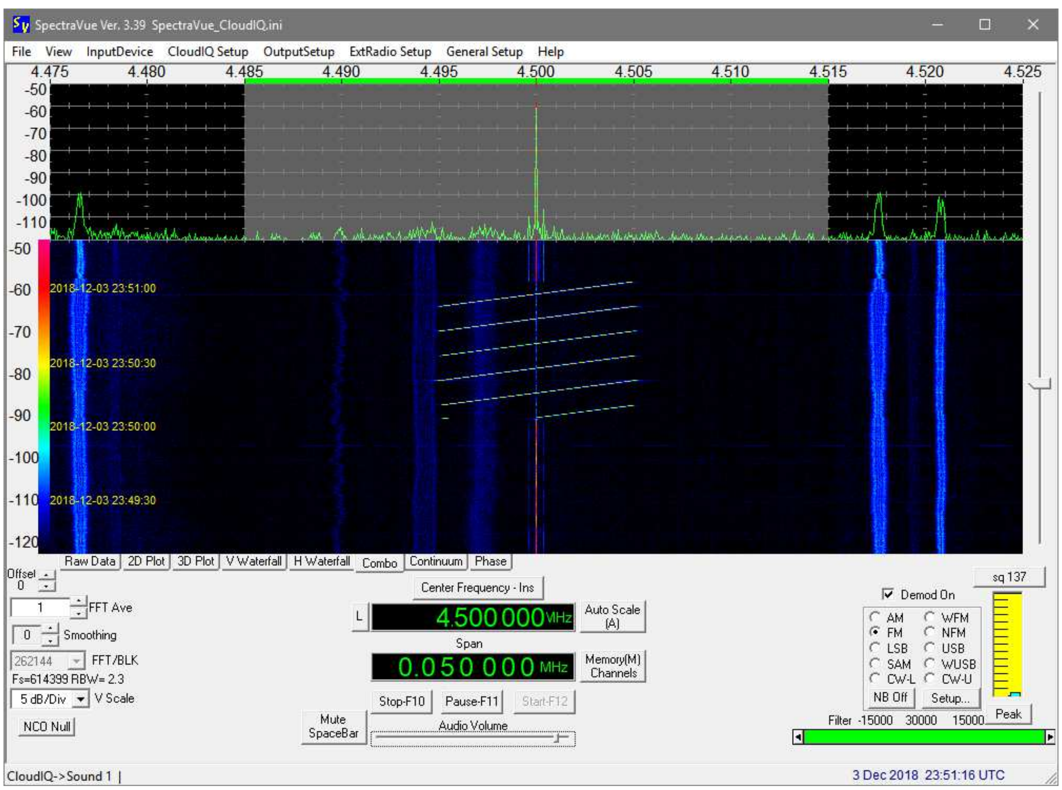



Gakona Ionogram, 03 December, 2015

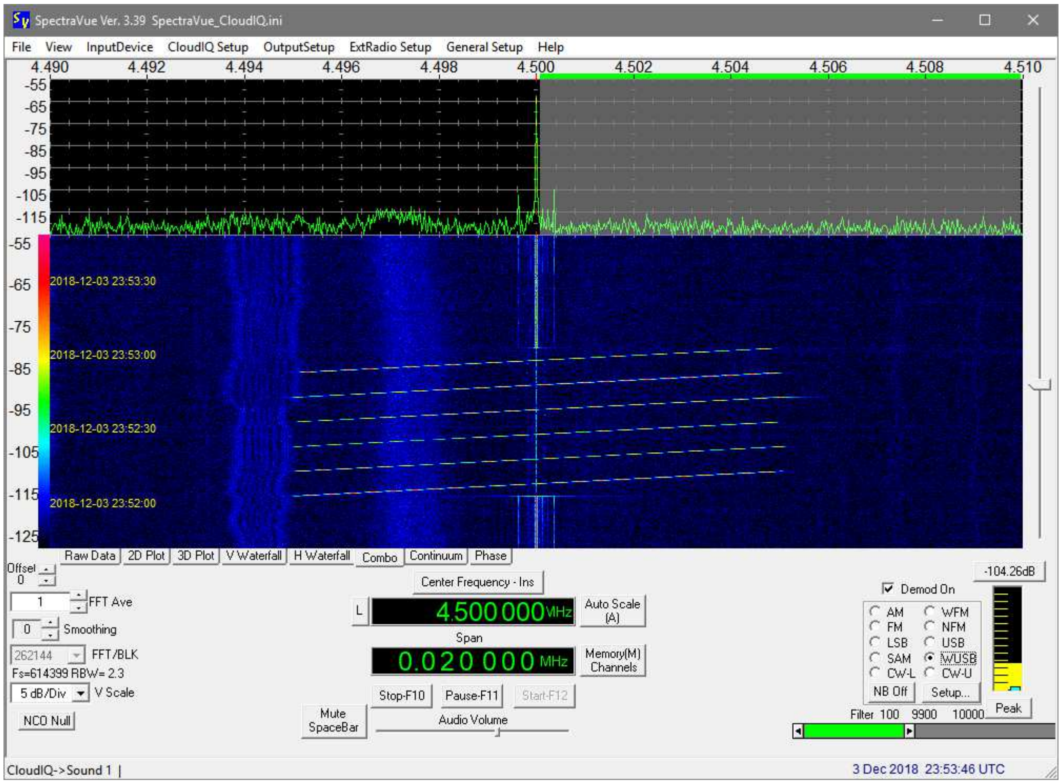
3 – 4 December 2018 (3 December local)



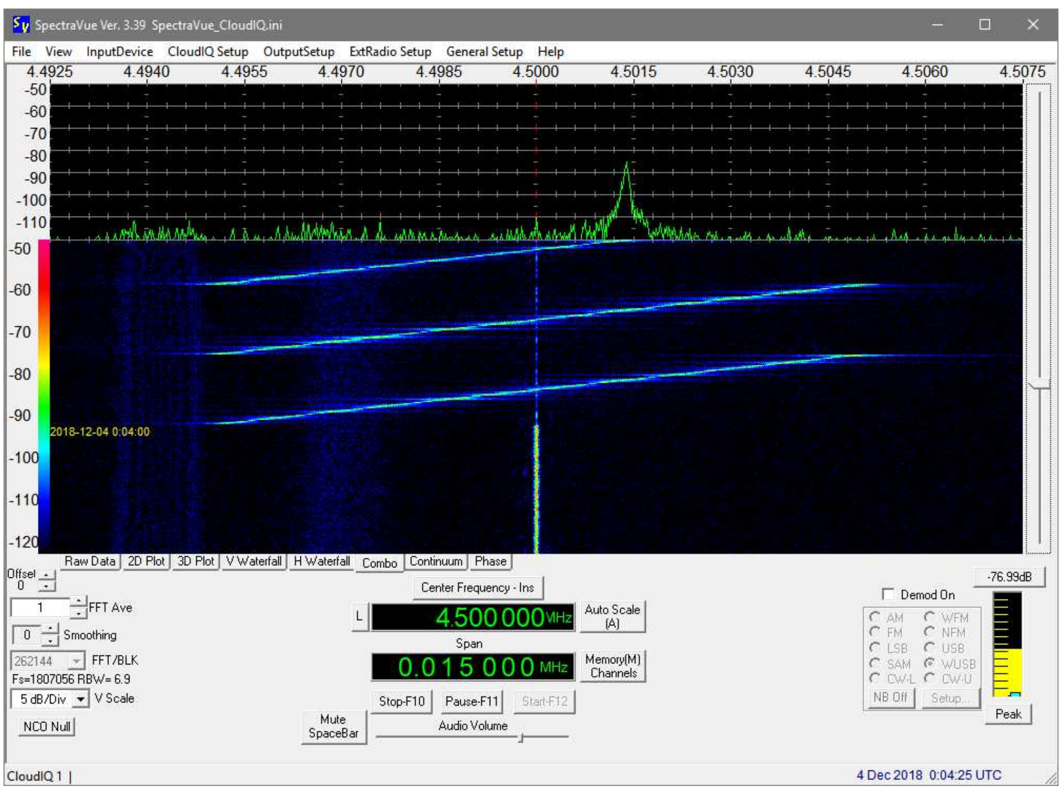

Cloud-IQ, 5.90 MHz, 50 kHz span, 3 December, 2324. Note that all indications on the waterfall are RFI except the line at 5.900 MHz. HAARP settings 5.9 and 7.2 MHz.




Cloud-IQ, 4.50 MHz, 50 kHz span, 3 December, 2351. FM sweep modulation. RFI is present to left and right of the HAARP transmitter frequency in the waterfall. HAARP settings 4.5 and 3.25 MHz.

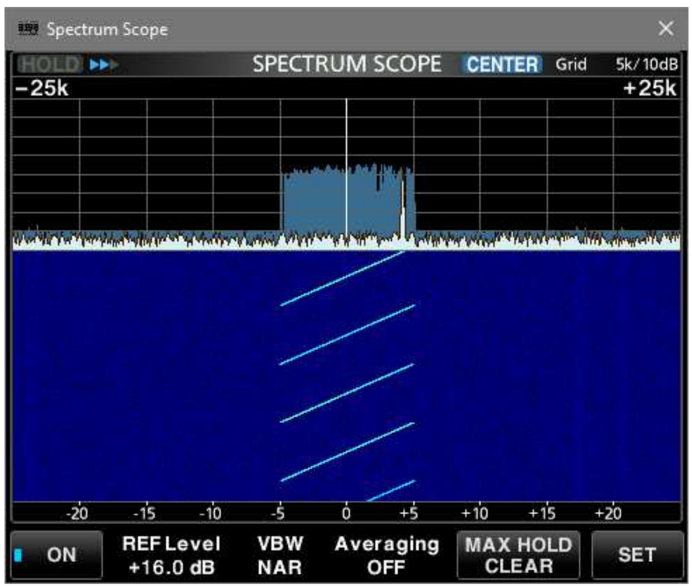



Cloud-IQ, 4.50 MHz, 20 kHz span, 3 December, 2353. Similar to previous except a narrower span is shown here. HAARP settings 4.5 and 3.2.5 MHz

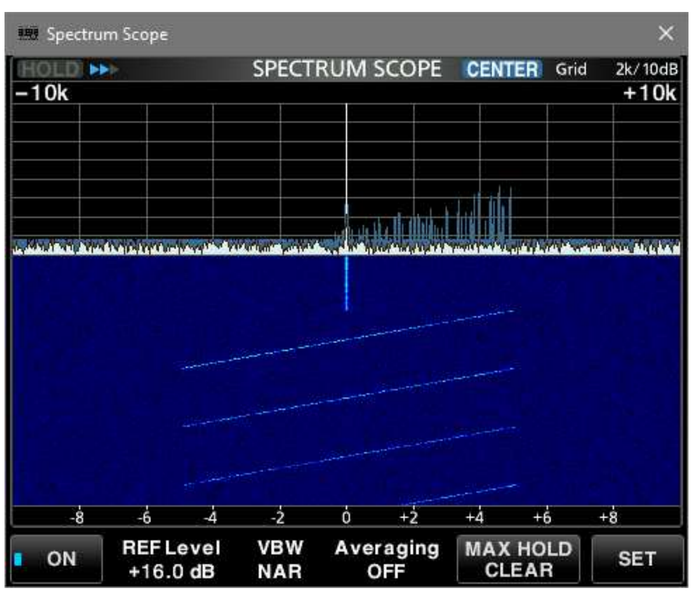



Cloud-IQ, 4.50 MHz, 15 kHz span, 4 December, 0004. HAARP settings 4.5 and 3.25 MHz. Same as previous.

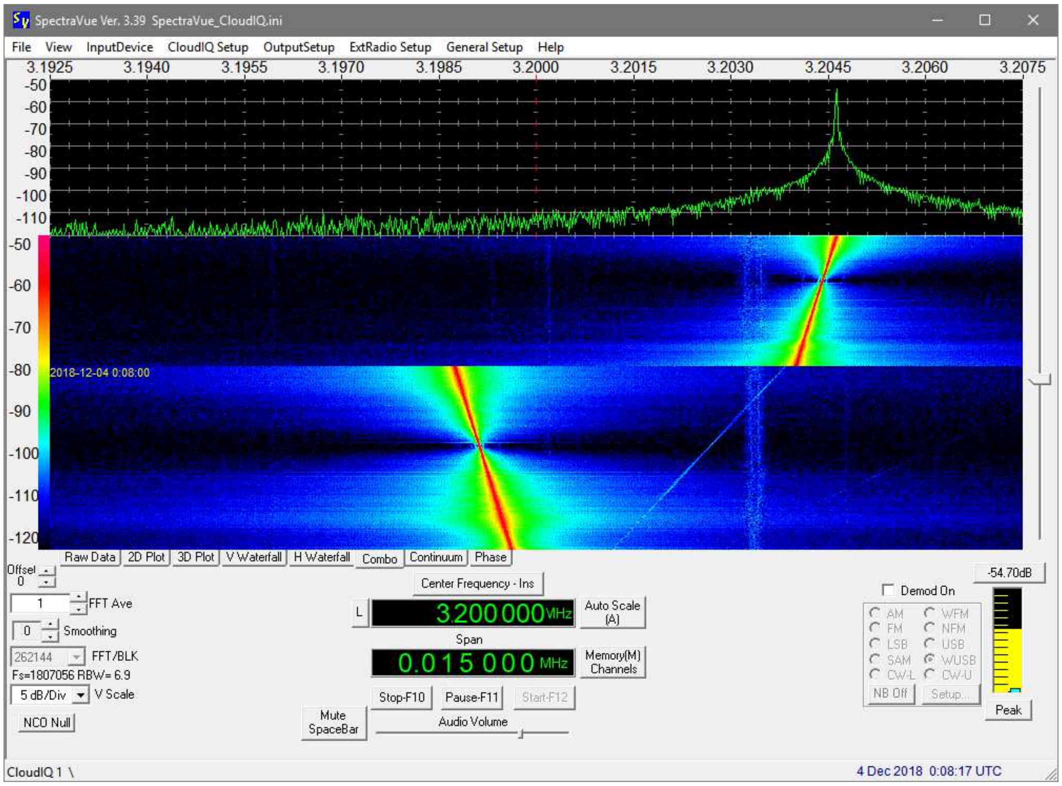

R-8600 receiver settings, 4.50 MHz, 4 December, 0004.



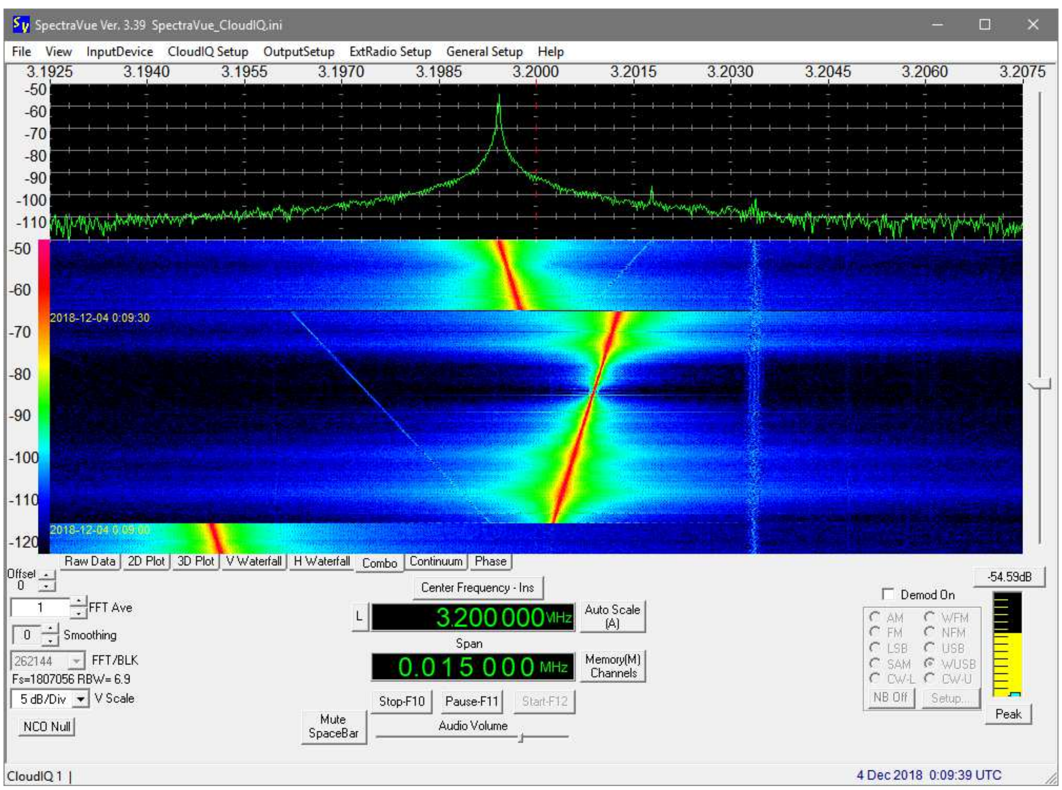

R-8600, 4.50 MHz, 50 kHz span, 4 December, 0004. FM sweep modulation.



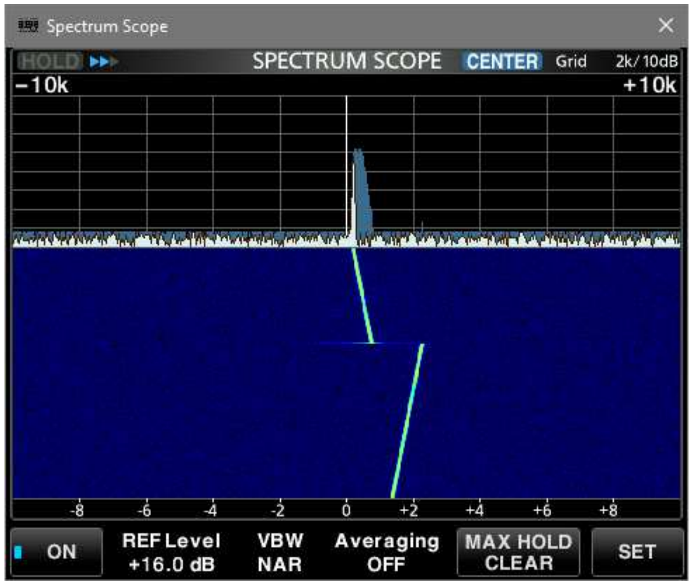

R-8600, 4.50 MHz, 20 kHz span, 4 December, 0004. Similar to previous except narrower span.



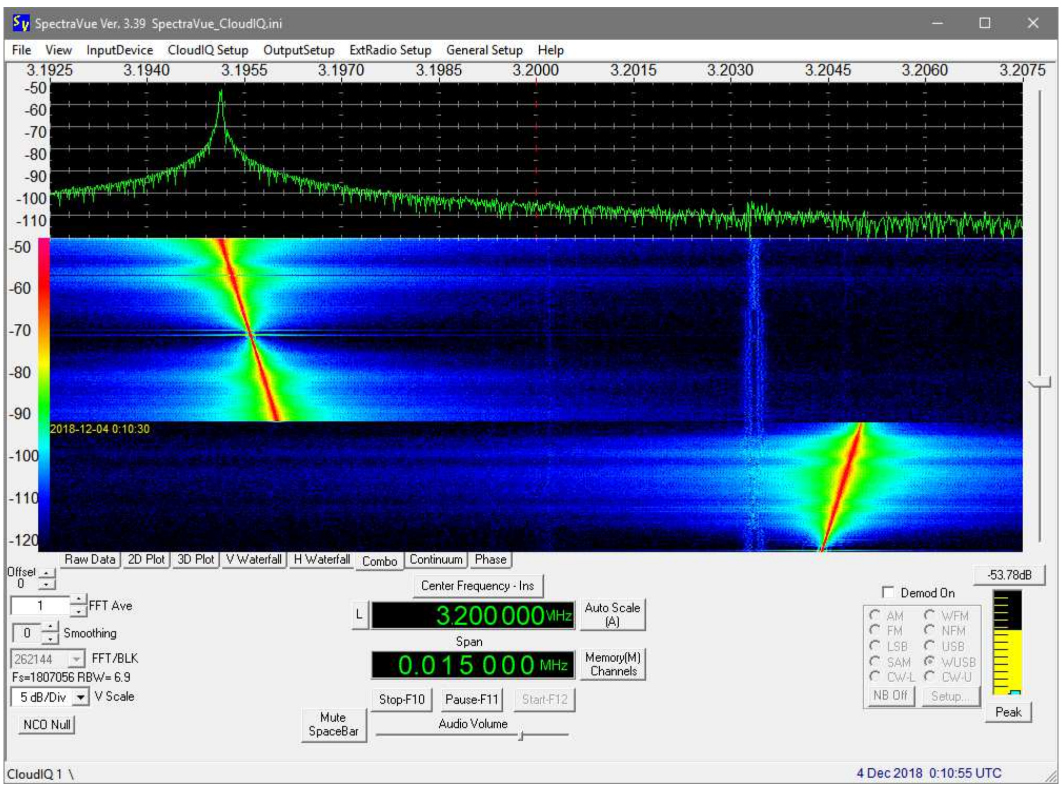

Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0008. HAARP settings 3.2 and 6.4 MHz.



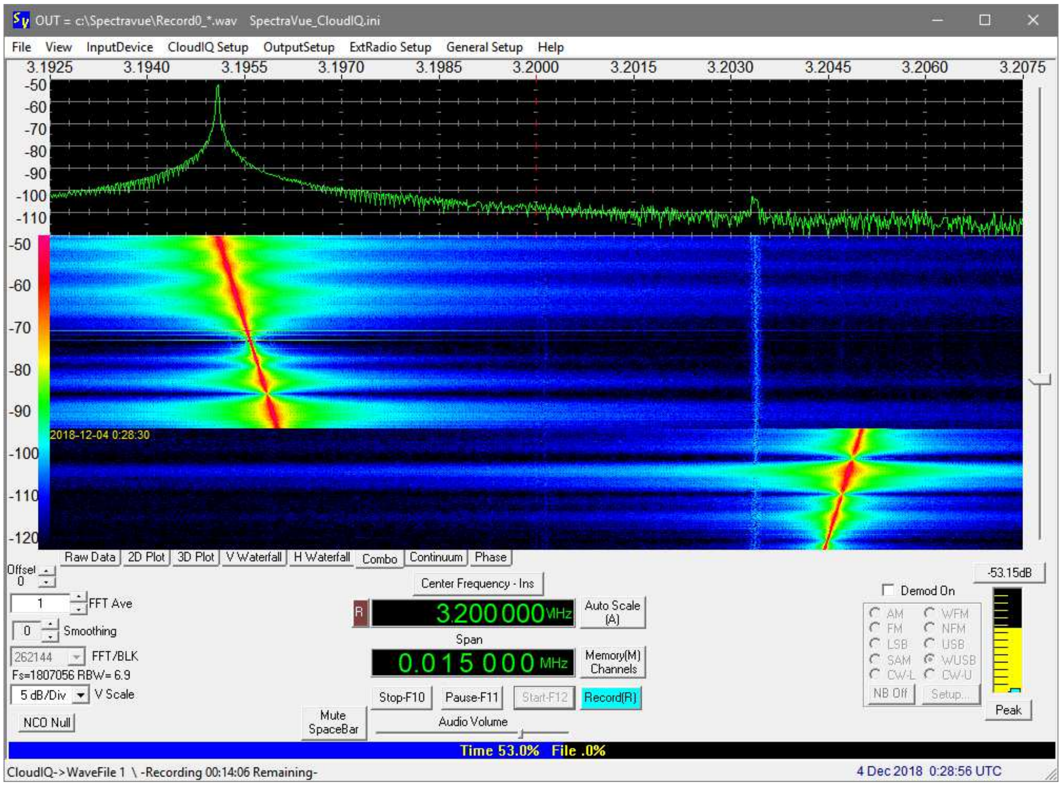

Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0009. HAARP settings 3.2 and 6.4 MHz.




R-8600, 3.20 MHz, 4 December, 0009. HAARP settings 3.2 and 6.4 MHz.

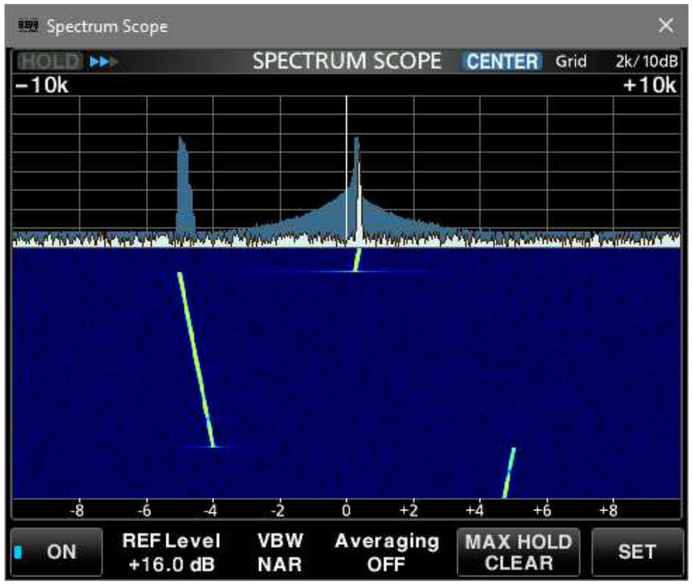



Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0010. HAARP settings 3.2 and 6.4 MHz.

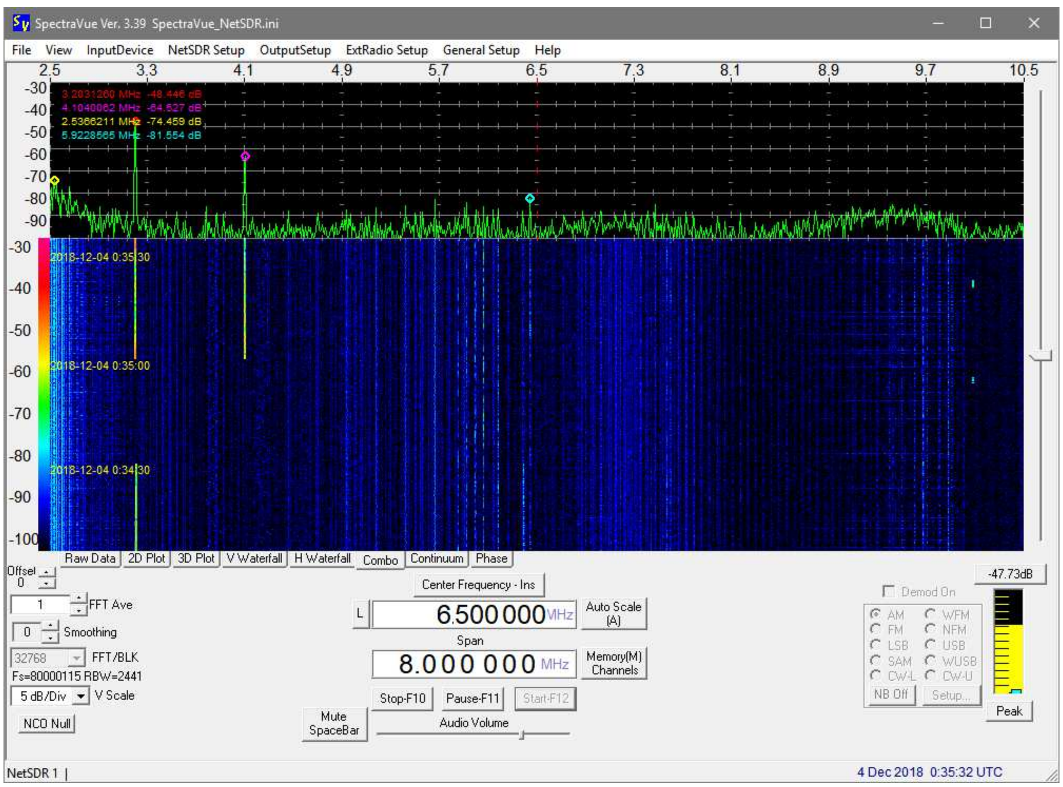



Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0028. HAARP settings 3.2 and 6.4 MHz.

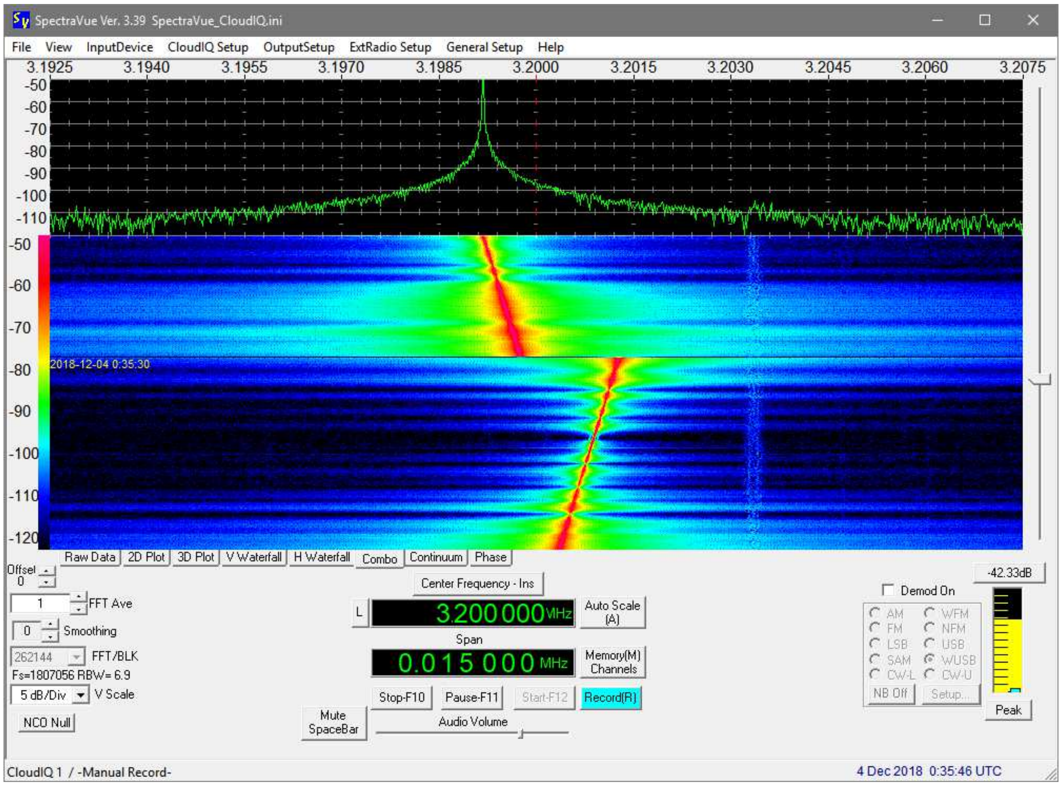

R-8600 receiver settings, 3.20 MHz, 4 December, 0028.



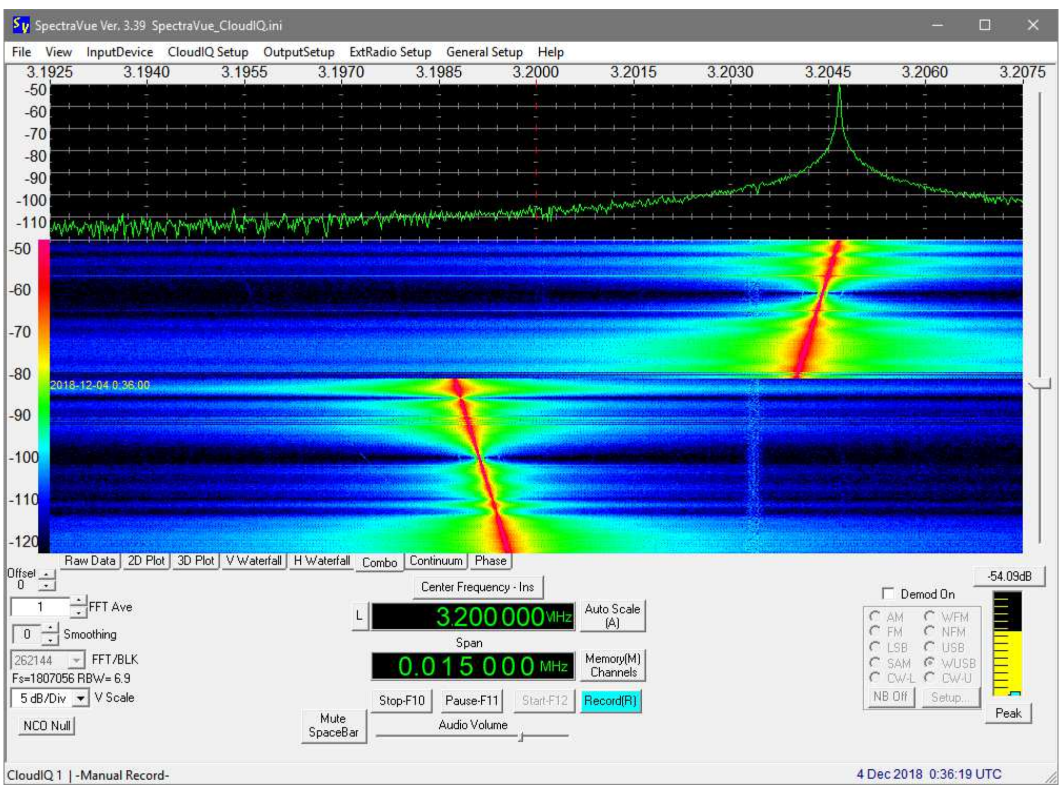

R-8600, 3.20 MHz, 20 kHz span, 4 December, 0028. HAARP settings 3.2 and 6.4 MHz.



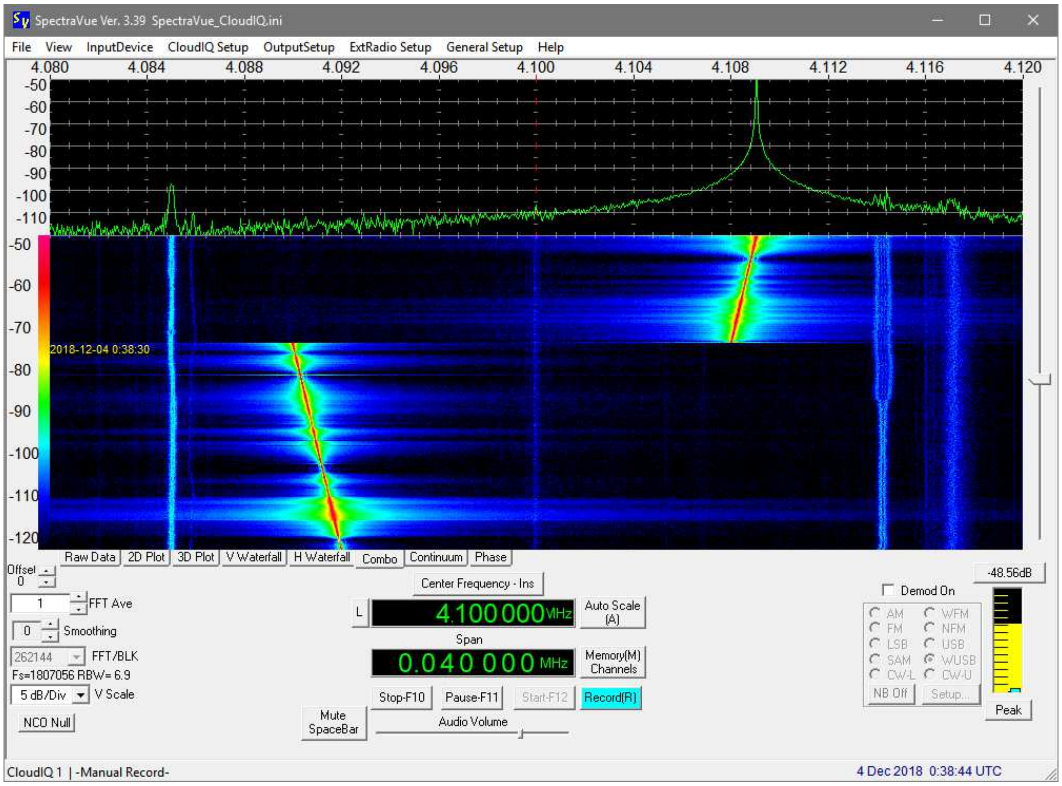

NetSDR, 6.5 MHz , 4 December, 0035. Note that the HAARP transmitter frequency $f_0$ = 3.2 MHz. Unknown signal at 4.1 MHz.



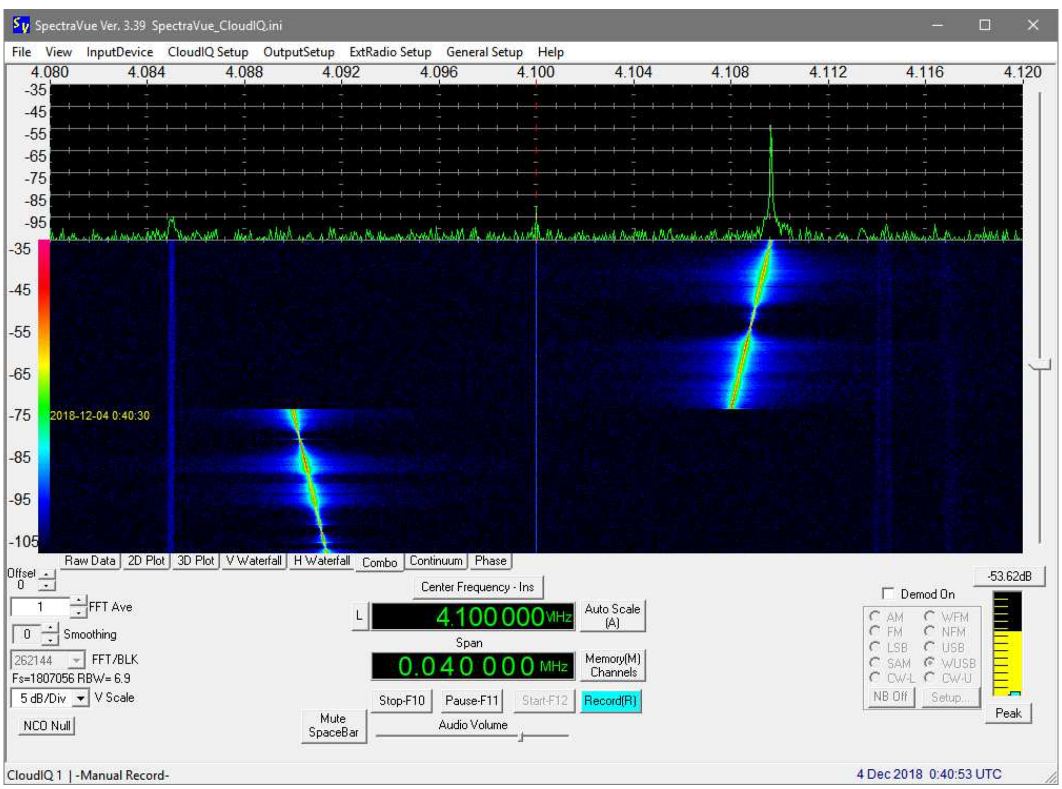
Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0035. HAARP settings 3.2 and 4.1 MHz.



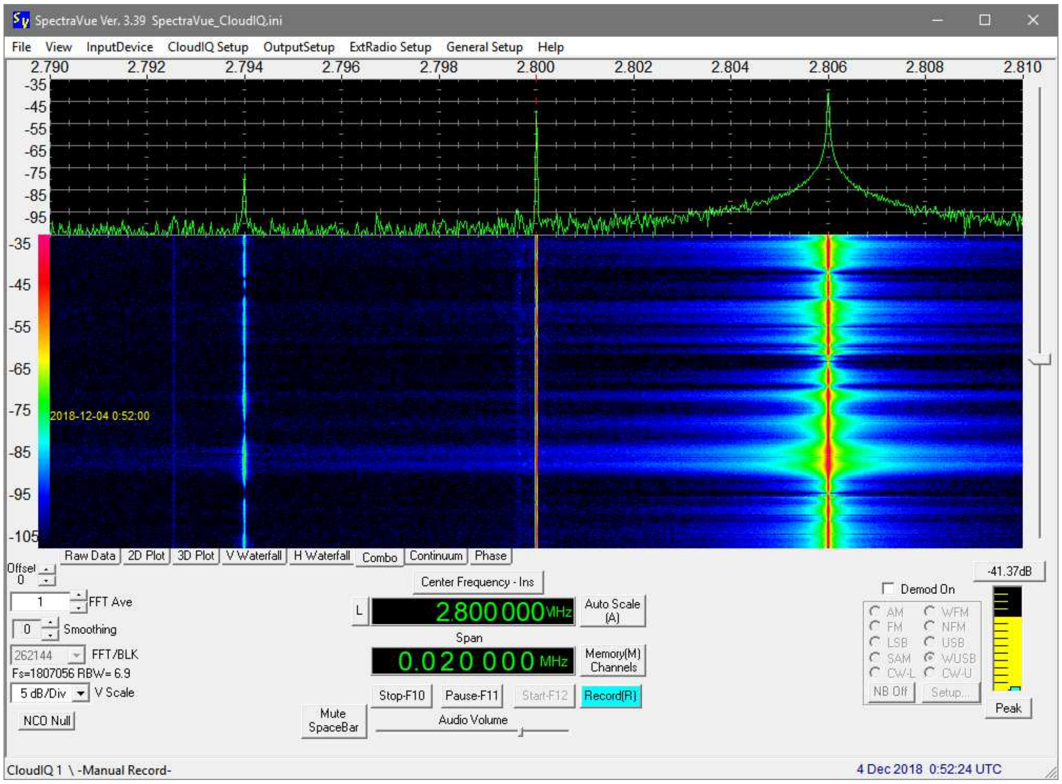
Cloud-IQ, 3.20 MHz, 15 kHz span, 4 December, 0036. HAARP settings 3.2 and 4.1 MHz.




Cloud-IQ, 4.10 MHz, 40 kHz span, 4 December, 0038. HAARP settings 3.2 and 4.1 MHz?

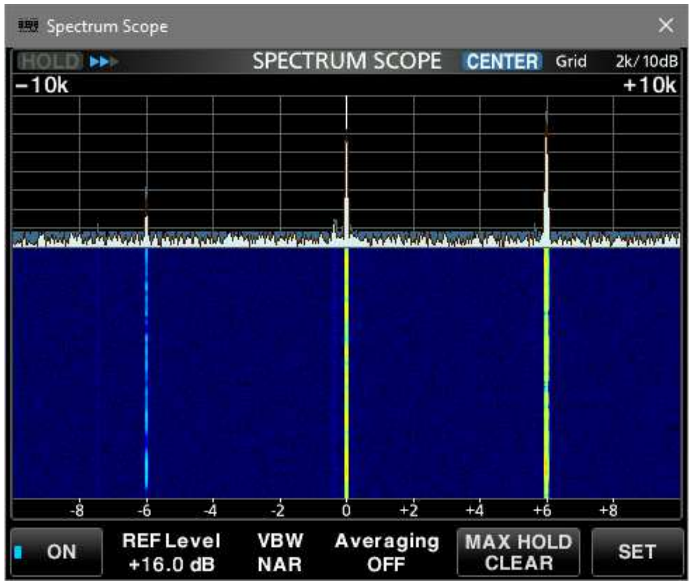



Cloud-IQ, 4.10 MHz, 40 kHz span, 4 December, 0040. HAARP settings 3.2 and 4.1 MHz.

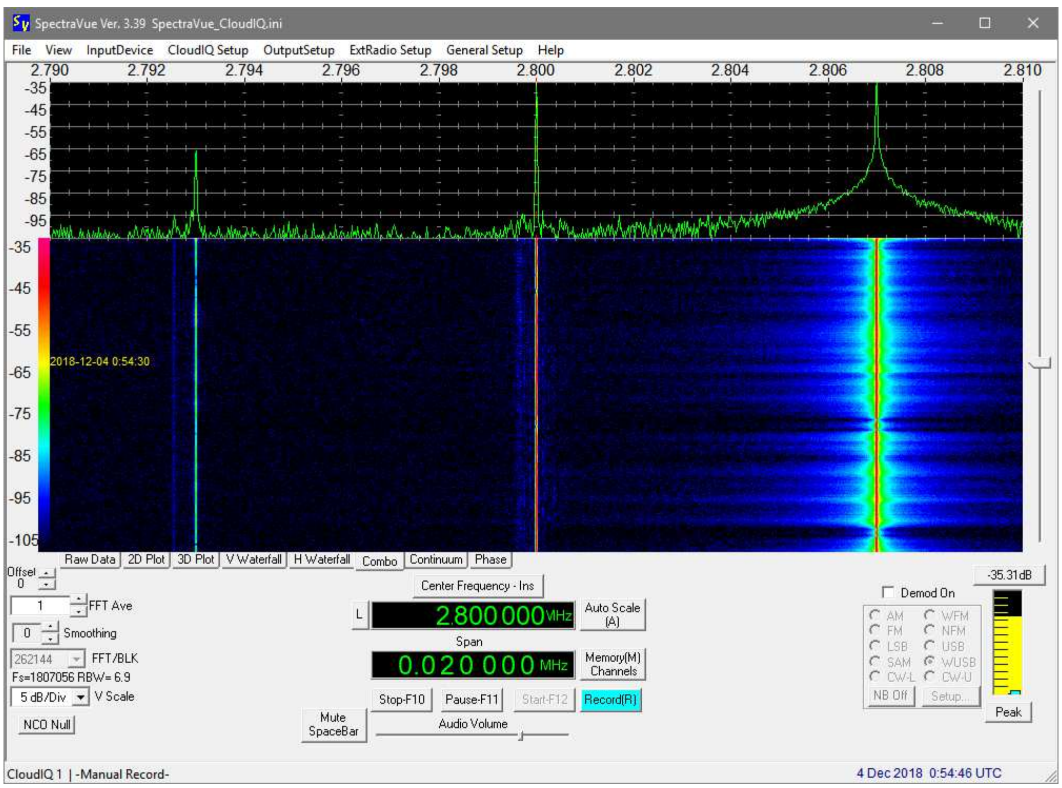



Cloud-IQ, 2.80 MHz, 20 kHz span, 4 December, 0052. HAARP settings 2.8 MHz.

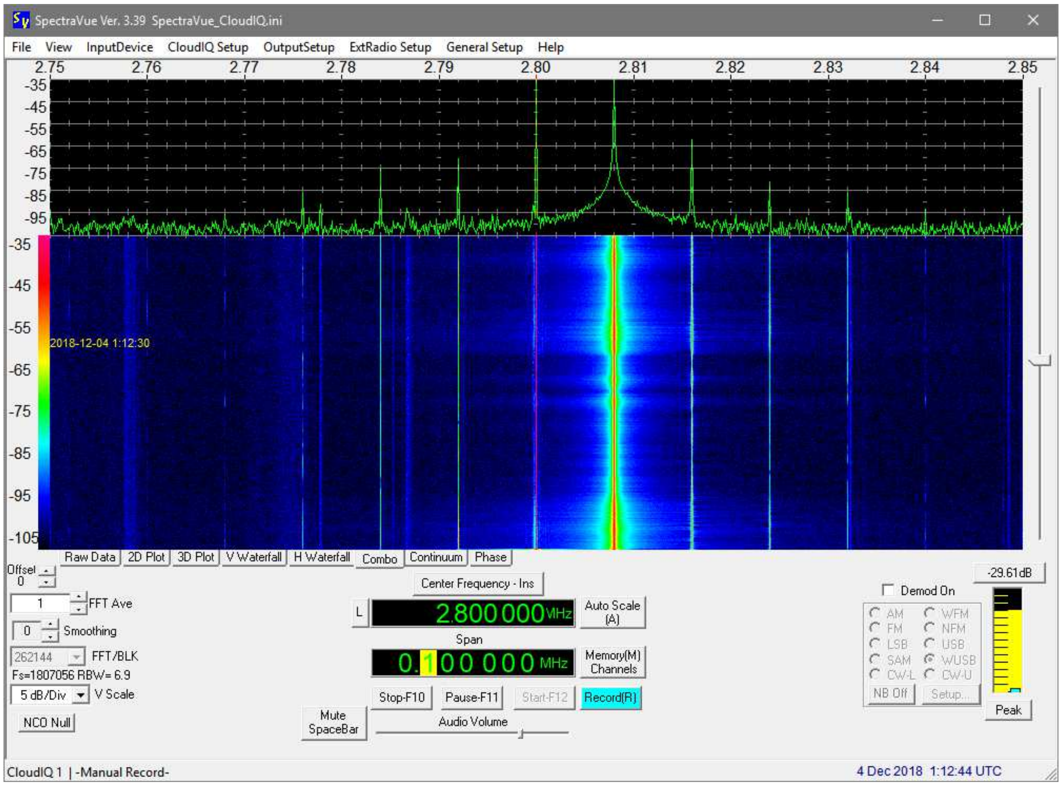

R-8600 receiver settings, 2.80 MHz, 4 December, 0052.




R-8600, 2.80 MHz, 20 kHz span, 4 December, 0052. HAARP settings 2.8 MHz.

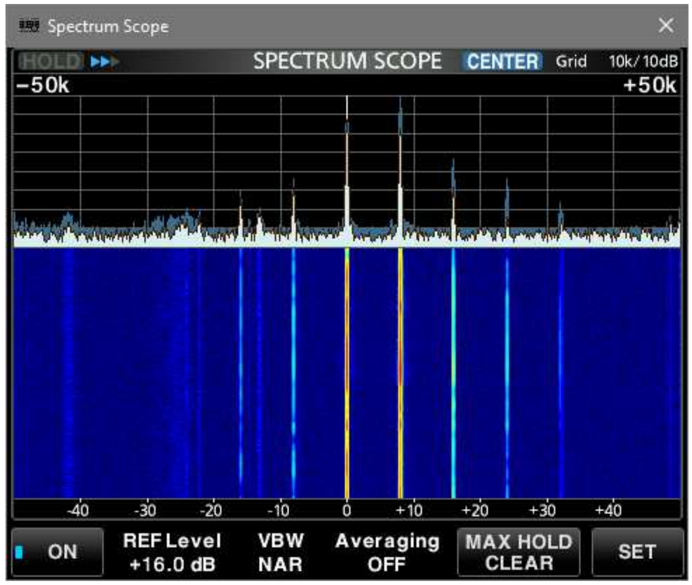



Cloud-IQ, 2.80 MHz, 20 kHz span, 4 December, 0054. Note carriers at 2.8000 ±0.007 MHz with stronger reception at 2.807 MHz weaker reception at 2.793 MHz. HAARP setting 2.8 MHz.

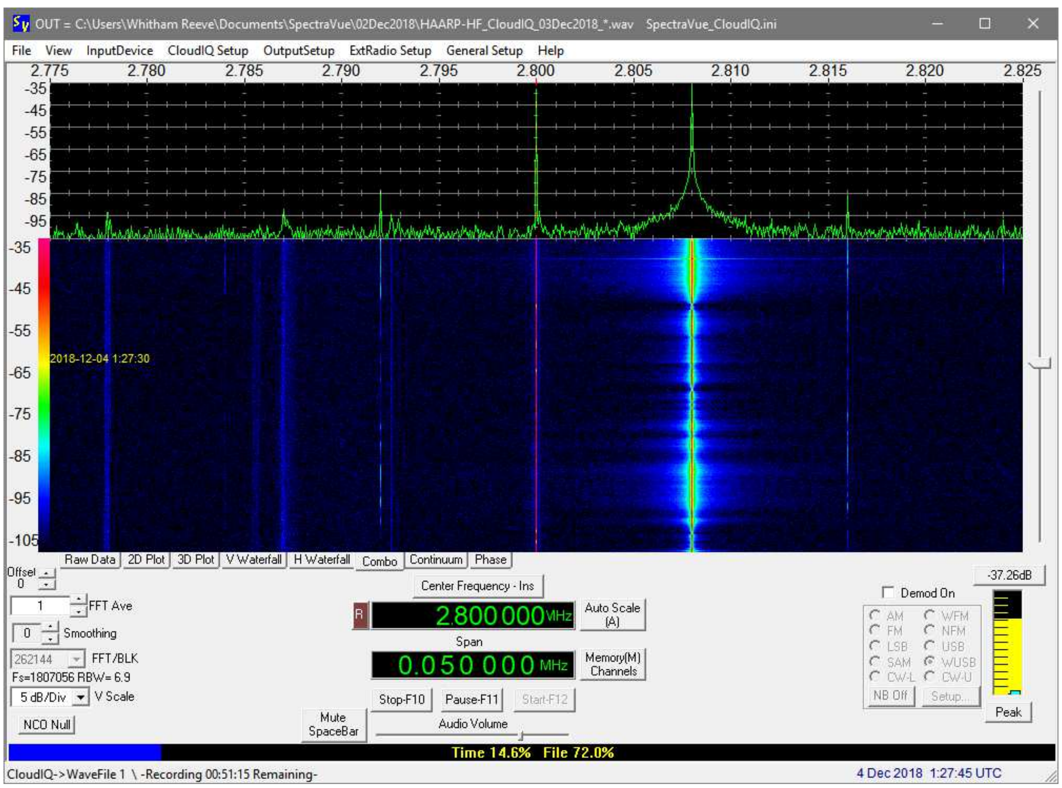



Cloud-IQ, 2.80 MHz, 100 kHz span, 4 December, 0112. HAARP setting 2.8 MHz. Multi-carrier with 8 kHz spacing. Carrier at 2.808 MHz much stronger for unknown reasons.


R-8600 receiver settings, 2.80 MHz, 4 December, 0112.

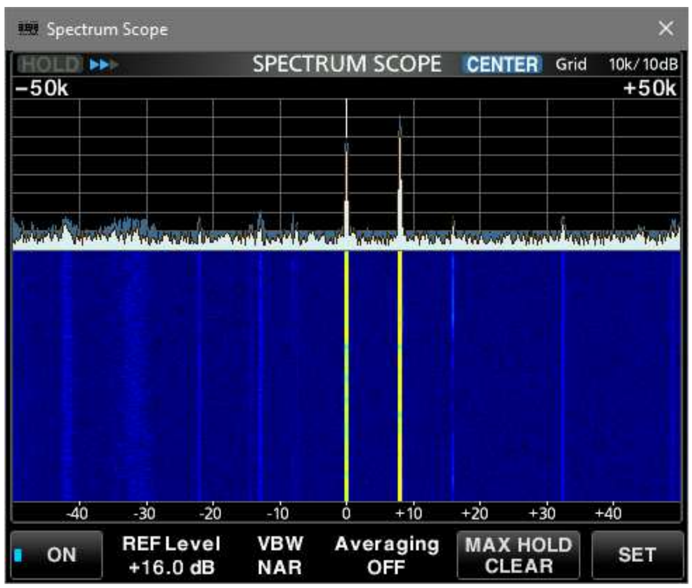



R-8600, 2.80 MHz, 100 kHz span, 4 December, 0112. HAARP setting 2.8 MHz. See previous spectrogram.

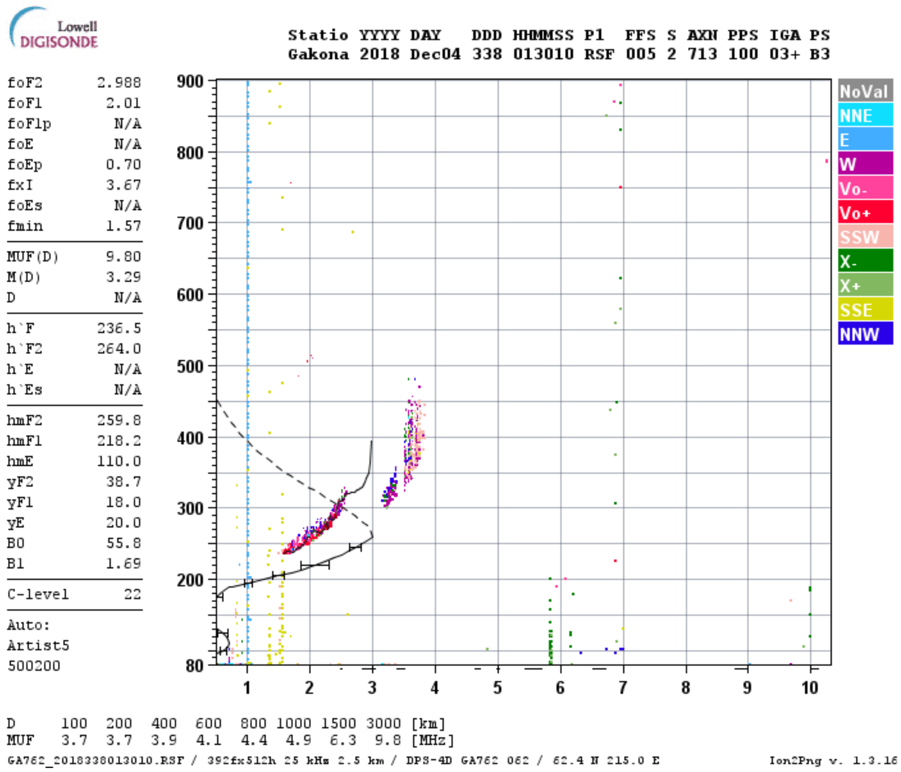



Cloud-IQ, 2.80 MHz, 50 kHz span, 4 December, 0127. HAARP setting 2.8 MHz. Why carrier at 2.808 MHz is so much stronger is unknown.

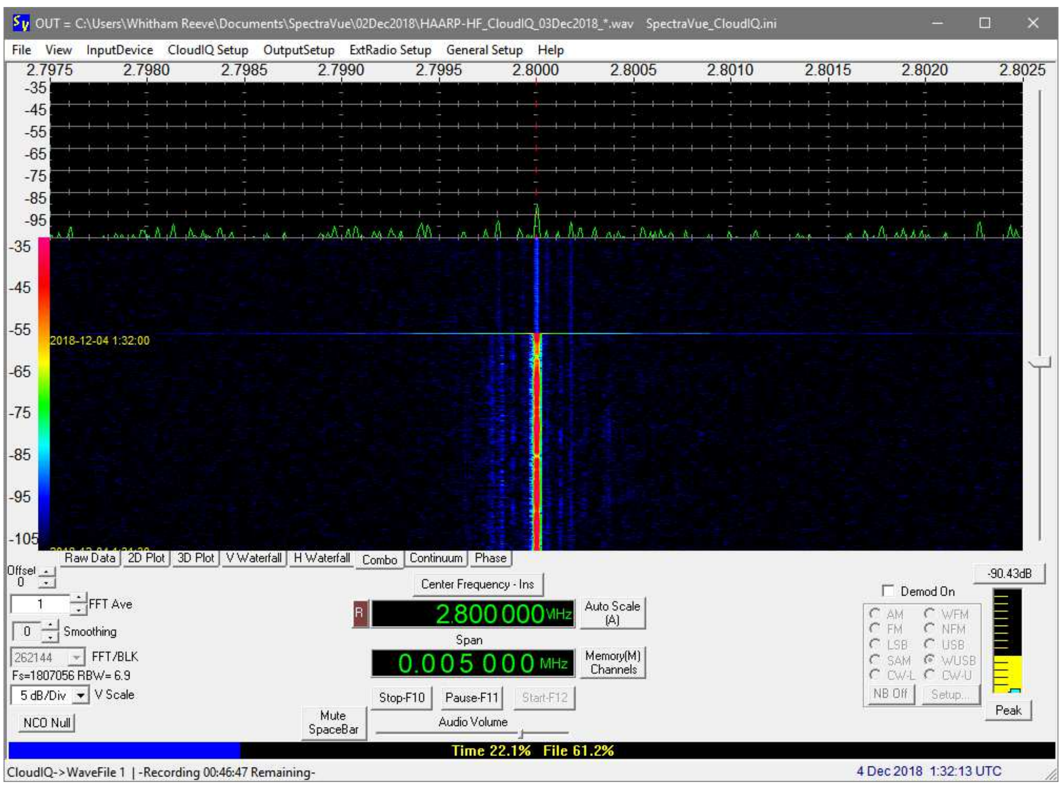

R-8600 receiver settings, 2.80 MHz, 4 December, 0127.



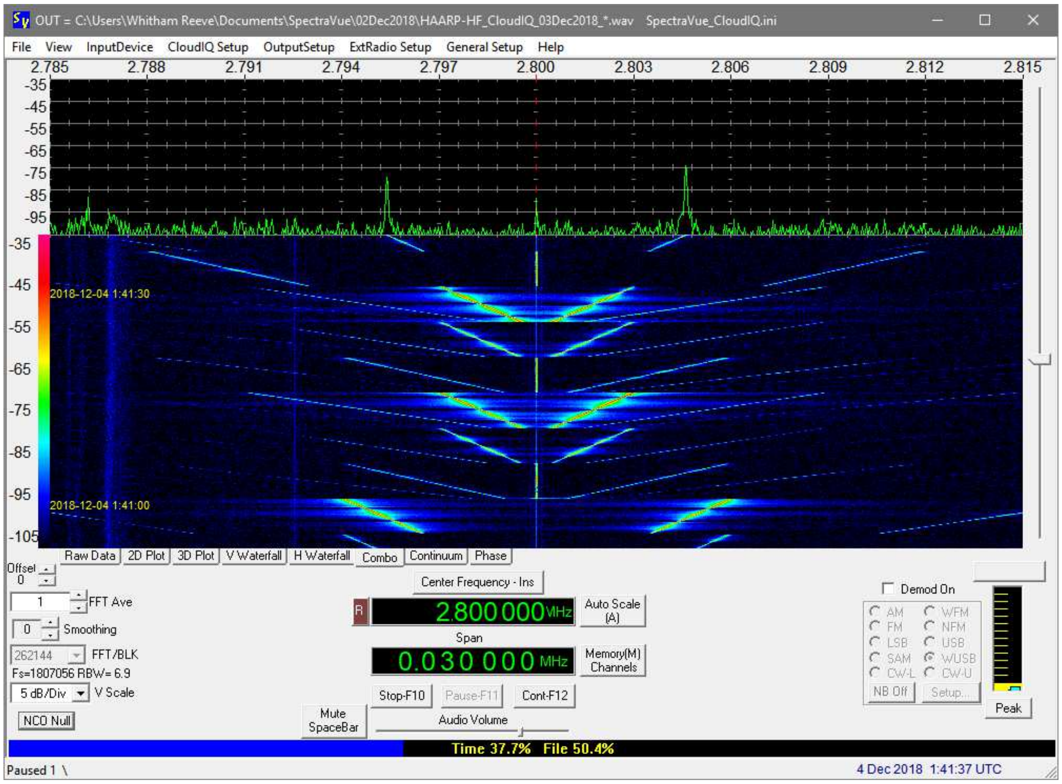

R-8600, 2.80 MHz, 100 kHz span, 4 December, 0127. HAARP setting 2.8 MHz. Second carrier at 2.808 MHz. See previous spectrogram.



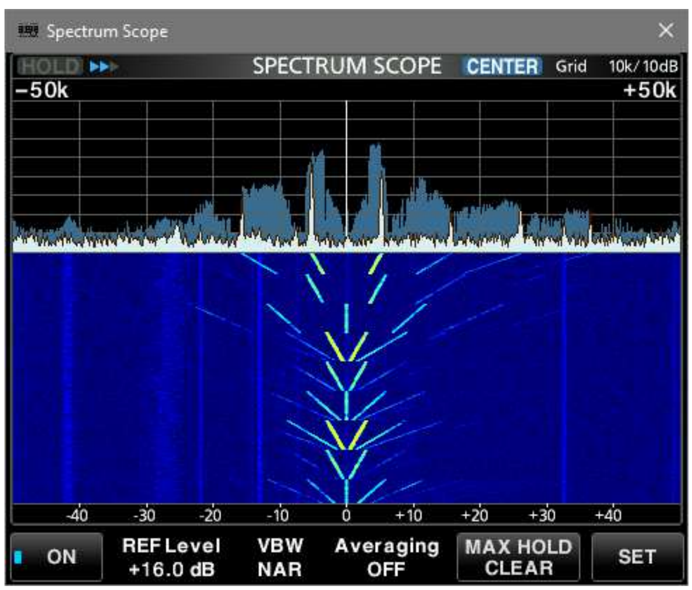
Gakona Ionogram, 4 December, 0130.



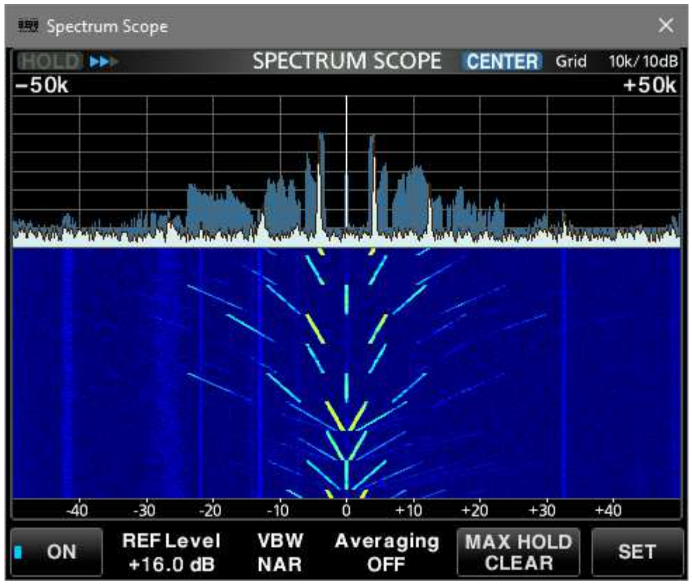
Cloud-IQ, 2.80 MHz, 5 kHz span, 4 December, 0132. HAARP setting 2.8 MHz. The horizontal line at end of transmission at 0132:00 is an artifact of signal processing.



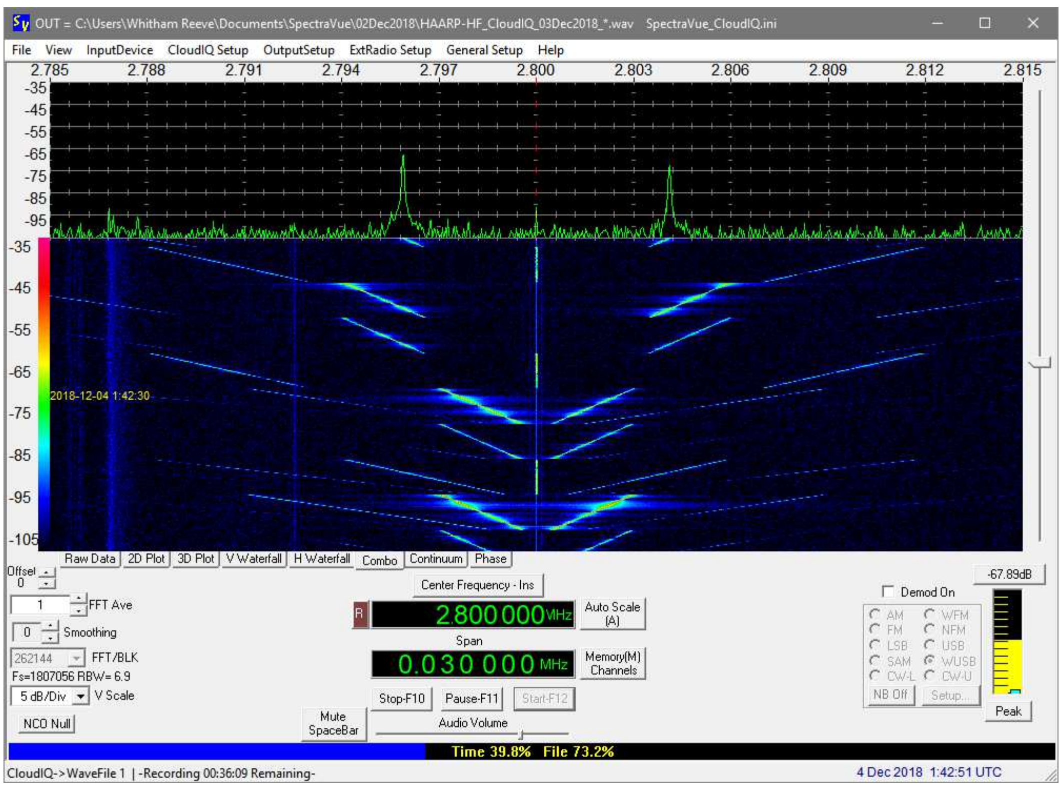

Cloud-IQ, 2.80 MHz, 30 kHz span, 4 December, 0141. HAARP setting 2.8 MHz. Chrip modulation.



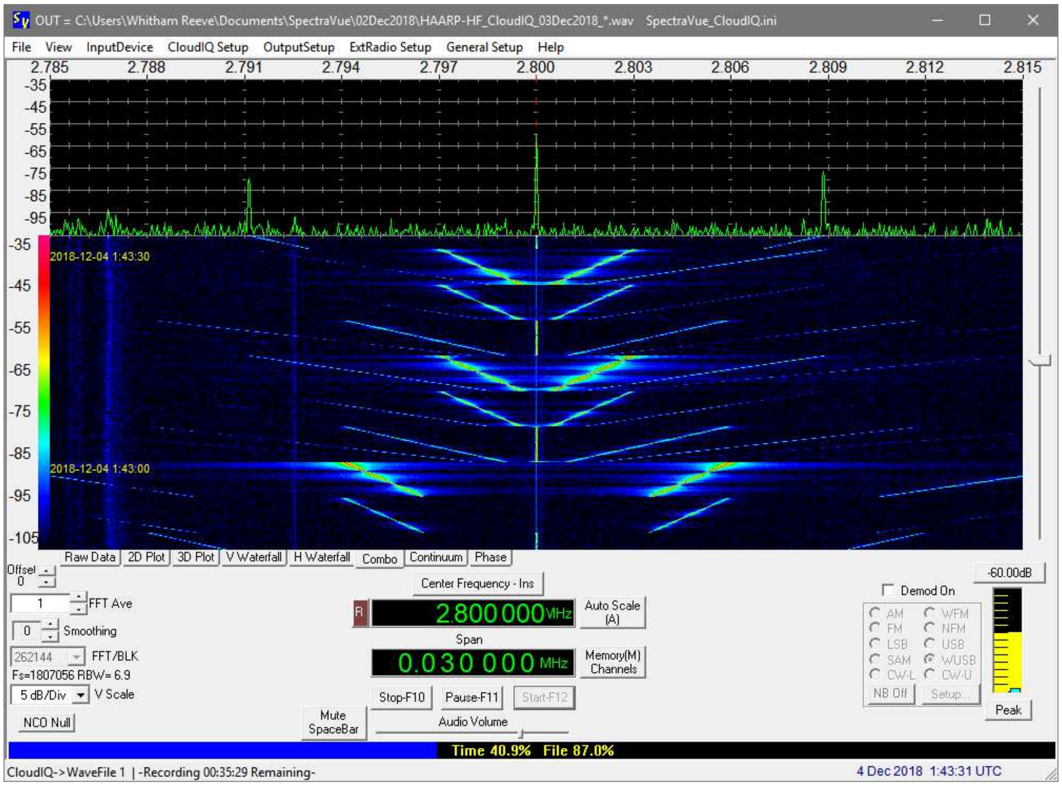

R-8600, 2.80 MHz, 100 kHz span, 4 December, 0141. HAARP setting 2.8 MHz. Chrip modulation.



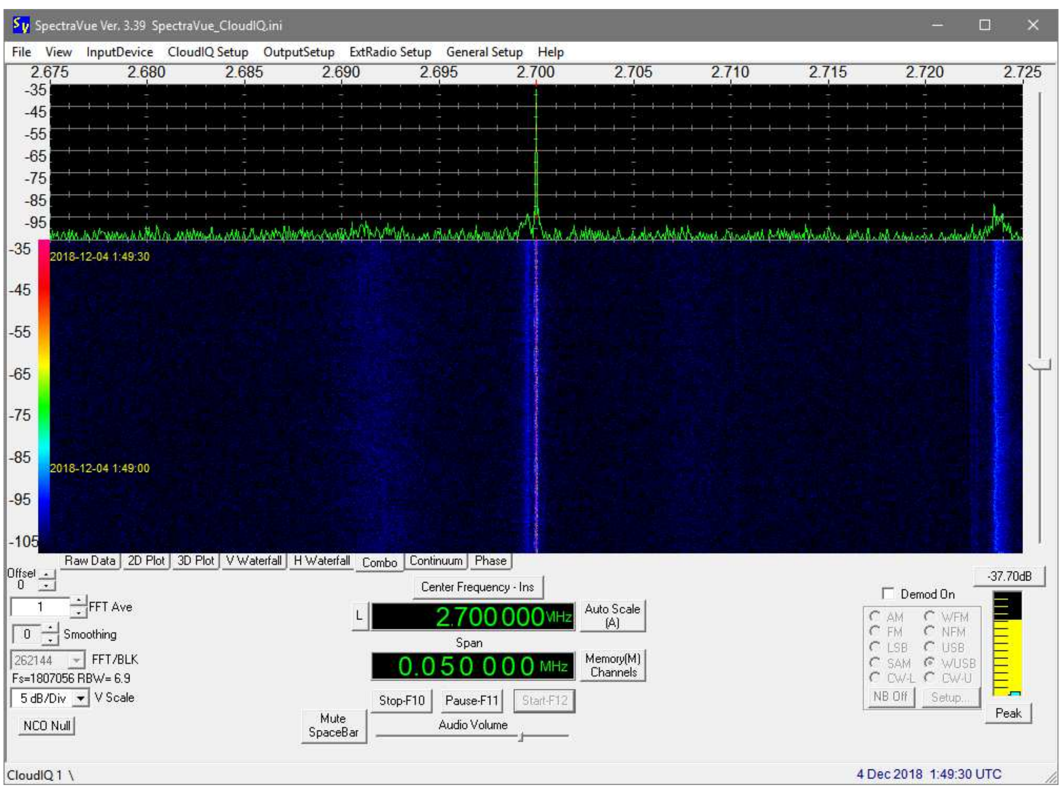

R-8600, 2.80 MHz, 100 kHz span, 4 December, 0141. HAARP setting 2.8 MHz. Chirp modulation.




Cloud-IQ, 2.80 MHz, 30 kHz span, 4 December, 0142. HAARP setting 2.8 MHz. Chirp modulation.

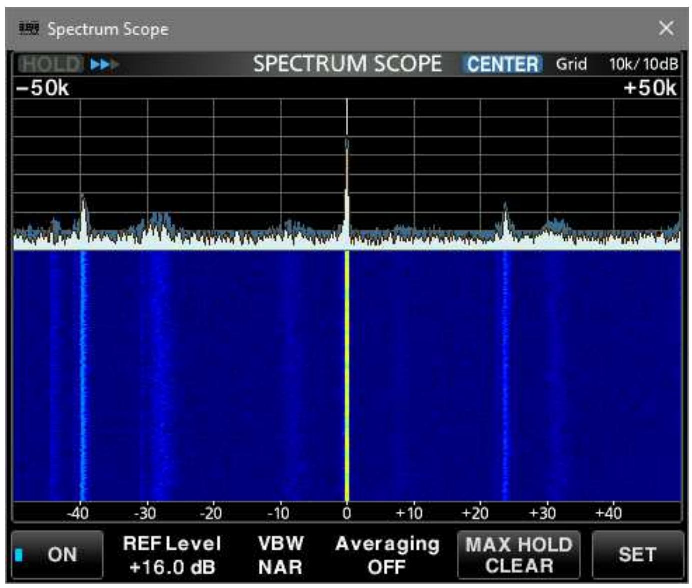



Cloud-IQ, 2.80 MHz, 30 kHz span, 4 December, 0143. HAARP setting 2.8 MHz. Chirp modulation.

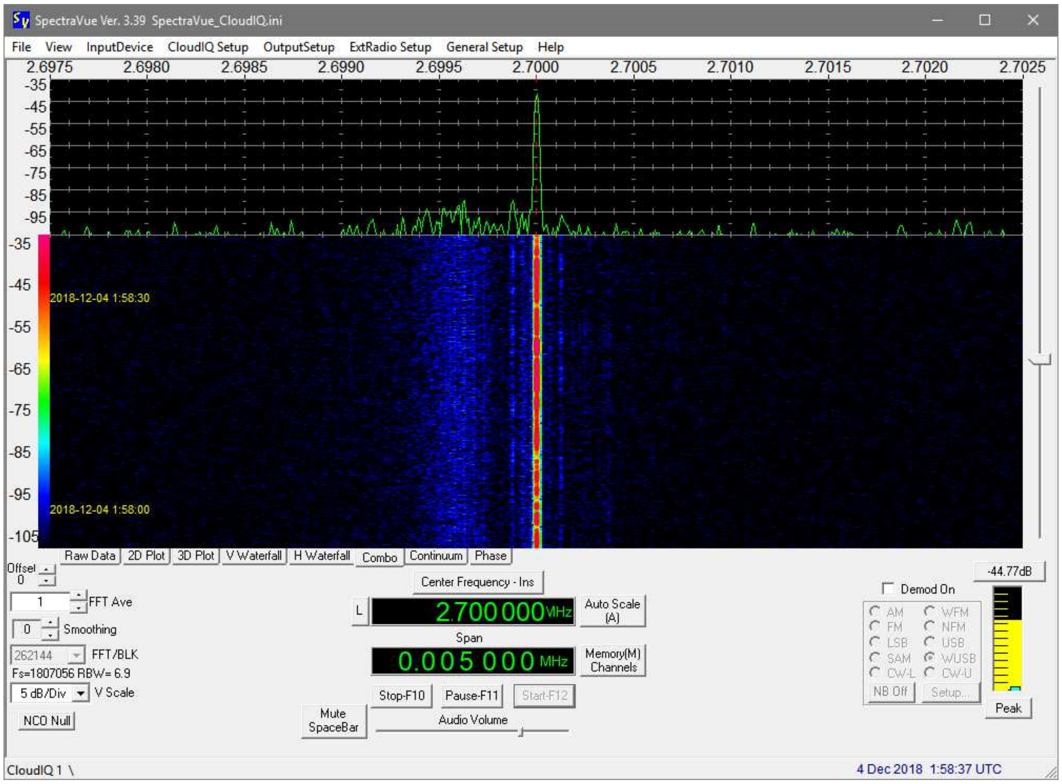



Cloud-IQ, 2.70 MHz, 50 kHz span, 4 December, 0149.


R-8600 receiver settings, 2.70 MHz, 4 December, 0149.

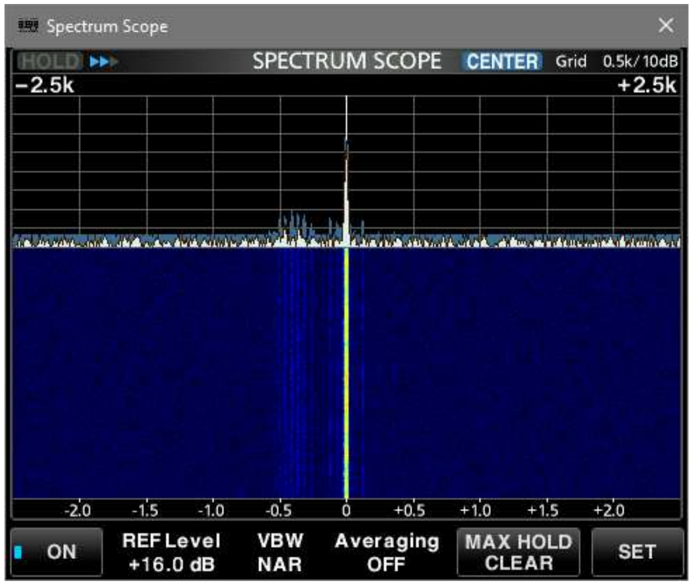



R-8600, 2.70 MHz, 100 kHz span, 4 December, 1049.




Cloud-IQ, 2.70 MHz, 5 kHz span, 4 December, 0158.


R-8600 receiver settings, 2.70 MHz, 4 December, 0158.




R-8600, 2.70 MHz, 5 kHz span, 4 December, 0158.

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## 6. Discussion

One aspect of HAARP radio observations that I have not yet explored is the relationship between the received signals and the IRI radiation patterns. The main IRI beam generally is pointed within 15° of vertical, but some RF power ends up in sidelobes. Even if sidelobe radiation is very small, the immense power fed into the IRI antenna array could result in significant groundwave and skywave propagation. My Anchorage observatory is within reasonable distance from HAARP (285 km) for groundwaves. On the other hand, NVIS also is a possibility, so I still have not resolved the propagation mechanism. I believe that skywave propagation is unlikely.

Sometimes, the received signal power was very high and I had to set the receiver RF input attenuators to 10, 20 or 30 dB to reduce the chance of receiver overload. However, even without the attenuators I never saw the overload indication on the SDR software.

In almost all observations, the transmitted signal was easy to find in spite of some strong and persistent local radio frequency interference. Some interference was relatively wide and drifting. Other interference appeared on spectrograms as narrowband combs. Both wide and narrowband interference appeared and disappeared at random times, sometimes lasting a few minutes and other times lasting a few hours.

A few times I confused the marine weather fax (*RadioFax*) transmitted by the US Coast Guard station from Kodiak Island about 420 km south-southwest of Anchorage with the HAARP signal. This station operates under call sign KOJ and transmits 4 kW at 4.298 MHz. The received signal level at Anchorage is quite high and easily confused with HAARP in a wide spectral view.

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### 7. References and Weblinks


{DTIC} HAARP Research and Applications, 1990, Defense Technical Information Center Report ADA355641, available at: https://archive.org/details/DTIC_ADA355641

{GKNIono} https://lgdc.uml.edu/common/DIDBYearListForStation?ursiCode=GA762

{GCMap} http://www.gcmap.com/mapui?P=5KS-GKN

{Reeve14-1} Reeve, W., Position, Distance and Bearing Calculations, 2014, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_PosDistBrngCalcs.pdf

{Reeve14-2} Reeve, W., Ionosphere-Distance Calculations, 2014, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_Ionosphere-DistanceCalc.pdf

{Reeve16} Reeve, W., HAARP Antenna Array ~ Photographic Tour 2016, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_HAARP16.pdf

{Reeve17} Reeve, W., HAARP Diagnostic Instruments ~ Photographic Tour 2017, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_HAARP17.pdf

{Reeve18-1} Reeve, W., HAARP: Radio Observations of the HAARP Research Campaign in April 2018, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_HAARP_Obsv_Apr2018.pdf

{Reeve18-2} Reeve, W, HAARP: Radio Observations of the HAARP Summer 2018 Research Campaign, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_HAARP_Obsv_Jul2018.pdf

{Reeve18-3} Reeve, W., Packaging a Bias-Tee Module, 2018, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_BiasTeePkg.pdf

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[QSTAug99] HAARP Listening Tests Go Off with a Hitch, QST, pg 72, August 1999

[Workshop] Auroral Research Workshop: Opportunities for HAARP, Sponsored by the White House Office of Science and Technology Policy (OSTP), January 9, 2014, Arlington, VA


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Author: Whitham Reeve is a contributing editor for the SARA journal, Radio Astronomy. He obtained B.S. and M.S. degrees in Electrical Engineering at University of Alaska Fairbanks, USA. He worked as a professional engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and now manufactures electronic equipment used in radio astronomy. He has lived in Anchorage, Alaska his entire life. Email contact: whitreeve@gmail.com


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Author: Whitham D. Reeve



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0.2 (Added last of spectrum images, 14 Dec 2018)
0.3 (Revised phenomena and spectra captions, 08 Mar 2019)
0.4 (Added audio waveform/spectrogram images, 10 Mar 2019)
0.5 (Minor revisions prior to distribution, 12 Mar 2019)
0.6 (Final revisions and distribution, 14 Mar 2019)

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