Radio Observations of the HAARP Research Campaign in April 2018

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1. Introduction

The *High Frequency Active Auroral Research Program* (HAARP) in interior Alaska includes a very powerful HF transmitter and antenna system (figure 1), which is used to study *aeronomy*, the science of Earth's upper atmosphere – the ionosphere. Some of the phenomena studied are scintillations, magnetic field-aligned plasma irregularities, artificial and natural atmospheric airglow (aurora), stimulated electromagnetic emissions, plasma waves, and radio-enhanced ionization. The enormous amounts of radio frequency energy transmitted by the HAARP to heat Earth's ionosphere above the site during research campaigns can propagate over long distances.

Figure 1 ~ The HAARP crossed-dipole antenna array for the Ionospheric Research Instrument. Image © 2016 W. Reeve

This article describes my radio observations of the HAARP research campaign on 6 – 14 April 2018. I easily detected the HAARP transmissions at my Anchorage observatory, a distance of about 285 km from HAARP. Observers many thousands of kilometers away in several of the lower-48 states in the USA and in Canada and Europe also detected the transmissions. The propagation mode to the very distant stations most likely was multi-hop skywave but to my station the mode could have been groundwave from an antenna sidelobe or near vertical incidence skywave (NVIS). I hope to determine the actual mode (or modes) during future HAARP campaigns.

I am not associated with HAARP but have learned some of its operational details while pursuing radio astronomy over the last 10 years. I used data produced by the original program when it was run by the US Air Force and participated as a voluntary observer in a HAARP experiment in January 2008, the *Lunar Echo Experiment* {ReeveLEE}. Later, I toured the HAARP facility in the early autumns of 2016 and 2017 and produced photographic reports of the HAARP facilities; see {Reeve16} and {Reeve17}.

Note: Internet links and references in braces { } are provided in **section 6**.

The *Ionospheric Research Instrument* (IRI) is the primary instrument at HAARP, and its job is to heat and excite electrons in the ionosphere above the site (figure 2). Measurements of the effects are made by the other *diagnostic instruments*, most located at the facility or within 10 km. The IRI antenna consists of 180 crossed-dipoles. Each dipole of the crossed-dipole assembly is associated with a 10 kW transmitter giving 3.6 MW total transmitted power. The US Air Force removed the transmitter tubes before transferring the facility in mid-2015 to University of Alaska Fairbanks – Geophysical Institute (UAF-GI) but most have been replaced. The transmitter presently operates at about 80% capacity, or 2.9 MW. The IRI operates in the frequency range 2.7 to 10 MHz and supports AM, SSB, DSB, CW, FM, PM and pulse modulations with single and multiple carriers. The transmitter is model D616-G by Continental Electronics Corporation (datasheet at {CEC-TX}).

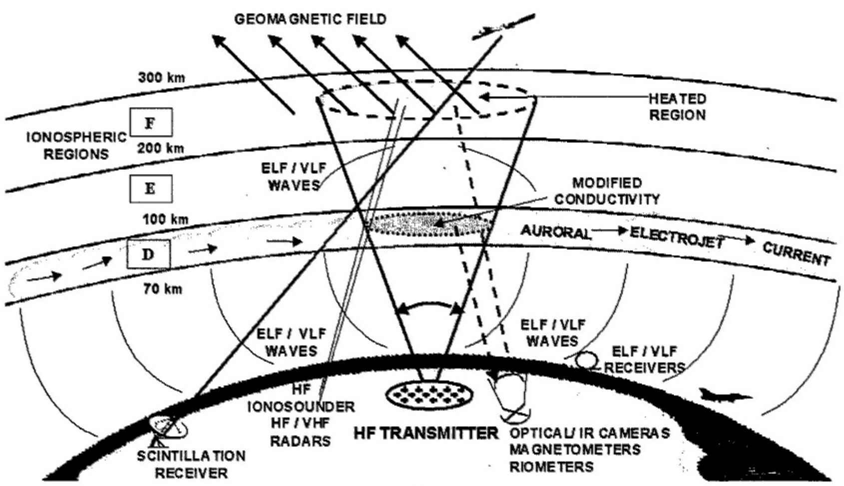

Figure 2 ~ Schematic showing HAARP's diagnostic instruments and how the IRI transmitted energy affects the various ionospheric regions. Diagnostic instruments cover a very wide frequency range, from extremely low frequencies (ELF) to ultra-high frequencies (UHF). Of particular interest is heating of the ionosphere's F-region between approximately 200 and 300 km altitude. Almost all of the instruments are located at the HAARP facility, but some are off-site. Image source: {HAARP02}

A typical HAARP research campaign can span the full IRI frequency range between 2.7 and 10.0 MHz. The specific frequencies are chosen based on the conditions in the local ionosphere in terms of the D-region absorption and F-region characteristics while considering the potential for interference to other spectrum services. The ionosphere naturally changes quite quickly and these changes are tracked in near real-time with ionograms during any given campaign (figure 3). The ionograms are produced by a Lowell Digisonde International DPS4D ionosonde located about 1 km from the IRI antenna center. The ionosonde is described in {Reeve17} and {Digisonde}.

Many scientific papers that were produced when HAARP was run by the US Air Force are publicly available (for example, search {NASA-ADS} with keyword *HAARP* in the abstracts field). A list of scientific papers may be found at {HAARPList}.

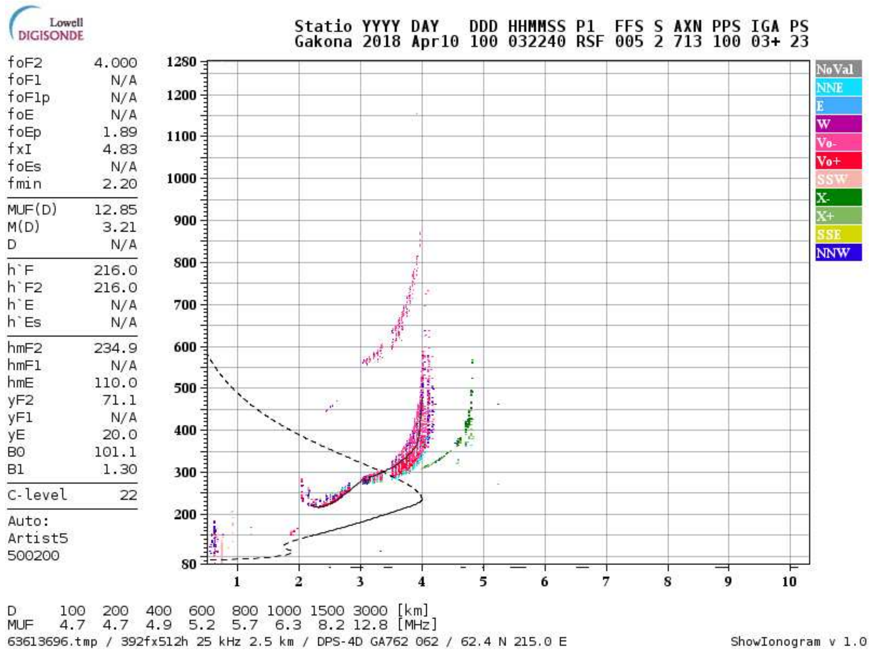

Figure 3 ~ Ionogram (also called *vertical incidence sounding*) produced by the HAARP digital ionosonde at 0322 on 10 April UTC. This was local evening about 1.5 h before sunset. Frequency (MHz) is shown on the horizontal scale at the bottom of the plot and height (km) is shown on the vertical scale to the left. This plot represents the ionosphere above the HARRP site between the afternoon and late evening transmitting sessions. As it turned out, the transmitter frequency was set to 3.400 MHz for that session. For a description of the parameters shown, see {Ionogram}. Image source: {UAF-GI_10042018}

2. Federal Communications Commission Licensing

The HAARP transmissions take place within frequency bands allocated by the US Federal Communications Commission (FCC) for many purposes. For example, I observed transmissions that overlapped fixed, land mobile, maritime mobile, aeronautical and broadcast frequency allocations. The transmissions often overlapped the US amateur radio bands from 3.5 to 4.0 MHz (80 m band) and 7.0 to 7.3 MHz (40 m band). The HAARP IRI operates under FCC *experimental research* (radio service code XR) and *experimental test* (radio service code XT) licenses including special temporary authorizations. The call sign is WI2XFX. The allowable effective radiated power (ERP) depends on the frequency but can be as high as 2.8 GW (ERP uses a dipole as the reference antenna as opposed to EIRP, or Effective Isotropic Radiated Power, which is based on an isotropic antenna). The FCC authorization requires that certain frequencies be notched out to prevent interference to specific radio services. The digital ionosonde at HAARP is licensed separately under call sign WI2XDV.

3. Amateur Involvement

An interesting aspect of the current HAARP operation is that one of its most active researchers, Dr. Chris Fallen, HAARP Chief Scientist, also is radio amateur KL3WX. It is through him that HAARP’s new owner, UAF-GI, openly supports amateur observers. Dr. Fallen uses Twitter to briefly announce research campaigns and provide near real-time commentary on the experiments as well as details about the frequencies used; see {Fallen}. His tweets before and during experiments are essential to distant observers who would like to attempt reception of very weak signals. Additional operational details are available at {HAARPOps} and {UAFHAARP}. Also, the American Radio Relay League (ARRL) usually posts announcements of the experiment dates in their weekly email newsletter, the ARRL Letter {ARRLLetter}. Amateur observers undoubtedly will find HAARP transmissions interesting and challenging.

A February 2017 experiment attempted to produce artificial aurora, called *RF-induced airglow*, with the powerful HAARP transmitter. Clouds impeded visual detection of the airglow during most of the experiment nights but there were some successes. The HAARP transmitter also was used to demonstrate the so-called *Luxembourg Effect* as a crowd-funded experiment. The Luxembourg Effect originated with Radio Luxembourg broadcasts in the 1930s when listeners heard programs transmitted simultaneously on two widely separated frequencies combined onto a single receiver frequency. It is thought that ionospheric cross-modulation (interactions in the ionosphere due to variations in the electron collision frequency) is involved in this phenomenon. Technical readers can learn more about the Luxembourg Effect at {Benson}. During the HAARP transmissions, both tones and stereo music were transmitted on separate frequencies.

The Luxembourg Effect experiment was doubly interesting because radio enthusiast Jeff Dumps, KL4IU, in the USA used *Indiegogo* to crowd-fund 12 minutes of HAARP time for the transmissions (see: {Indiegogo}). As would be expected for a remote and extremely powerful research station such as HAARP, the operating costs and consequently the fees for its use are substantial, reportedly 5 000 USD/hour. The needed 1 000 USD funds were obtained but no specific conclusions from the experiment have been posted as of May 2018.

An experiment in September 2017 also attempted to produce artificial aurora. Although clouds prevented visual detection, embedded in the HAARP transmissions were some slow-scan television (SSTV) frames. The HAARP antenna beam was pointed at an elevation angle of 75° (15° from zenith), but the SSTV frames were received in British Columbia and Colorado (about 4 000 km away), possibly by skywaves from antenna sidelobes or other propagation modes. Unfortunately, although I followed the prelude to that experiment, I was unable to make my own observations at the right time.

4. Observations during the 6 – 14 April 2018 Campaign

A research campaign was operated during the 2nd week of April to explore the full range of phenomena mentioned in section 1. Most transmissions were continuous wave (CW) with some amplitude shift keying (on-off or ASK) and frequency shift keying (FSK) modulation. No information was provided as to transmitter power but, since one of the goals was to produce artificial aurora, it was likely the maximum available power. A table gives the locations and antenna heights of the transmitting and receiving stations (table 1).

Table 1 ~ Transmitting and receiving station characteristics
(AMSL: above mean sea level; AGL: above ground level)

Station	**Latitude**	**Longitude**	**Elevation (m AMSL)**	**Antenna height (m AGL)**	**Distance (km)**
HAARP (IRI)	62° 23’ 32.7” N	145° 09’ 02.0” W	570	22	285
Anchorage	61° 11' 58.0"N	149° 57' 22.9"W	13	13	

To monitor the transmissions I used two Icom R-75 general coverage receivers in CW mode with AGC Off and an RFSpace NetSDR software defined radio receiver with *SpectraVue* software. My station also consists of several supporting subsystems and accessories (figure 4). I charted the post-detection audio output from the R-75 with the *Radio-SkyPipe II* chart recording software (figure 5). I also used *Argo* software to study received frequency deviations and other propagation phenomena. Argo was originally designed to visualize very low speed CW mode such as QRSS. For these observations I set it up to QRSS10, which provides 92 mHz resolution.

My antenna is an 8-element log periodic dipole array with a design frequency range of 18 to 32 MHz but it works reasonably well at lower frequencies. The antenna is about 13 m above ground level. The receivers are connected to the antenna through a 4-port active (zero loss) multi-coupler. The antenna direction is set by a rotator that is, in turn, operated by a controller I modified for software operation over the local area network. I pointed the antenna 60° true azimuth directly toward HAARP using *PstRotator* software (figure 6).

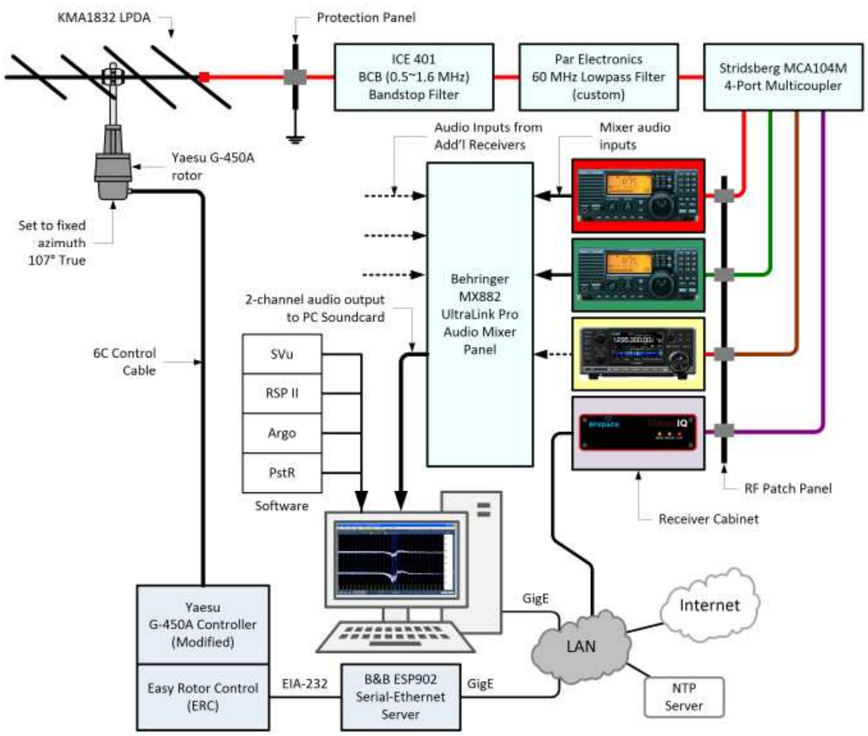

Figure 4 ~ System block diagram showing the setup used to receive the 6 – 14 April 2018 HAARP transmissions. Initially, only one R-75 (green) and the NetSDR (blue) were used to collect HAARP data, but I later used both R-75 receivers (red and green) along with the NetSDR. The software used was SpectraVue (SVu), Radio-SkyPipe II (RSP II), Argo and PstRotator (PstR). PstRotator was open only long enough to set the antenna azimuth and then closed. Not shown are support systems such as the ac uninterruptible power supply (UPS) and multi-voltage dc power supply. The PC is a Lenovo ThinkCentre M710 Tiny running 64-bit Windows 10 operating system. Image © 2018 W. Reeve

Figure 5 ~ Two Radio-SkyPipe charts showing the output from one R-75 receiver for a 5 min period while receiving at 4.440 MHz. The vertical scale is uncalibrated and shows relative received power. Time is shown on the horizontal scale. Upper: The modulation is very slow ASK (5 s On, 25 s Off). The pulses themselves are amplitude modulated (shown later). Lower: A longer On cycle, this one lasting 2 min 40 s with only small variations during the On period.

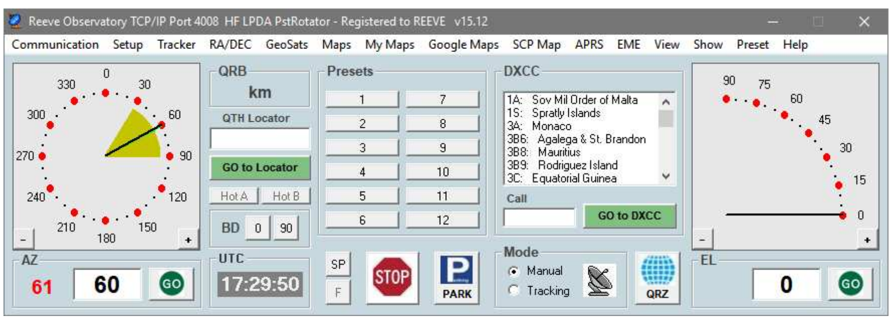

Figure 6 ~ PstRotator software and receive antenna were set at 60° true azimuth throughout the mid-April HAARP campaign. This azimuth points directly toward HAARP from Anchorage. The antenna beamwidth is shown by the shaded area around the compass pointer at left. The window shown here is the PstRotator full view.

I setup the NetSDR at the beginning of each session to display the full HAARP frequency range from 2.7 to 10 MHz so I could quickly locate the transmissions (figure 7). I easily saw the signals because of their high SNR. By going to a higher resolution bandwidth (RBW) setting in SpectraVue, I could then zoom into a signal in real-time for more detailed frequency domain analysis (figure 8) and also to find weak signals by using averaging. For detailed time domain analysis, I used the vertical and horizontal scale zoom functions in the Radio-SkyPipe software (figure 9) after finishing a daily recording (post processing).

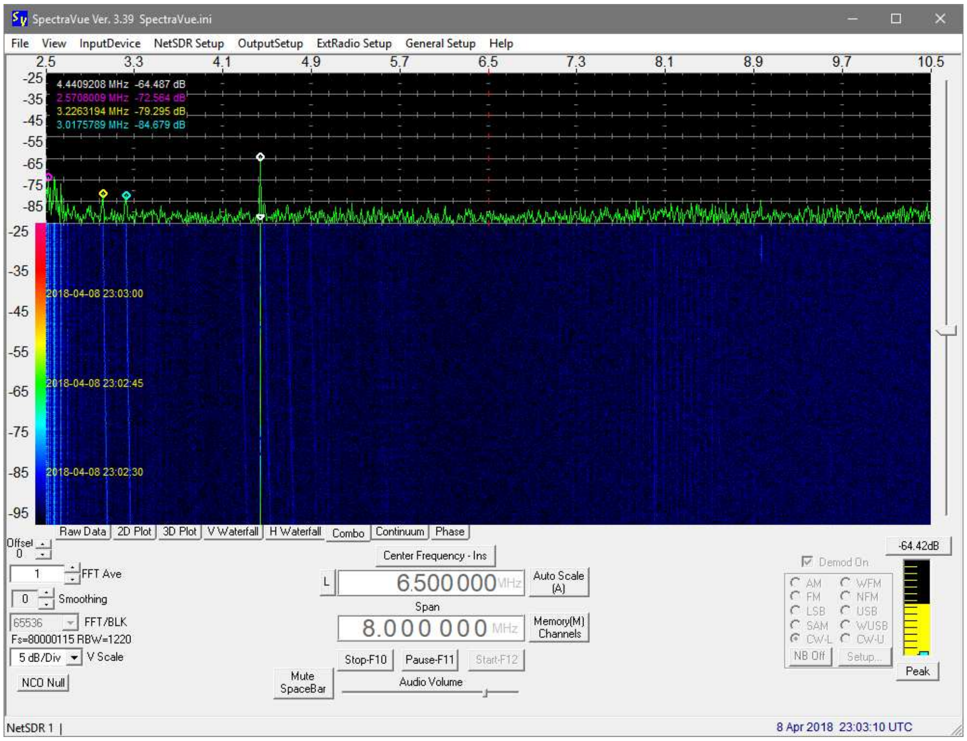

Figure 7 ~ Image from SpectraVue software shows combination dynamic spectra and waterfall plot of HAARP transmissions received at 1500 local time (2300 UTC) about 6 h before twilight on 8 April 2018. The frequency is displayed left-to-right according to the scale at the top of the image. The displayed center frequency is 6.500 MHz and span is 8.00 MHz as indicated by the text fields in the lower-middle portion of the image. The signal processing settings are 65 536 FFT bits per block (16 bit frame length) and 80 MHz sample rate, giving a 1220 Hz resolution bandwidth (bin size). The waterfall plot covers approximately a 45 s time span with time increasing from top to bottom. The HAARP transmissions at 4.440 MHz can be seen as a green vertical line approximately midway between the plot center and left edge. The signal power is indicated on the spectrum by the calibrated left-hand scale. The noise floor is about –90 dBm and the signal peak is about –65 dBm, giving a displayed signal-to-noise (SNR) ratio of 25 dB (power ratio of 316). Peak markers are shown and summarized in a table on the upper-left side of the spectrum display; only the first (white) marker indicates the HARRP transmissions (the others are superfluous). Power levels are indicated on the waterfall plot by colors according the left-hand scale with red-orange indicating higher powers and black-blue indicating lower powers.

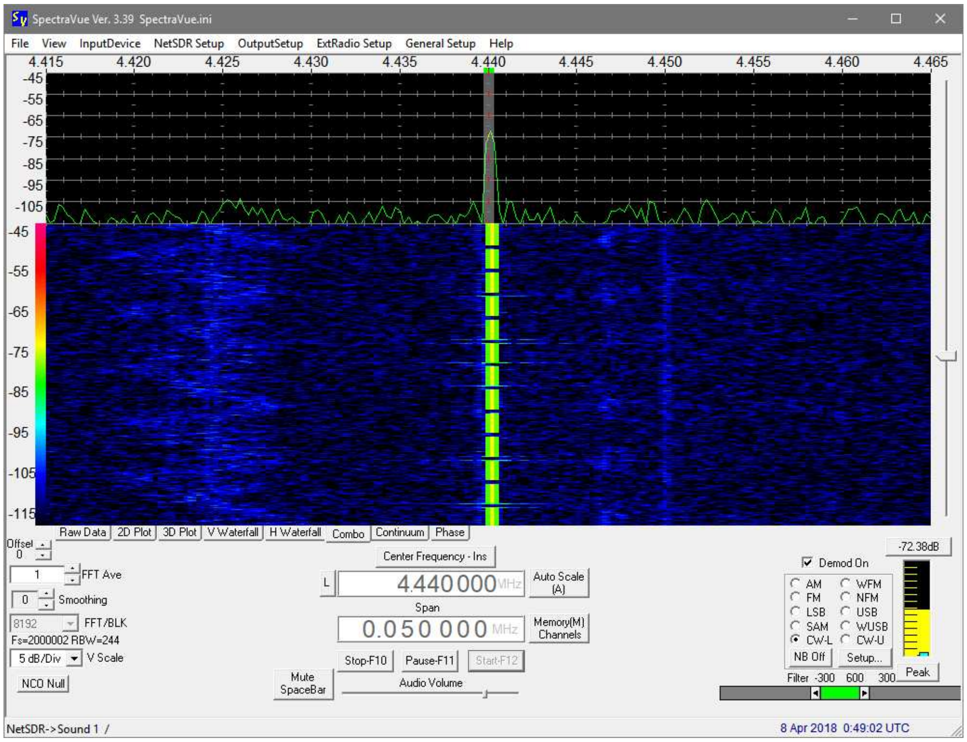

Figure 8.1 ~ HAARP transmissions at 4.440 MHz on 7 April 2018 in the late afternoon at 1649 local time (0049 on 8 April UTC) about 4 h before twilight. The signal processing settings gave a 244 Hz resolution bandwidth. The waterfall plot time span is less than 30 s and was captured at 0049:02 UTC. The pulsed transmissions dominate the center of the plot; each On pulse is amplitude modulated (shown in more detail in the next image). The narrow bandwidth setting (50 kHz) yielded a lower noise floor than the previous plot, in this case about –110 dBm. The signal peak is about –70 dBm, giving a signal-to-noise (SNR) ratio of 40 dB (power ratio of 10 000).

Figure 8.2 ~ Time domain Radio-SkyPipe chart zoomed into one amplitude modulated pulse captured at the same time as the previous spectrum-waterfall combination frequency domain plot. The Radio-SkyPipe sampling period was set to 100 ms, probably too long to capture a high level of detail in the modulation.

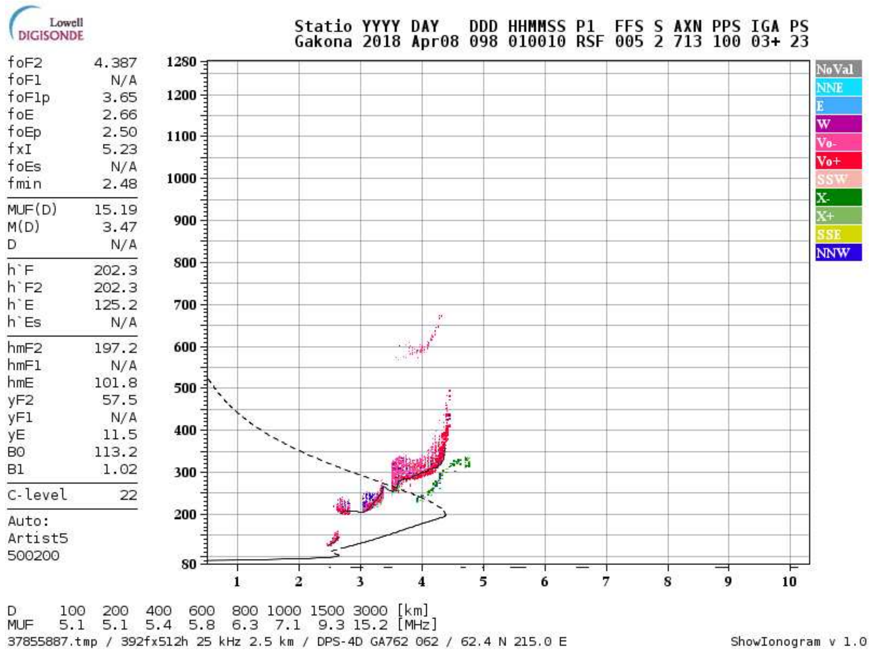

Figure 9 ~ Ionogram produced by the HAARP digital ionosonde at 0100 on 8 April UTC. This would have been local evening about 5 h before sunset and about the same time as the two previous images. The IRI transmitter frequency was 4.440 MHz during this time period. The solid (and dotted) black line indicates the computed plasma frequency at true height whereas the black line embedded in the magenta traces (difficult to see) is the plasma frequency at virtual height. Image source: {UAF-GI_080418}.

Dr. Fallen usually tweeted the start-stop times, frequencies and modulation modes for most of the transmission sessions but some tweets lagged the actual event or were never sent presumably because he was busy with the experiment. Using wide spectrum monitoring in the NetSDR and SpectraVue came in handy many times because I could spot the transmissions and zoom into the frequency without waiting for a notification.

Conveniently, most transmission start and stop times were on the 00, 15, 30 or 45 s time mark, making identification quite easy. All of my station PCs use the *Network Time Protocol* (NTP) for accurate timekeeping. I have two local time servers based on Global Navigation Satellite Systems that use Pulse Per Second (PPS) for timing {GpsNtp-Pi}, and this ensures the PC real-time clocks are very accurate (within a few milliseconds of Coordinated Universal Time, UTC). In the following discussion I usually state the local time of an event followed by UTC in parentheses. The time scale on all plots is UTC.

The sequence was similar on each day and consisted of afternoon and evening transmission sessions:

- Simultaneous On-Off transmissions at one low and one high frequency during local mid-afternoon with the Sun still above the local horizon;
- Switch to a single frequency around 4 MHz or lower during late afternoon and early evening;
- No transmissions from early evening to around nautical twilight a few hours later;
- Steady session of ASK or FSK transmissions for a couple hours from twilight to midnight.

For reference, solar terminator (gray line) plots show day and night conditions for the afternoon and evening sessions (figure 10).

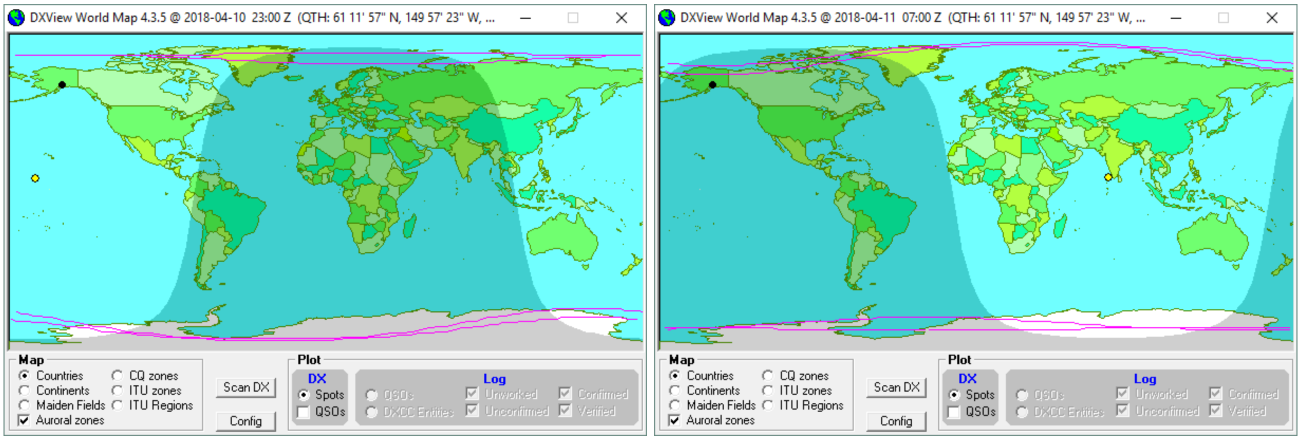

Figure 10 ~ Solar terminator (gray line) maps for local mid-afternoon at 2300 UTC on 10 April (left) and local late evening 0700 UTC on 11 April (right). My station at Anchorage, Alaska is shown by a black dot (seen in upper-left corner of the maps). The Sun is shown as a yellow circle centered in the daylight regions. Images produced from DXView software {DXVeiw}.

I missed the first day (6 April) of this campaign but successfully received transmissions for several hours on each of the remaining days and nights. The initial transmissions during the first few days were at 4.000 or 4.440 MHz but later decreased to 2.700 or 3.400 MHz or increased to 5.900 MHz after that. The frequencies are determined by the ionosphere's characteristics above the HAARP site as indicated on the local ionosonde. I was surprised by the high received signal-to-noise ratio (SNR), which reached 60 dB (a power ratio of 1 000 000) at the lower frequencies. My Anchorage station is located about 285 km west-southwest of the HAARP site. At first, I assumed the propagation mode was groundwave from a HAARP antenna sidelobe but I now believe near vertical incidence skywave, NVIS, was involved. I plan to confirm the propagation mode by more detailed analyses of future experiments aided by what I learned in the campaign described here.

I was unable to detect the HAARP transmissions at 9.500 MHz on the second day and at 5.925, 6.765 and 9.500 MHz on the third day. This could be explained by the ionosphere's transparency at these higher frequencies, which prevented reflection of the near-vertical radio waves. Later at night for the first few days, from twilight to midnight, other frequencies were used by HAARP including 3.250 and 4.900 but I did not attempt to receive the late-night transmissions until later.

On the third day, 9 April, starting at 1502 local time (2302 UTC) and ending at 1530 (2350 UTC), the transmission frequency was 4.600 MHz. For the first 30 minutes of this transmission, the 4.600 MHz carrier wave was barely detectable, only occasionally breaking through the noise. However, over the next 30 min the signal became much stronger, sometimes approaching 20 dB (power ratio of 100) SNR (figure 11). The initial weak received signal might be explained by 1) heavy absorption of the HAARP carrier in the ionosphere's D-region, which attenuates (absorbs) the signal on its way up and again on its way back down after reflection at an upper region, 2) relatively weak reflection at the upper region, or 3) a combination of absorption and weak reflection. Decreasing absorption and increasing reflection, the latter perhaps induced by the HAARP's powerful radio beam, might explain the increasing received signal level later in the transmission. The D-region is that part of the ionosphere between approximately 60 and 100 km above Earth's surface, and it disappears quite rapidly at sunset.

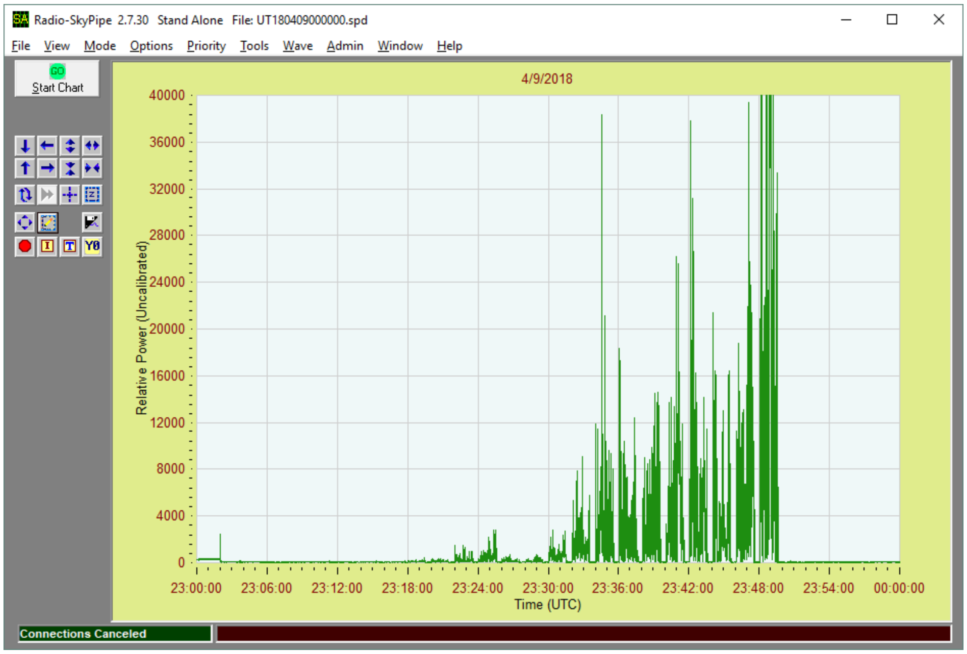

Figure 11.1 (left) ~ Radio-SkyPipe chart showing the steadily increasing received signal level over time during the mid-afternoon on 9 April. The plot covers a 1 h interval; transmissions started at 2302 and ended at 2350 UTC. Transmission frequency was 4.600 MHz.

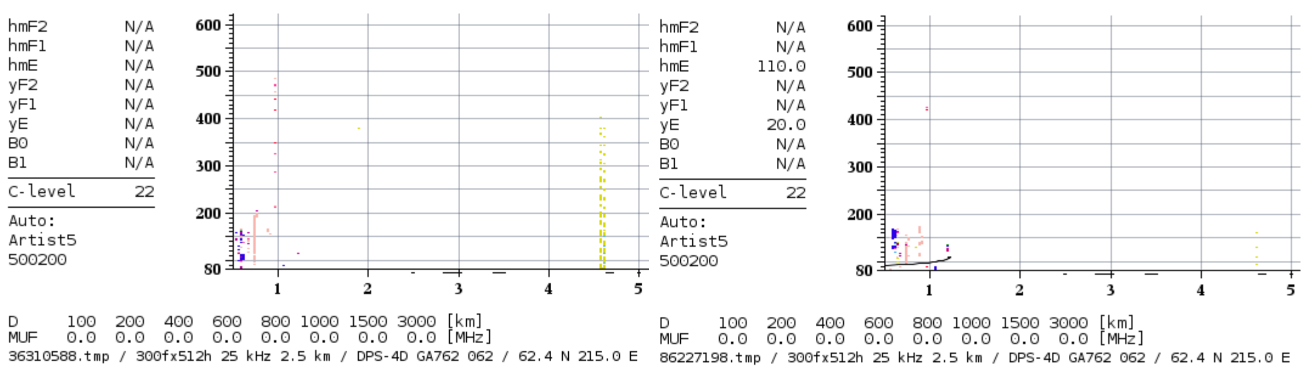

Figure 11.2 (above) ~ Cropped ionograms for 9 April at 2315 UTC on the left and 2345 on the right corresponding to the times shown on the previous Radio-SkyPipe chart. The HAARP transmissions are easily seen at 4.6 MHz on the left plot and some differences are visible near 1 MHz in the right plot. Note that there is heavy absorption in the D-region indicated by the lack of reflections in the upper regions, which should be well-developed at this time of day. The solid black line in the lower-left corner of the right plot shows the computed plasma frequency or equivalently the computed electron density. No black line is shown in the left plot apparently because it could not be computed. Image source: {UAF-GI_090418}

Later on the third day at 1800 local time (0200, 10 April UTC) transmissions commenced on 4.000 and 9.500 MHz and ran for 1 h until 1900 (0300 UTC). The lower frequency was very strong at Anchorage while the higher frequency was very weak but detectable. If the mode was NVIS, the weak signal indicated weak reflections. The transmissions were then halted until 2230 local time (0630 UTC). Meanwhile, the *natural* ionosphere over the HAARP site dissipated. The ionosphere starts to dissipate quite rapidly after sunset but the Sun's rays continue to illuminate the upper atmosphere above the site and produce some ionization until the end of nautical twilight. Nautical twilight is the time when the center of the Sun's disk is between 6° and 12° below the local horizon. Sunset at the HAARP site on this day was 2051 local time (0451 UTC) and nautical twilight ended about 2 h later at 2246 (0646 UTC). Transmissions, which might have been intended to produce a man-made ionosphere above the site, ran from 2239 to local midnight at 2400 (0639 to 0800 UTC) on 7.000 and 4.300 MHz. I did not attempt to receive these later transmissions on this night.

Day four used different frequencies and yielded different results at Anchorage. The initial transmissions started during local mid-afternoon at 1430 (2230 UTC) and ran continuously on 3.400 and 9.500 MHz. This session was interrupted 40 min later for 5 min at 1510 (2310 UTC) and again at 1525 (2325 UTC). Transmissions continued from 1530 until 1559:30 (2359:30 UTC). The lower frequency was weak (5 to 10 dB SNR) and variable at first but easily recognized. As this session continued the received signal at 3.4 MHz became much stronger, reaching 50 to 60 dB SNR (figure 12). The signal was so strong I had to use the selectable attenuation on the input of both the NetSDR and R-75 receivers. The higher frequency was not received at all.

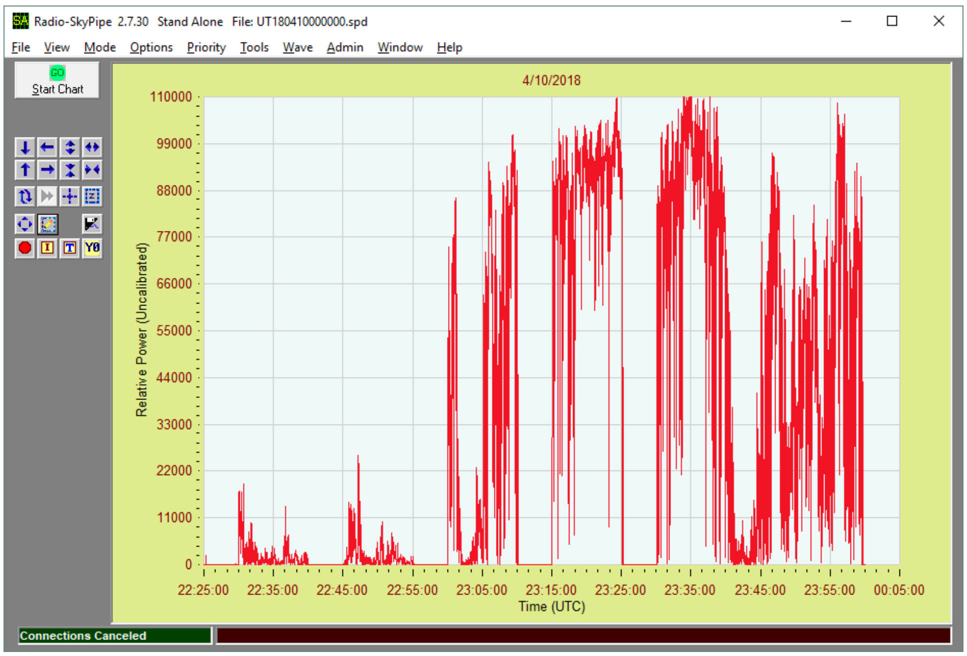

Figure 12.1 (left) ~ The change in received signal level on 10 April between 2230 and 2359:30 UTC is shown here. Transmission frequency was 3.400 MHz, and the received signal-to-noise ratio reached 60 dB. The chart time scale a 1.5 h long and shows 5 min interruptions every 15 min at 2225, 2240, 2255, 2310 and 2325 UTC.

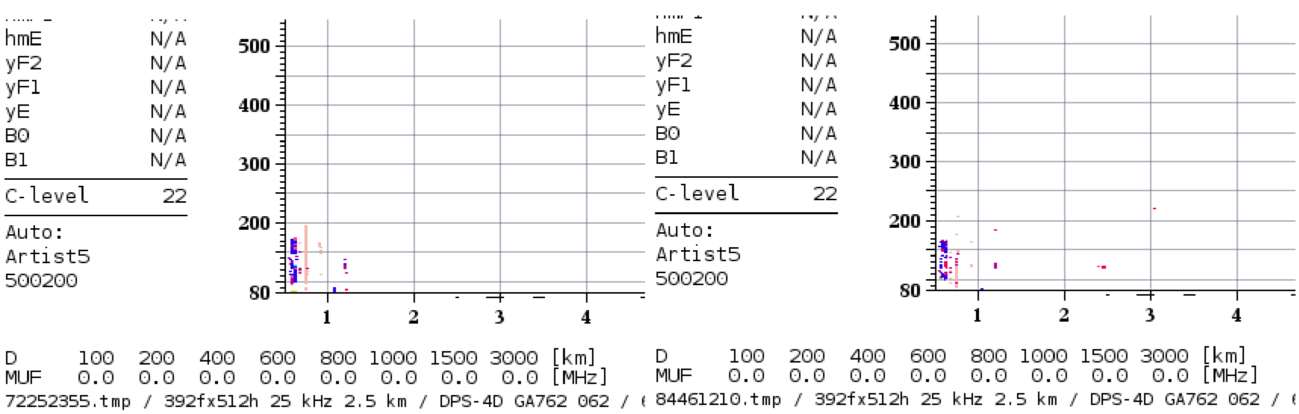

Figure 12.2 (above) ~ Cropped ionograms for 10 April at 2300 UTC (left) and 2352 (right) corresponding to the time interval shown in the previous plot. There is no obvious difference. Image source: {UAF-GI_100418}

On 10 April at exactly 1600 local time (0000, 11 April UTC), the HAARP transmitter was keyed on 6.230 MHz. This frequency was mostly weak and variable at my station but easily detectable. At 1615 (0015 UTC), my receivers detected a very strong (several 10s of dB above background noise) impulse at 6.230 MHz, which tapered off over a 20 s period to a low level. The trace on the Radio-SkyPipe chart had a shark fin shape (figure 13) and was similar to a solar radio burst; however, there was no recorded solar radio activity at the time and a solar radio burst does not have an almost instantaneous rise-time like the pulse seen here. Except for this impulse, the

6.230 MHz carrier was transmitted simultaneously with offsets at one of 7, 8, 10 or 12 kHz. Many of the transmissions throughout the research campaign used offsets and multi-carriers such as these (two examples are shown; see figure 14 and 15).

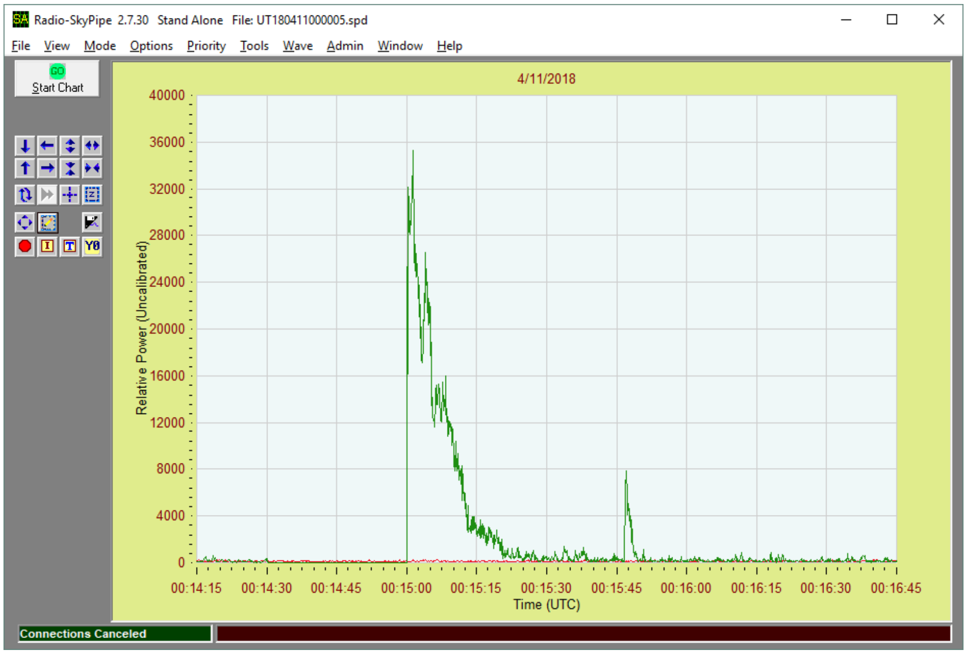

Figure 13.1 ~ Radio-SkyPipe chart showing an interesting pulse at 6.230 MHz received from HAARP on 11 April. The carrier appears at 0015:00 UTC and then tapers off over the next 20 s. I have not determined if the transmitter was programmed to emit such a pulse shape or if the ionosphere and propagation was altered by the powerful transmissions over the time interval shown. The smaller pulse near 0015:45 probably is noise.

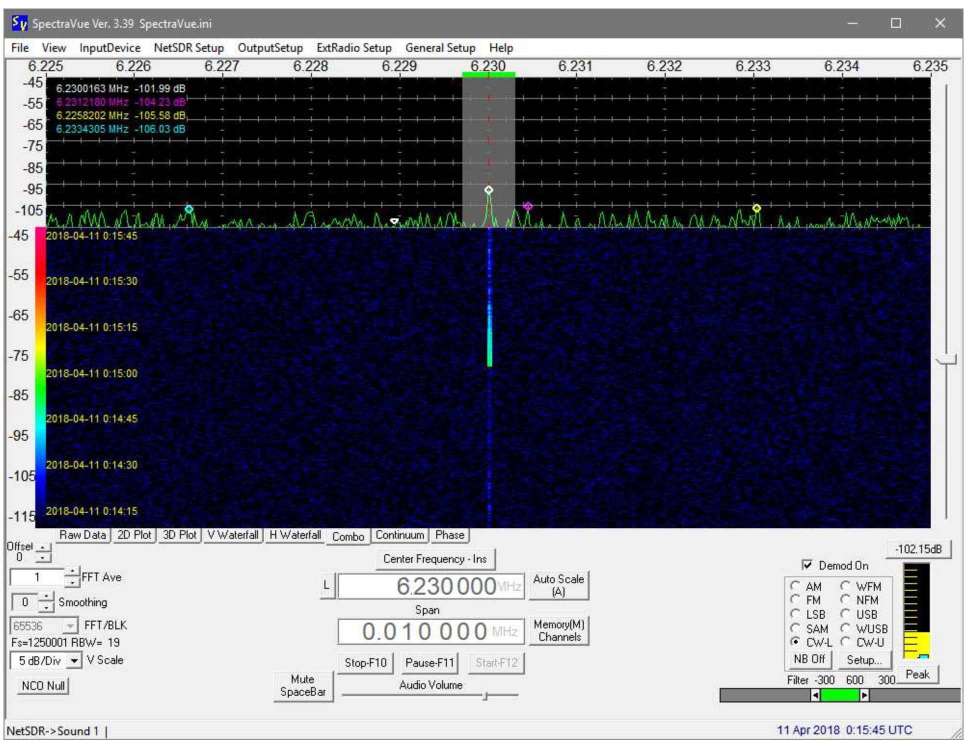

Figure 13.2 ~ Spectrum plot and waterfall associated with the "shark fin" carrier impulse received at Anchorage at 0015 UTC.

Figure 14 ~ Radio-SkyPipe chart showing simultaneous transmissions on 2.700 (red trace) and 2.708 MHz (green trace) in the 0700 UTC time frame on 13 April. The post-detection signal levels output from the two R-75 receivers are remarkably steady with occasional 3 dB dips in each On period for unknown reasons. Closer scrutiny indicates that the trace for 2.708 MHz is steadier than 2.700 MHz. The receiver outputs are uncalibrated so the two channels are recorded at slightly different relative power levels.

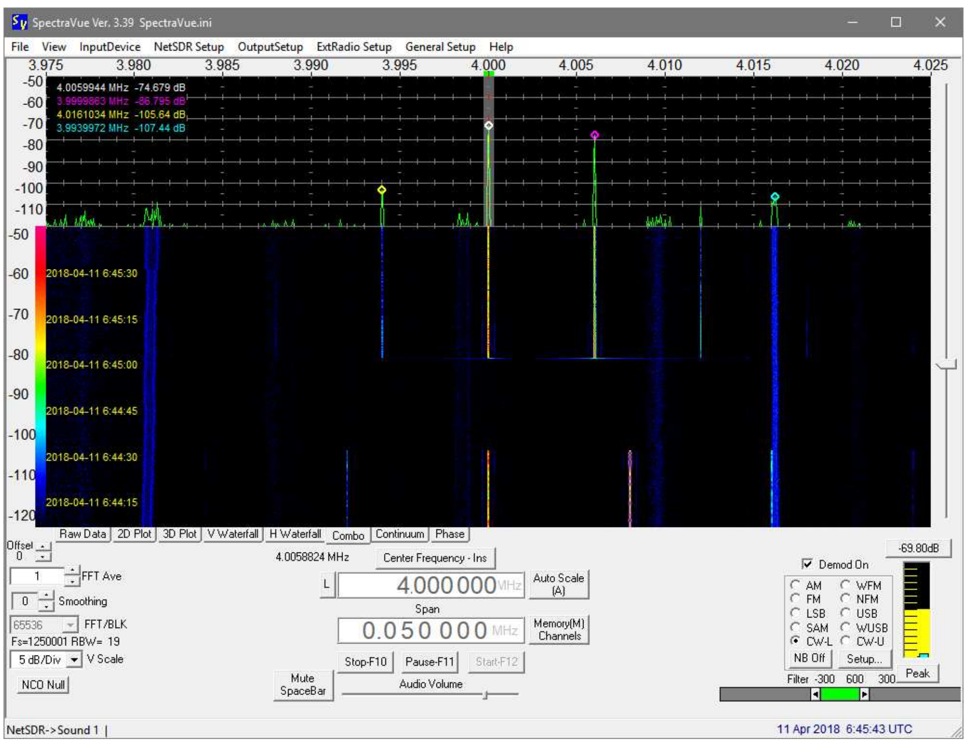

Figure 15 ~ Spectrum and waterfall plot showing transmissions with frequency offsets on 11 April around 0644 and 0645 UTC. This image shows simultaneous carriers at 3.992, 4.000, 4.008 and 4.016 MHz followed by carriers at 3.994, 4.000, 4.006 and 4.012 MHz. The two inner carriers are close to the same power level and the outer carriers are lower.

The afternoon transmissions on 10 April ended at 1700 local time (0100, 11 April UTC) but recommenced on 5.100 MHz near local twilight at 2230 local time (0630 UTC). The evening session was not announced and no frequency details were provided on Twitter. However, I had setup the NetSDR receiver to display the full HAARP band and was able to quickly spot the relatively strong signals. The transmission on 5.100 MHz did not last long and the frequency changed to 4.000 MHz at 2233 local time (0633 UTC). I also had setup Argo and used a 600 Hz offset to capture the demodulated carrier. During the late night sessions on 10, 11 and 12 April (local dates, note that UTC dates are one day later), the Argo plots clearly showed a disturbed ionosphere with rapidly varying propagation characteristics (figure 16). These transmissions lasted for an hour. The HAARP transmitter frequency then changed to 6.800 MHz. These had an unusual sounding modulation, which I could not identify, and some of the transmissions lasted only a few seconds. However, I was able to obtain audio recordings. There also was a group of transmissions on 7.0753 MHz, which had a very odd sounding warbling modulation (when demodulated in the CW mode), but they were too brief for me to record. The overall late evening session ended right at local midnight (0800 UTC).

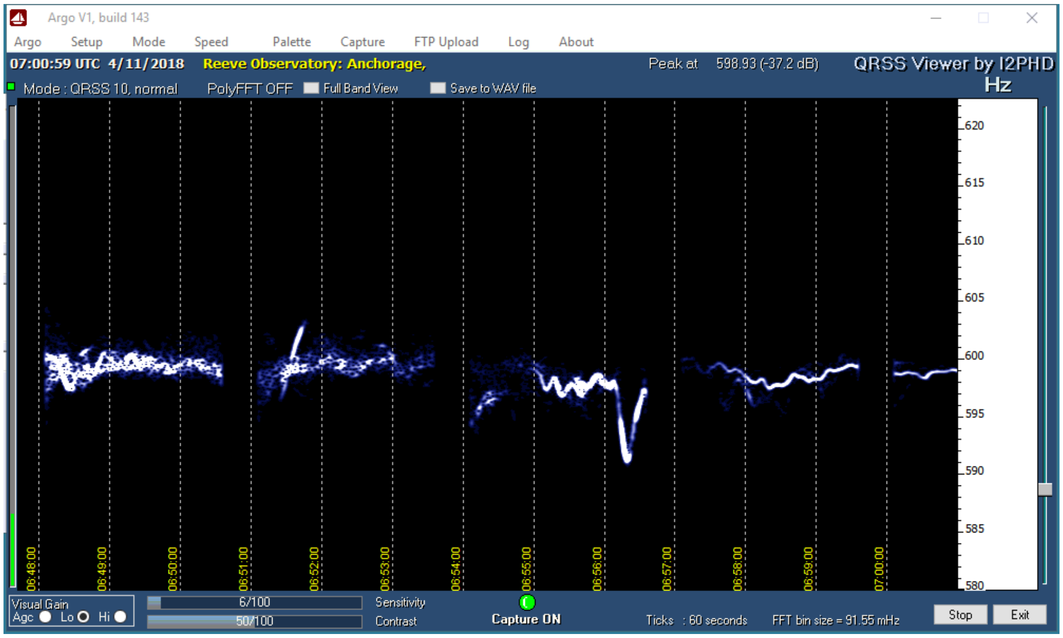

Figure 16.1 ~ Image of Argo plot from 11 April at 0648 to 0700 UTC showing the demodulated carrier at 4.000 MHz with the 600 Hz offset for the CW mode (there is a 1 Hz error). The FFT bin size is 91.55 mHz. The horizontal scale shows time (UTC) progressing left-to-right. The plot covers 12 minutes and the On-Off transmissions are evident. The vertical scale indicates frequency from 580 to slightly more than 620 Hz. The rapid frequency deviations of more than 10 Hz indicated on this plot are similar to sudden frequency deviations produced by solar flares (see, for example, {Reeve15-1} and {Reeve15-2}).

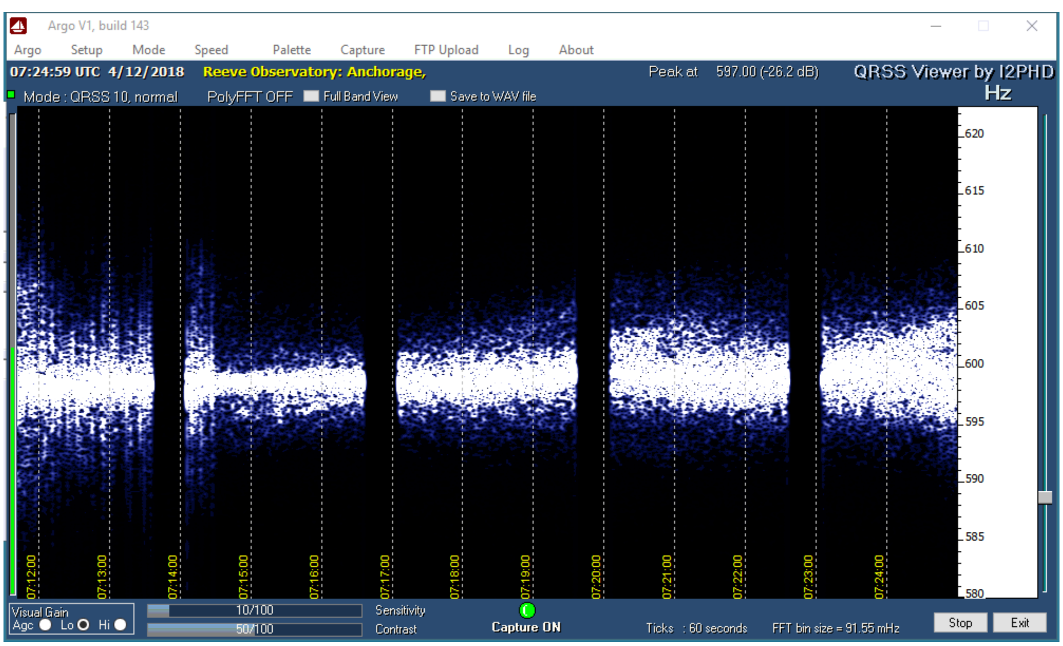

Figure 16.2 ~ Argo plot from 0712 to 0725 UTC on 12 April showing the demodulated carrier at 2.710 MHz with the same 600 Hz offset as the previous plot. The 2.5 min On, 0.5 min Off transmission cadence and disturbed propagation is clearly shown.

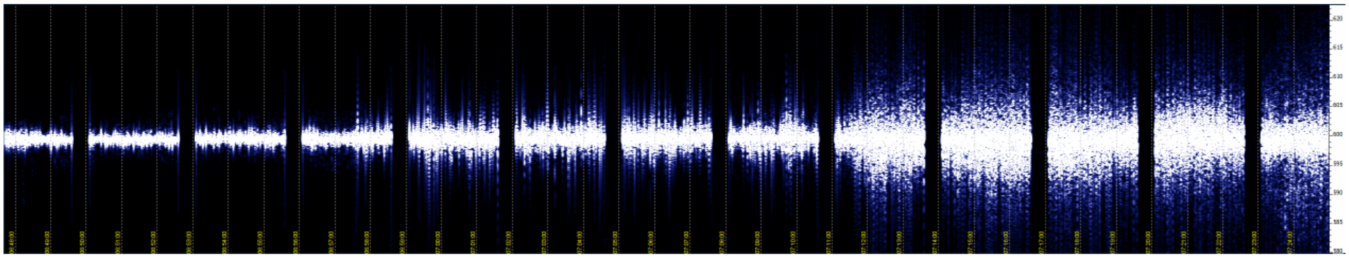

Figure 16.3 ~ Composite of three consecutive 12 min Argo plots from 0648 to 0725 UTC on 13 April (nighttime) showing the demodulated carrier on 2.700 MHz. The receiver CW mode provides the 600 Hz offset. Each vertical tick mark is 1 min and the composite plot covers a 37 min interval. This series of images appears to show an increasingly disturbed propagation causing rapid frequency deviations of the received carrier. The 2.5 min On, 0.5 min Off period is clearly seen. The frequency scale on the right is hard to read but each major tick is 5 Hz as in the previous plots. The frequency deviation at the beginning of the recording is about 5 Hz and about 30 Hz at the end.

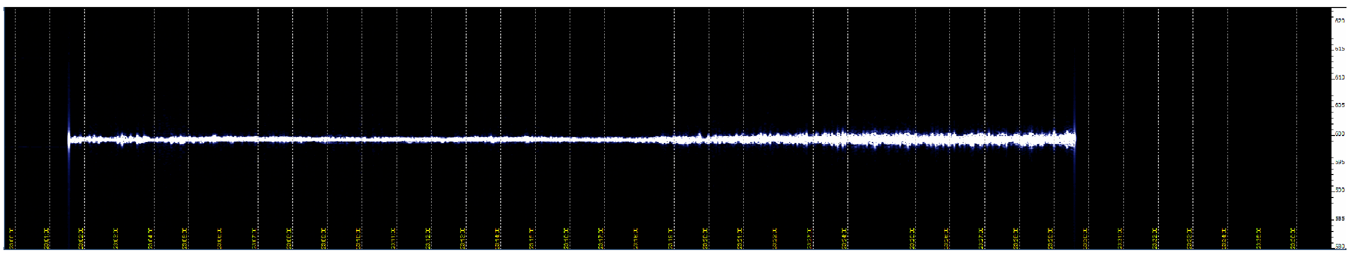

Figure 16.4 ~ Composite of three consecutive Argo plots from 2300 to 2337 UTC on 13 April (daytime) showing the demodulated carrier at 3.900 MHz. The receiver CW mode provides the 600 Hz offset, as in previous Argo charts. Contrast this image series, which was made of a steady carrier during the day, with the previous series, which was made the night before of On-Off transmission. This transmission interval of 29 min shows only a slightly increasingly disturbed propagation, with frequency deviation at the beginning is 1 or 2 Hz and about 4 Hz at the end.

The remaining campaign days and nights followed much the same pattern described above. The lowest frequency I observed was 2.700 MHz and the highest was 9.500 MHz. The frequencies below 5 MHz were by far the strongest at Anchorage and in some cases I had to select the 30 dB attenuator in the NetSDR front-end and the 20 dB attenuator in the R-75 front-end to prevent overload. Often the carrier frequency would be stepped in 10 or 20 kHz increments and at other times several frequencies with 7, 8, 10 or 20 kHz would be transmitted simultaneously.

I heard the last transmission from this HAARP campaign on 2.800 MHz. It ended at 2329:30 local time about 30 min before midnight on 13 April (0729:30, 14 April UTC) (figure 17). This final transmission followed an alternating pattern with a single carrier and multiple carriers with 8 kHz offsets. While in progress, I noted that the carrier shown on the SpectraVue waterfall did not completely disappear during the Off periods of the transmit cycle; some residual power appeared to be present until 2329:30. However, the R-75 receiver outputs on Radio-SkyPipe chart indicated reduction to the normal background noise level during all Off periods. This might be explained by assuming the NetSDR noise floor is lower than the R-75 noise floor but I did not pursue a definite explanation.

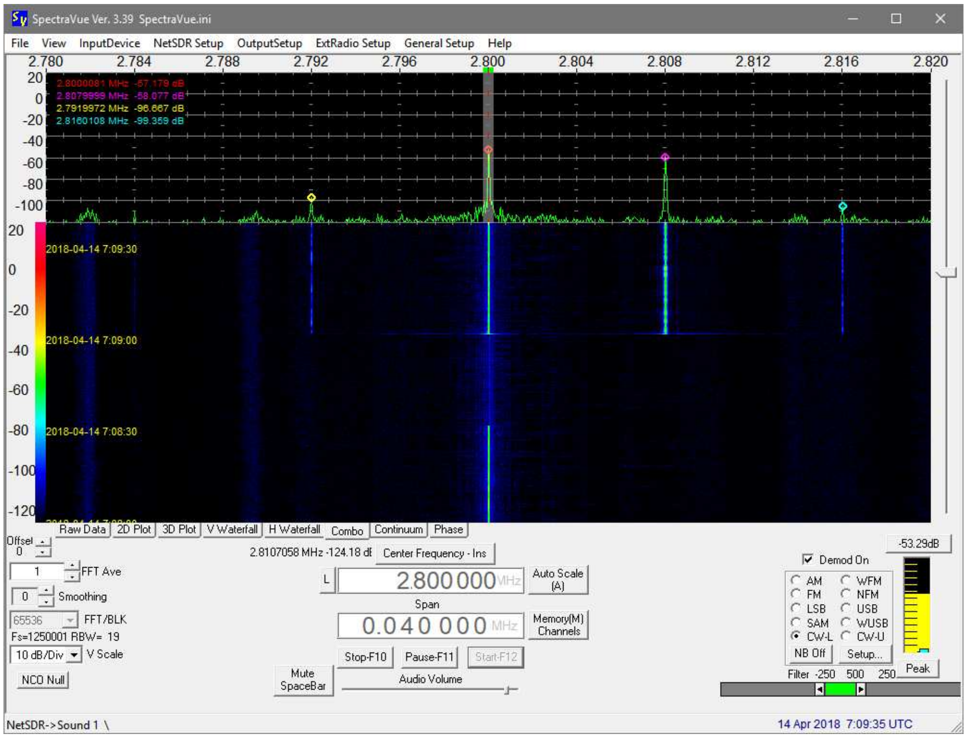

Figure 17.1 ~ Spectrum plot and waterfall showing transmissions near the end of the mid-April research campaign on 14 April. The carriers at 2.800 and 2.808 MHz have approximately the same amplitude but the carriers at 2.792 and 2.816 MHz are weaker. There appears to be some residual transmission during the Off period between 0708:30 and 0709:00 UTC. This residual was observed throughout this session. The pattern of a single carrier alternating with four carriers continued to the end of the campaign at 0729:30 UTC on 14 April.

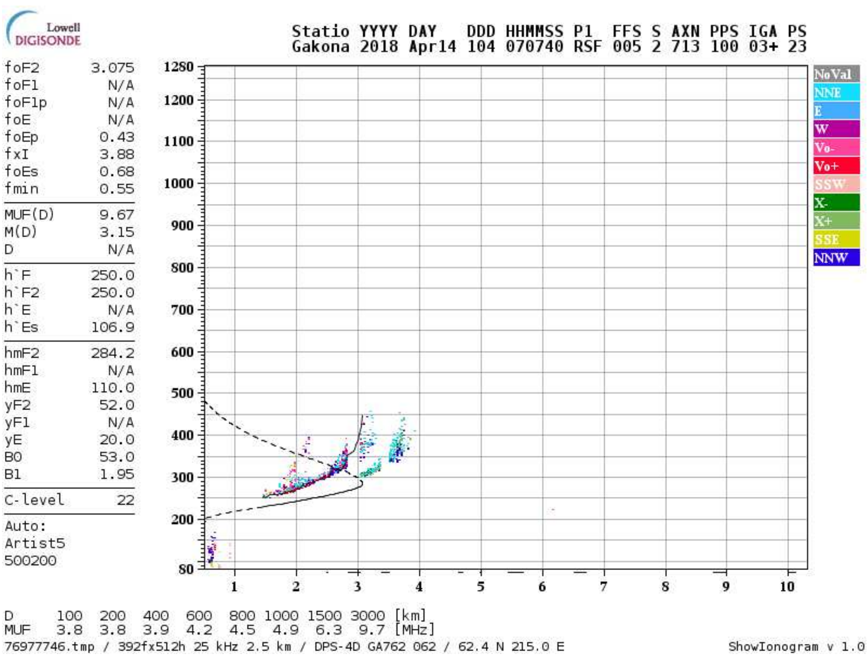

Figure 17.2 ~ Ionogram produced by the HAARP digital ionosonde at 0708 on 14 April UTC about 1 h after sunset and the same time as the previous image. The IRI transmitter frequency was 2.800 MHz with offset multi-carriers. It is possible the profiles indicated on this ionogram were produced by an artificial ionosphere from the HAARP transmissions. Image source: {UAF-GI_080418}.

Throughout the mid-April campaign I noted Twitter responses from listeners-observers who successfully detected the HAARP transmissions in Illinois, Arizona, Washington and California USA and Ontario Canada. An observer in Thessaloniki Greece used a remote "web SDR" in Alberta Canada to detect the transmissions. The same observer in Greece also used his own receiver and antenna to successfully receive the transmissions on at least two separate days. Using a remote SDR receiver controlled over the internet may be a very good method for distant observers who have no receiving facilities of their own to detect HAARP transmissions. I am considering setting up one of my SDR receivers for web access during future HAARP campaigns. This may help very remote observers to quickly locate the transmission frequencies in case they are not announced while a research campaign is in-progress.

5. Conclusions

Attempting to receive transmissions associated with the HAARP research campaigns can be challenging but worth the trouble for listeners with motivation and patience. Because of my relatively close proximity to the HAARP site, only 285 km, I was able to easily receive its transmissions – especially those in the lower HF band – during the research campaign in mid-April. Other listeners and observers around the world also were successful.

6. References & Web Links

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{Benson} http://nvlpubs.nist.gov/nistpubs/jres/68D/jresv68Dn10p1109_A1b.pdf

{CEC-TX} https://contelec.com/htmlpages/pdf/haarp_data_sheet.pdf

{Digisonde} http://www.digisonde.com/

{DXView} http://www.dxlabsuite.com/

{Fallen} https://twitter.com/ctfallen

{GpsNtp-Pi} http://www.reeve.com/Documents/Articles%20Papers/Reeve_GpsNtp-Pi.pdf

{HAARP02} http://handle.dtic.mil/100.2/ADA426081

{HAARPList} https://www.gi.alaska.edu/haarp/publications-about-haarp-research-1990-2010

{HAARPOps} https://sites.google.com/alaska.edu/gakonahaarpoon/operations-news

{Indiegogo} https://www.indiegogo.com/projects/amateur-radio-science-experiment-at-haarp#/

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{Reeve15-2} Reeve, W., Sudden Frequency Deviations Caused by Solar Flares: Part 2 ~ Instrumentation and Observations, 2015. Available here: http://www.reeve.com/Documents/Articles%20Papers/Propagation%20Anomalies/Reeve_SuddenFreqDevMeas_P2.pdf

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{UAFHAARP} https://twitter.com/uafhaarp

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