

Lunar Echo Experiment – Reflections of an Observer

Author: Whitham D. Reeve, Anchorage, AK USA
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The Lunar Echo Experiment

On January 19 and 20, 2008, the High Frequency Active Auroral Research Program (HAARP) in Alaska, and the Long Wavelength Array (LWA) in New Mexico, conducted a bi-static high-frequency lunar radar experiment. The experimenters invited radio amateurs and others to monitor the signal transmissions and lunar echoes and to submit receiving reports.

I participated as a voluntary observer and submitted a report to the HAARP researchers a few days after the experiments (this report is available to interested readers). I used my receiving station in Anchorage, Alaska. This article describes the experiment, my receiver setup and my observations. I used public information available on the HAARP website (<http://www.haarp.alaska.edu>) for background material.

In a bistatic radar experiment, the transmitter and receiver are fixed (static) at two different locations as opposed to normal radar in which the transmitter and receiver are collocated and may be mobile (as in an airplane). In the case of the Lunar Echo Experiment, the transmitter was located at the HAARP station in Alaska and the receivers were located at observer locations throughout the world. The January 2008 experiment followed a similar experiment in October 2007.

The experiments involved the transmission of an unmodulated high-frequency carrier (Continuous Wave, or CW) from the HAARP transmitting station. What made this experiment somewhat unique were the relatively low transmission frequencies near 7 MHz (40 – 44 m). Echoes have been received from the Moon almost since the introduction of radar systems, but in all cases the frequencies were considerably higher than those used by HAARP.

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The purpose of the experiment was given in the original October 2007 press release: "Analysis of the echo gives information on the properties of the lunar sub-surface topography, because the low frequency radar waves propagate to varying depths below the visible surface of the Moon. It is somewhat like sonar, except that we are using electromagnetic waves rather than sound waves. The experiment also allows us to study the interaction of the echo signal with the Earth's ionosphere along its return path, because the ionosphere is only partially transparent at low frequencies."

Some people question HAARP's true purpose. Indeed, the HAARP has been controversial since the program began in 1990, mainly because of the involvement of the United States Air Force Research Laboratory (AFRL) and Naval Research Laboratory (NRL) in construction and management of the HAARP facility. It is well-known in this and probably every other country on the planet, that as soon as the government sponsors research, there has got to be a conspiracy.

Several books have been published that describe vast government conspiracies to use HAARP to control everything from the weather to human behavior. In one book, "(HAARP is) a super-powerful radiowave-beaming technology that lifts areas of the ionosphere by focusing a beam and heating those areas. Electromagnetic waves then bounce back onto earth and penetrate everything -- living and dead." In another, "This new system manipulates the environment in a way which can disrupt human mental processes, jam all global communications systems, change weather patterns over large areas, interfere with wildlife migration patterns, negatively affect your health, and unnaturally impact the Earth's upper atmosphere."

The book's credibilities are crippled by gigantic leaps of logic and deduction and, of course, there are no proofs of any of the claims. None of the HAARP-made disasters happened and its only effect has been to give a number of crackpots something to do. According to the HAARP website, HAARP is not classified: "There are no classified documents pertaining to HAARP. The Environmental Impact Process (EIP) documents have always been, are now, and will always be completely descriptive of the program in its entirety. The EIP documents are a matter of public record."

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The HAARP Facility

The HAARP HF antenna array is located at geographical coordinates 62-23-30.00 N : 145-09-07.00 W on the Glenn Highway - Alaska Highway 1 - adjacent to the Copper River (home of the world-famous Copper River Red Salmon) and about 12 km northeast of the small community of Gakona. See map image in Figure 1 and photographs in Figures 2 and 3. Part of the array and the on-site power plant at 62-23-28.00 N : 145-07-53.00 W are included in high-resolution satellite photography that is accessible through the free Google Earth imaging program (<http://earth.google.com>). Coordinates are given in degrees-minutes-seconds.

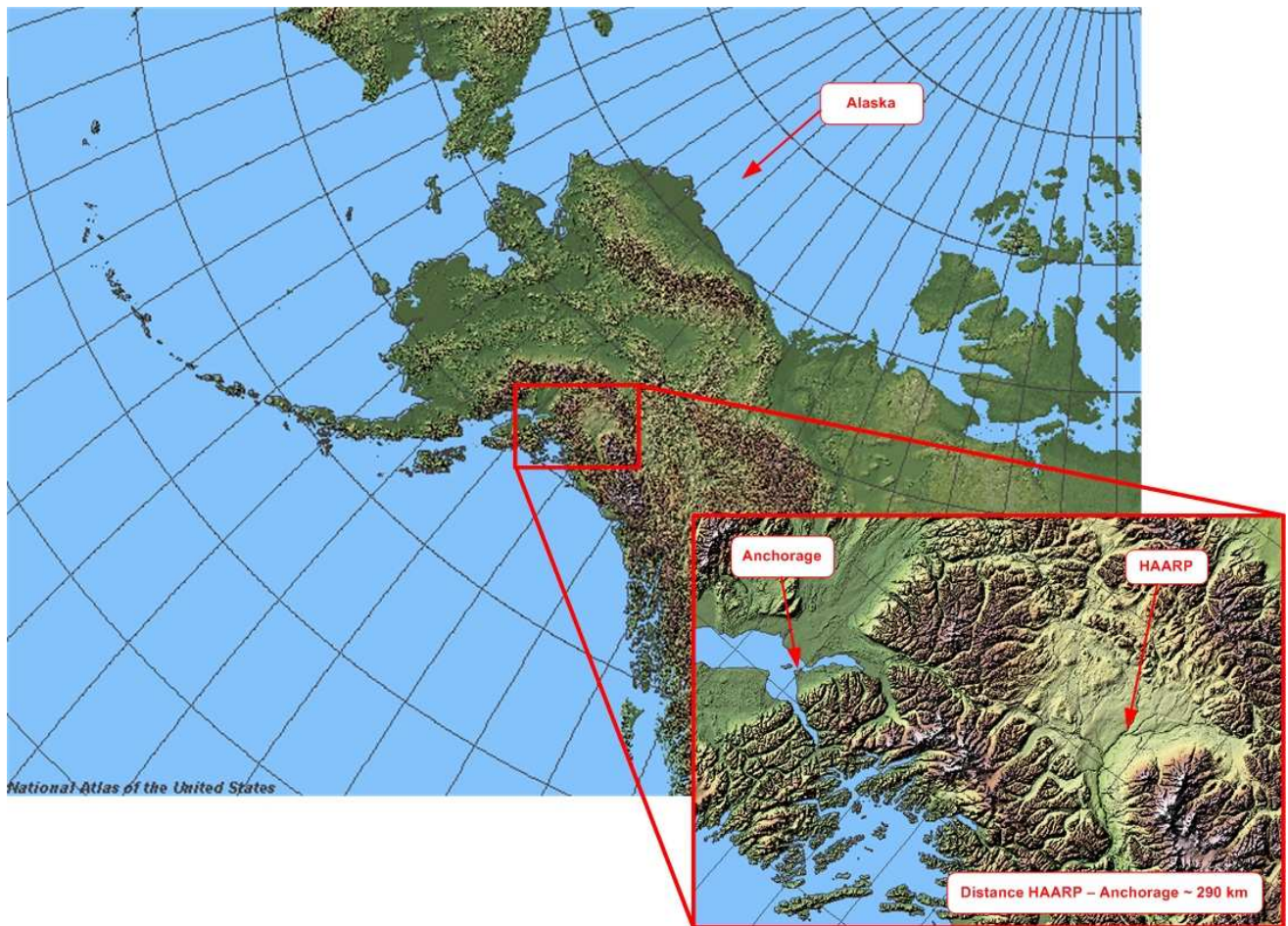


Figure 1 – Map image of Alaska with Anchorage and HAARP locations annotated for easy identification. (Source: “Maps & Tools” tab at <http://www.usgs.gov/state/state.asp?State=AK>; composite image Copyright W.D. Reeve)

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Figure 2 – The Wrangell Mountains provide the backdrop for this summer aerial photograph of the HAARP HF array. The facility power plant is located on the middle-left and the Copper River can be seen on the upper-right. (Photo Source: High Frequency Auroral Research Program website)

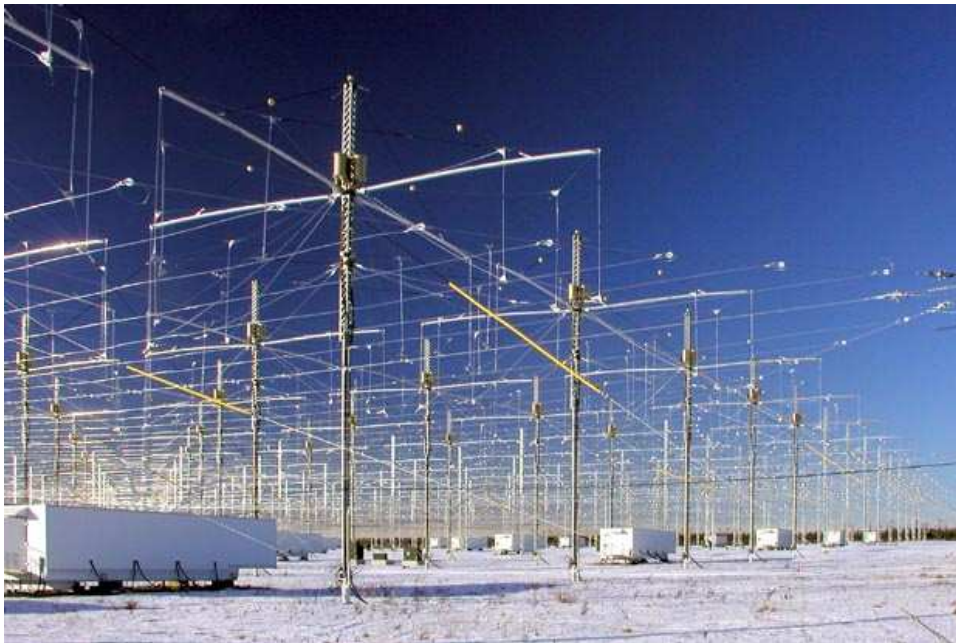


Figure 3 – Close-up winter view of the HAARP HF antenna array elements as viewed from the northeast corner. The rectangular, planar array consists of 180 cross-dipole antenna elements. The HAARP transmitter is capable of delivering 3.6 MW into the array. Temperatures in the vicinity vary from -52°C in winter to $+33^{\circ}\text{C}$ in summer. (Photo Source: High Frequency Auroral Research Program website)

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The HAARP antenna array consists of 180 individual cross-dipole antenna elements (a cross-dipole also is known as a turnstile antenna and consists of two dipole antennas that are placed at right angles to each other). The phase of the transmitted signal is adjusted at each antenna element. The signal radiated from each antenna element then adds to or subtracts from the signals radiated from other elements. In this way, the resulting composite signal is focused and aimed in a certain direction.

The Radar Equation

The signals transmitted by the HAARP station propagate toward the Moon. A portion of that signal is reflected by the Moon's surface and propagates back toward Earth. The received power on Earth can be calculated from the radar equation

$$P_R = \frac{P_T \cdot G_T \cdot G_R \cdot \sigma \cdot \lambda^2}{(4 \cdot \pi)^3 \cdot R^4}$$

where

- P_R = Received signal power (watts)
- P_T = Transmitted signal power (watts)
- G_T = Transmitter antenna gain (unit less)
- G_R = Receiver antenna gain (unit less)
- σ = Scattering (or radar) cross-section of the Moon (square meters)
- λ = Wavelength (meters)
- R = Distance from the Earth to the Moon (meters)

The HAARP transmitter power output, P_T , is 3.6×10^6 watts (+65.6 dBw, or +95.6 dBm) and the transmitter antenna gain, G_T , is 735 (28.7 dB). The Moon's scattering cross section, σ , can be approximated by first assuming it is a sphere with equal reflective properties along all axes (that is, it is isotropic) and then modifying this assumption by the fraction of the incident signal reflected back (this takes into account that the Moon's albedo is less than 100%). At the frequencies of interest, the Moon's albedo is approximately 15%. The Moon's diameter is 3,474,000 m and its cross-sectional area is about 9.5×10^{12} square meters; therefore, σ is about 1.4×10^{12} square meters, indicating that the Moon is a pretty good radar target.

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The free-space wavelengths, λ , of the transmitted signals are 44.1 and 40.5 m (the exact frequencies are given later). I use the average wavelength of 42 m in the radar equation. The distance from the Earth's surface to the Moon's surface, R , is about 376,000,000 m.

The only parameter in the radar equation left to define is the receiver antenna gain. As expected, this depends on the observer's setup, including type of antenna and orientation. For purposes of calculation, I assume that a resonant half-wave dipole antenna is used and it is oriented at right-angles to the Moon's direction. A half-wave dipole antenna has a gain of 1.64 (2.15 dB).

Substituting these values gives

$$P_R = \frac{P_T \cdot G_T \cdot G_R \cdot \sigma \cdot \lambda^2}{(4 \cdot \pi)^3 \cdot R^4} = \frac{3.6 \cdot 10^6 \cdot 735 \cdot 1.64 \cdot 1.4 \cdot 10^{12} \cdot 42^2}{(4 \cdot \pi)^3 \cdot (3.76 \cdot 10^8)^4} = 2.7 \cdot 10^{-13} \text{ watts}$$

Therefore, the received signal power is -126 dBw, or -96 dBm. The impedance of a resonant dipole antenna is 70 ohms; therefore, the voltage at the antenna terminals is 4.3×10^{-6} volts, or 4.3 μ v. In terms of familiar signal strength units, or S-units, a voltage of 50 μ v approximately corresponds to an S-9 indication, and each successively lower S-unit represents a decrease of approximately 5 – 6 dB in voltage. Therefore, for the conditions and assumptions above, the received lunar echo signal is about S-5 signal strength.

The above assumptions are close enough for the purposes of my observations, but they suffer potential limitations:

- The electrical characteristics (such as gain, vertical and horizontal radiation patterns and impedance) of a dipole antenna depend on its height above ground and the characteristics of the ground itself. Different observers with different antenna configurations would see significant variations from calculated receive power levels;
- Antenna gains used in the above radar equation are net and include transmission line (feed line) losses. Even though a dipole antenna has a maximum gain of 2.15 dB, that gain may

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never be realized in the radar equation if there are significant feed line losses or if the antenna is not oriented correctly;

- The HAARP web reported that the HAARP antenna beam was repositioned at 3 minute intervals to track the Moon. The experiments took place at the low point of the solar sunspot cycle and during evening hours when ionization normally would be low; however, ionospheric absorption and refraction could have been possible. Absorption would cause a small decrease in both the transmitted and received signals. As reported on the HAARP web, the HAARP Riometer¹ indicated no absorption during the January 19 test and a small amount during the January 20 test. Also, ionospheric refraction, if present, could have affected the direction of the HAARP transmitted signal peak as it passed through the ionosphere;
- The HAARP antenna array loses gain as the beam is positioned off the zenith. For this experiment, the Moon was at a zenith angle of about 35 degrees as seen from HAARP, resulting in transmitter antenna gain decrease of a few dB. The above calculation does not take this into account;
- The Earth-Moon distance varied during the test, resulting in a Doppler shift on the lunar echo signal frequency of up to ± 7 Hz. The Doppler shift would be most noticeable in receivers with vary narrow bandwidths and could affect received signal levels. As described below, I retuned my receiver a few times during the experiments, and it may have been this Doppler shift that led me to do this.

The January Experiment

The HAARP antenna focusing increased the transmitted power by a factor of 735 from 3.6 Megawatt to 2.6 Gigwatts (this is the effective isotropic radiated power, or EIRP). The radiated signal was aimed about 45 degrees away from the zenith (zenith means directly overhead) and tracked and illuminated the Moon as it traveled across the sky.

¹ Riometer stands for Relative Ionospheric Opacity Meter. It is a special receiver used to measure the absorption of the ionosphere.

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The HAARP transmitter was setup to transmit for the first 2 seconds of a 5 second cycle as shown in Figure 4. The 3 second quiet interval was necessary to allow time for the transmitted signal to travel to the Moon, be reflected by the Moon and travel back to receivers on the Earth and heard by a listener. The reflected signal would last 2 seconds (same as transmitted signal), and during the quiet interval there would be no interference by the original transmitted signal.

The 2 seconds On, 3 seconds Off cycle was repeated continuously for one hour at 6.7925 MHz and for another hour at 7.4075 MHz on both January 19 and 20. The researchers thought that it may or may not be possible to hear the HAARP transmission via skywave due to atmospheric conditions; however, in my case, I quite clearly heard the transmitted pulses during both 2-hour intervals. The HAARP station is about 290 km northeast of my receiving station in Anchorage, Alaska, and it is possible I heard groundwaves and not skywaves.

As mentioned above, the distance from the Earth to the Moon is around 376,000 km. Since radio signals in space travel at approximately 300,000,000 m/s, the propagation time from the Earth to the Moon is about 1.3 seconds. The signals have to travel all the way to the Moon and back to the Earth, so the roundtrip propagation delay for each transmitted pulse is around 2.6 seconds. That means a reflected pulse would be heard about 0.6 seconds after the end of a 2 second transmitted pulse and during the 3 second quiet interval.

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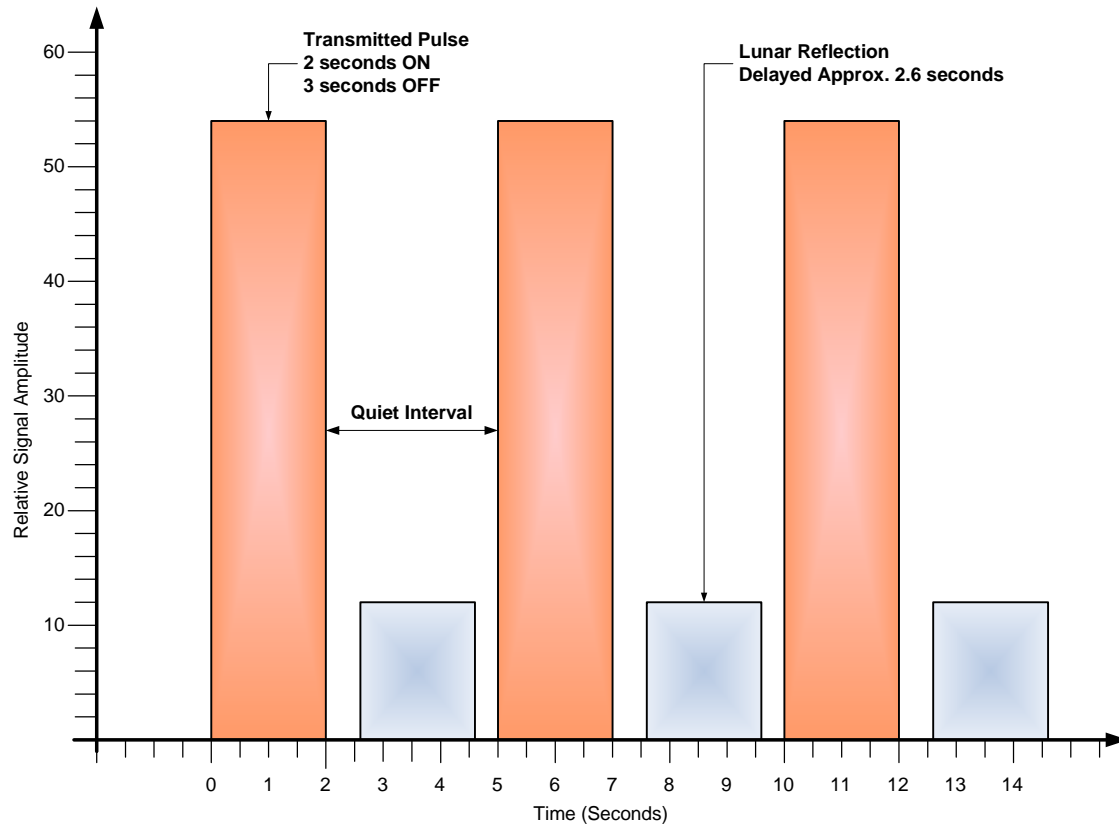


Figure 4 – Transmitted carrier duty cycle showing relative position of reflected lunar signals (Copyright W.D. Reeve)

My Receiving Setup

My receiver room and antenna are located at geographical coordinates 61-11-57.26 N : 149-57-23.76 W. If you use Google Earth and zoom into these coordinates, you can see the roof of my station and front and back yards. You may even see me on the deck.

For this experiment I used an Icom R-75 HF receiver with an optional CR-292 high-stability oven-controlled crystal oscillator (OCXO) and an external Icom SP-23 speaker. A photograph of the receiver installation and block diagram of the complete setup are shown in Figures 5 and 6.

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Figure 5 – The Icom R-75 HF receiver used in this experiment is in the lower portion of the upper cabinet. Above it is an Icom R-8500 wideband receiver. The bottom cabinet holds two speakers and a shelf with an Icom PCR-2500 wideband receiver (behind speakers). (Copyright W.D. Reeve)

I used an end-fed 46 m random-length (untuned), long-wire antenna placed from my roof in a North-South direction to a tree in my backyard. The 16 ga. antenna wire terminates in a so-called Magnetic Longwire Balun (MLB), which is used to match the antenna to the coaxial cable lead-in to the receiver. The antenna is about 10 m above ground at the receiver end and 6 m at the far end. Directly below the antenna and parallel to it is approximately 60 m of 12 AWG bare copper radial ground wire.

Because of interference from nearby AM broadcast stations, I use an Industrial Communication Engineers (<http://www.iceradioproducts.com>) model 401 broadcast band notch (band-stop) filter between the receiver antenna input and the antenna lead. This filter provides over 30 dB of loss at

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frequencies between 550 and 1700 kHz and effectively eliminates overloading of the receiver's front end caused by the high-powered broadcast band transmitters.

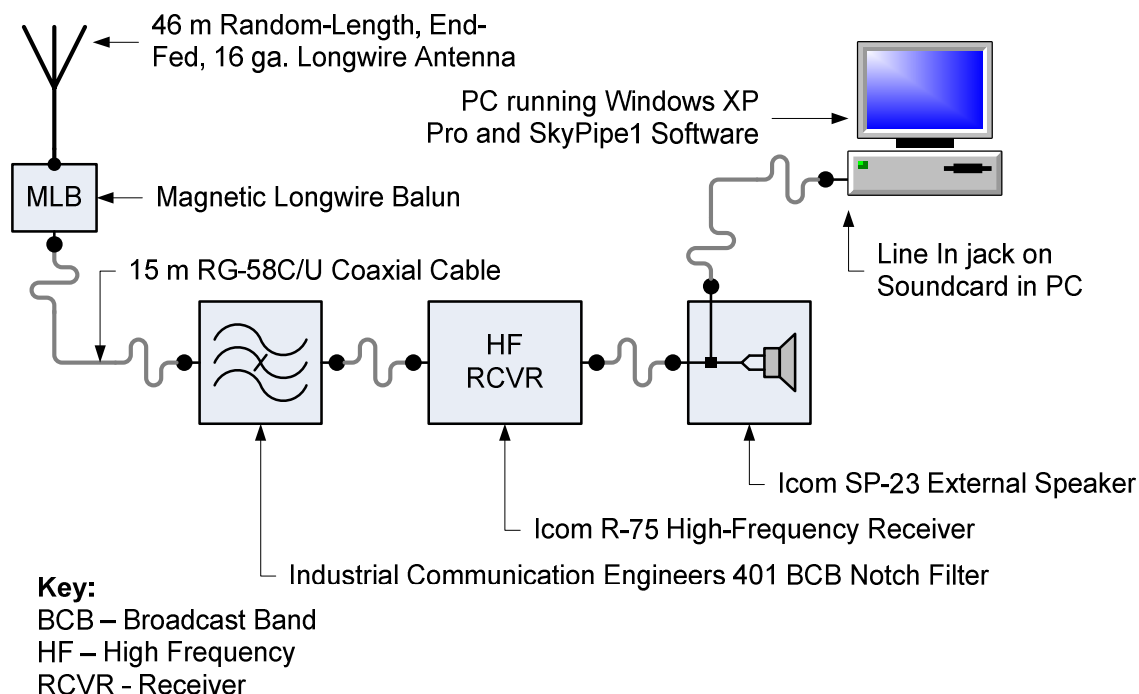


Figure 6 – Block diagram of receiving setup in Anchorage, Alaska. Note: Future applications will connect the Record output from the receive to the PC soundcard. (Copyright W.D. Reeve)

I connected the receiver Speaker audio output via the external speaker to the Line In jack of my station PC's soundcard and used Radio SkyPipe1 software to sample the incoming audio signal. Prior to the experiment, I had modified the external speaker by installing a second audio jack so that the audio output to the soundcard was bridged across the speaker. In future experiments, I will connect the Record audio output (rather than the Speaker output) of the radio to the soundcard Line In jack since it provides a more suitable signal.

The SkyPipe1 software was developed for NASA's Radio JOVE educational program and is available for free by download from <http://radiojove.gsfc.nasa.gov/software>. More advanced versions of this software are available from Radio-Sky Publishing at <http://radiosky.com> for a small fee. The software samples the audio at a slow rate (I set it for 10 samples/second on January 19 and 20

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samples/second on January 20) and displays a trace of the relative amplitude versus time. The relatively low sample rate is perfect for capturing the audio amplitude for trace purposes.

I synchronized my PC clock to the United States National Institute of Science and Technology (NIST) clock using Symmetricom's SymmTime program (available for free at <http://www.symmetricom.com>). It appeared the HAARP transmissions were synchronized to NIST as well, at least on January 19, because my trace recordings showed close correlation between the start of the transmitted pulses and the beginning of the timing intervals. The transmissions took place between 0500 and 0700 UTC on January 19 and 0630 and 0830 UTC on January 20. This worked out quite well for me since 0500 UTC is 2000 (8:00PM) local, and I did not have to stay up all night.

While monitoring the signals, I tried various receiver mode settings – CW, Lower Sideband (LSB) and Upper Sideband (USB). I ended up tuning the receiver so the detected carrier sounded like an Oboe musical instrument (in the 300 – 400 Hz range). I turned off the Automatic Gain Control (AGC) so that the receiver operated at maximum RF gain and to keep the AGC from altering the relative amplitudes of the received signals. Throughout the two sessions, I used the receiver Preamp1 based on received signal conditions and kept the DSP noise filter and Noise Blanker turned off.

I did not make an audio recording of the recovered signal but another observer did and put the recording on the web at <http://youtube.com/watch?v=L5E2ntIxAAsc>.

My Observation Logs

On both evenings, I could clearly hear the transmitted HAARP pulses; I also could regularly hear reflected pulses a fraction of a second after the transmitted pulse ended, although they faded in and out during the sessions. It was this difference in the received signal level along with the time stamp on the recordings that allowed me to identify the transmitted and reflected signals.

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Although I was able to hear the reflected signals at times, I found it difficult to pick them out of the SkyPipe1 trace recordings from January 19, possibly due to the low sample rate (10 samples/second). However, reflected pulses can be seen clearly in the January 20 trace recordings in which I used a higher sample rate (20 samples/second) and adjusted the receiver for optimum conditions. While listening to the signals, the amplitude of the reflected pulses seemed to decrease from their initial values; that is, they sounded like they had a steep rise time and relatively low decay time and were somewhat eerie when taken in context of the distance traveled. Here are additional details taken from my logs:

January 19, 2008:

Frequency: 6.7925 MHz – Used CW mode from 0500 to 0510, USB from 0510 to 0520 and LSB from 0520 to 0600 (best display results using LSB – direct and reflected pulses clearly visible); made no attempt to tune receiver for best reception. Did not adjust receiver audio output during this entire run but did momentarily disconnect audio for about 2.5 seconds at approximately 0550:15. Ran trace for several seconds after signal disappeared just prior to 0600.

Frequency: 7.4075 MHz – Used LSB from 0600:45 to 0610 and then switched to USB from 0610 to 0620. Retuned receiver at approximately 0623 to 7.40755 MHz and set to LSB for best reception. Adjusted audio output at 0626. Slightly retuned receiver to 7.40760 MHz and increased audio output at around 0640. No changes from 0640 to 0700. Continued trace from 0700 to 0705 after signal disappeared.

January 20, 2008:

Frequency: 6.7925 MHz – Used CW mode from 0630 to 0705 and LSB until 0730. At 0705 set the receiver for LSB and adjusted the receiver frequency so that the audio sounded like an oboe. This resulted in an indicated frequency of 6.792840 MHz. Adjusted the receiver input gain by switching in and out Preamp1 and Preamp2 as follows: No preamp from 0630 to 0640, Preamp1 from 0640 to 0643, Preamp2 from 0643 to 0645 and then no preamp from 0645 to

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0730 (traces seemed to be the best with no preamp). I occasionally disconnected and adjusted the audio (these are apparent on the traces). I also experimented a little with AGC and turned it On between 0712 and 0714. The audio and recordings were much better with it Off.

Frequency: 7.4075 MHz – Used LSB for entire recording and tuned the receiver for oboe sound. This resulted in an indicated frequency of 7.407850 MHz. I frequently adjusted the recording trace scale for best view. I had the preamp Off from 0731 to 0738 but turned Preamp1 On for the remainder of the session from 0738 to 0830.

SkyPipe Audio Signal Level Trace Recordings

Figures 7A and 7B show annotated snapshots from the trace recordings and Figures 8A, 8B, and 8C show basic trace recording snapshots. In all charts, the horizontal axis is a time scale based on Universal Coordinated Time (UTC) and the vertical axis shows the relative received audio signal amplitude (no units). The relative audio level on the traces is an arbitrary setting based on a combination of the receiver's adjusted output level and the soundcard's adjusted Line In level. Interested readers can obtain my original SkyPipe1 recording files by sending an email request to w.reeve@ieee.org.

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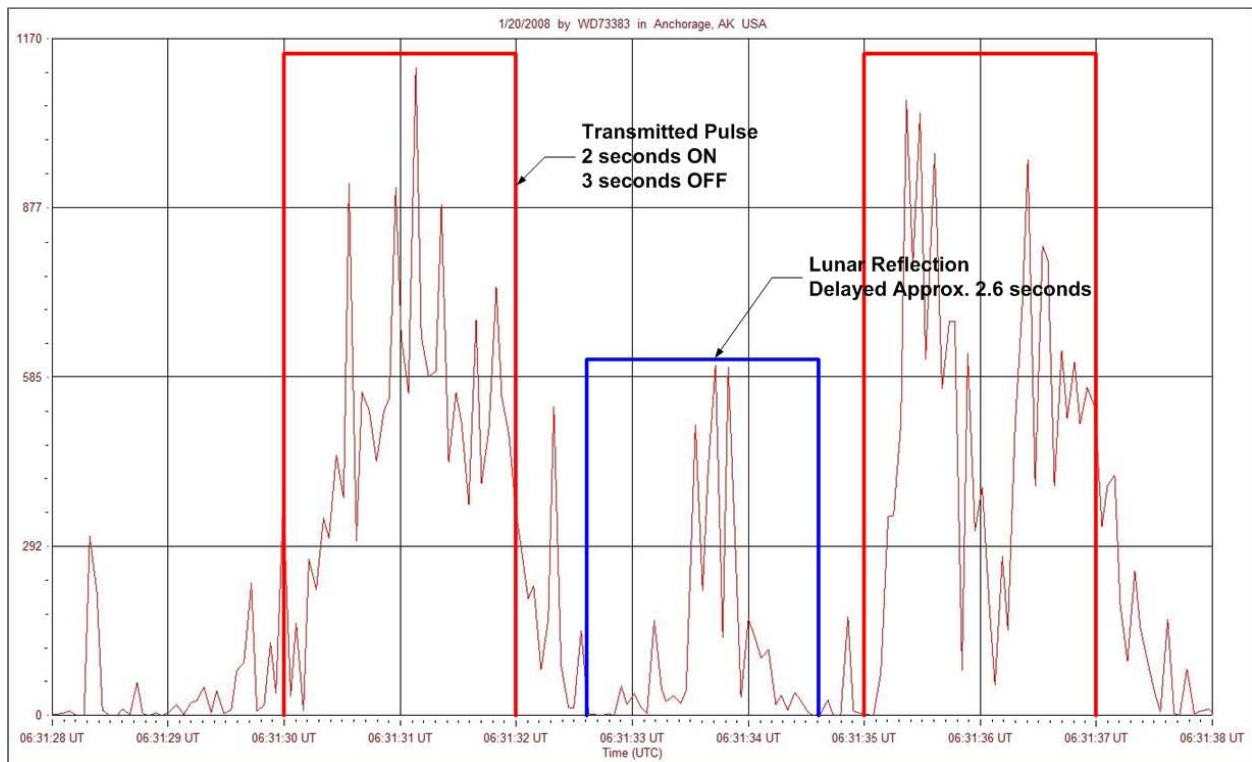


Figure 7A – Snapshot of the January 20 trace recording at 0631:30 with annotations showing the position of the transmitted and reflected signals as received.

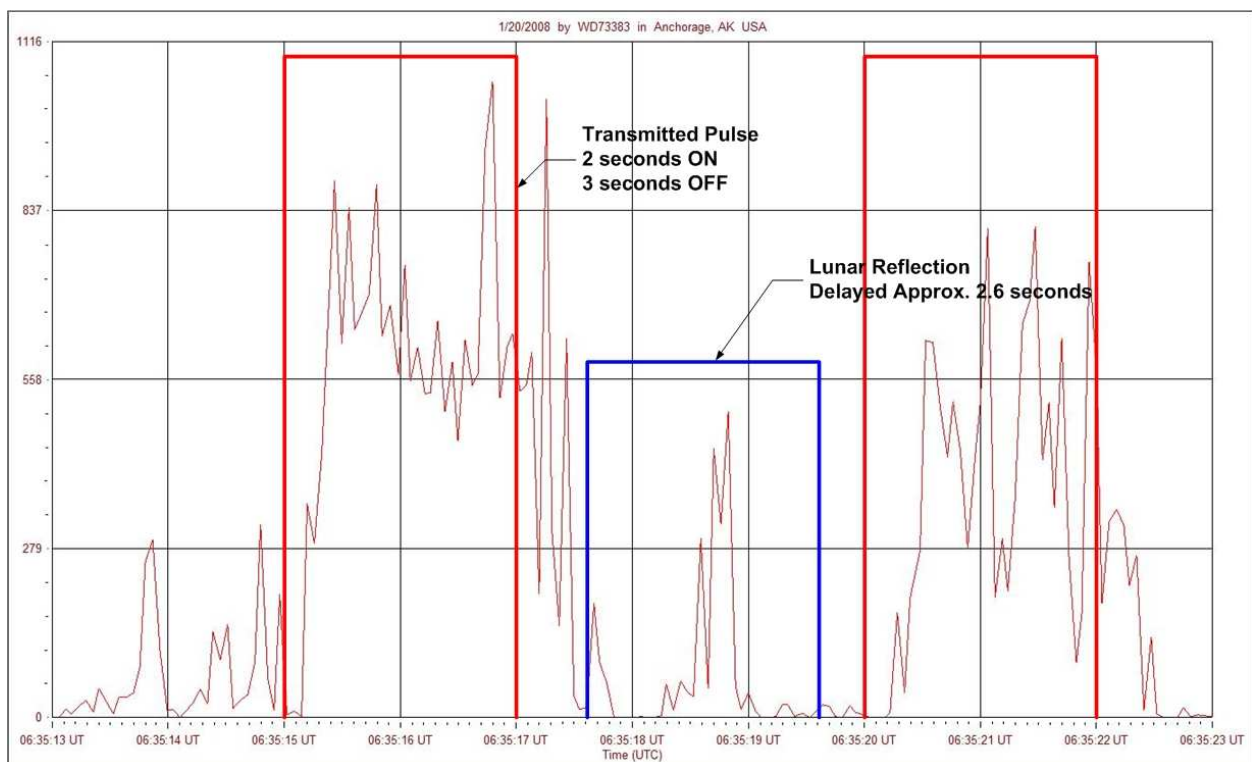


Figure 7B – Snapshot of the January 20 trace recording at 0635:15 with annotations showing the position of the transmitted and reflected signals as received.

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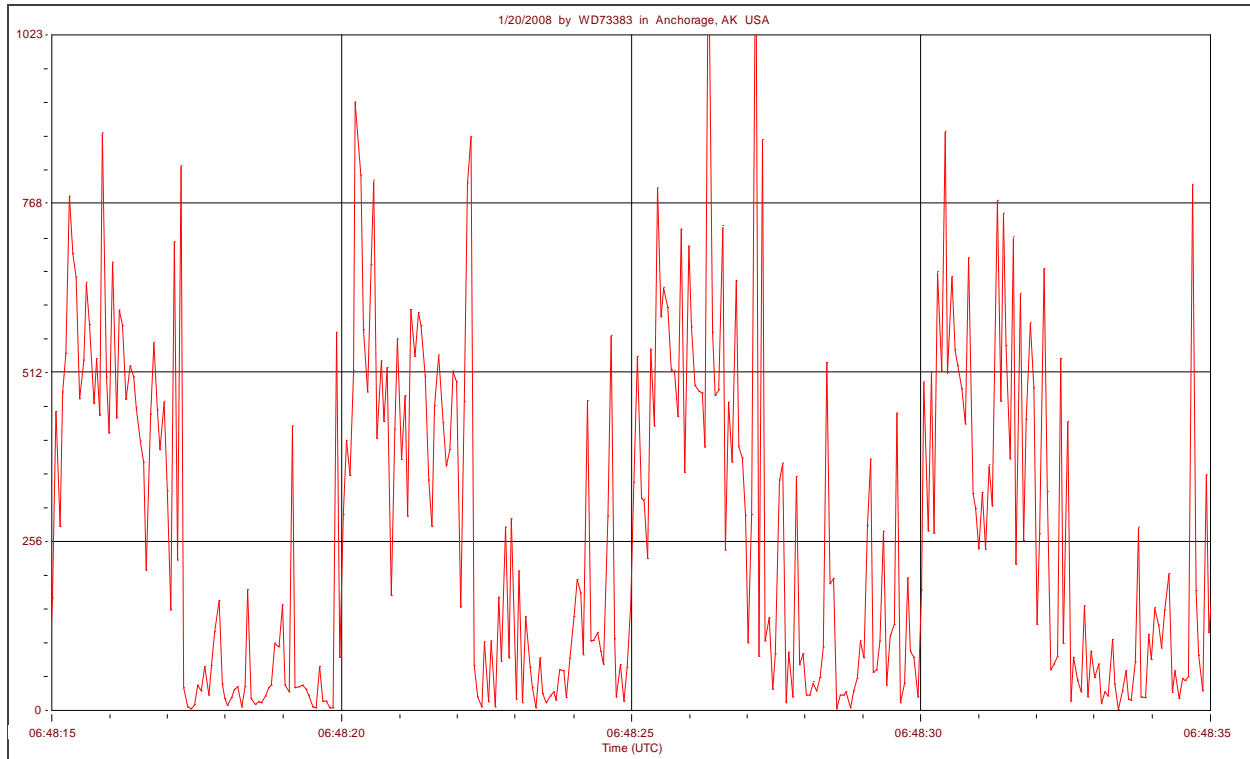


Figure 8A – Snapshot of a trace recording from 0648:15 to 0648:35 on January 20. It is not obvious from an initial examination of this trace but reflected signals are there between the transmitted signals.

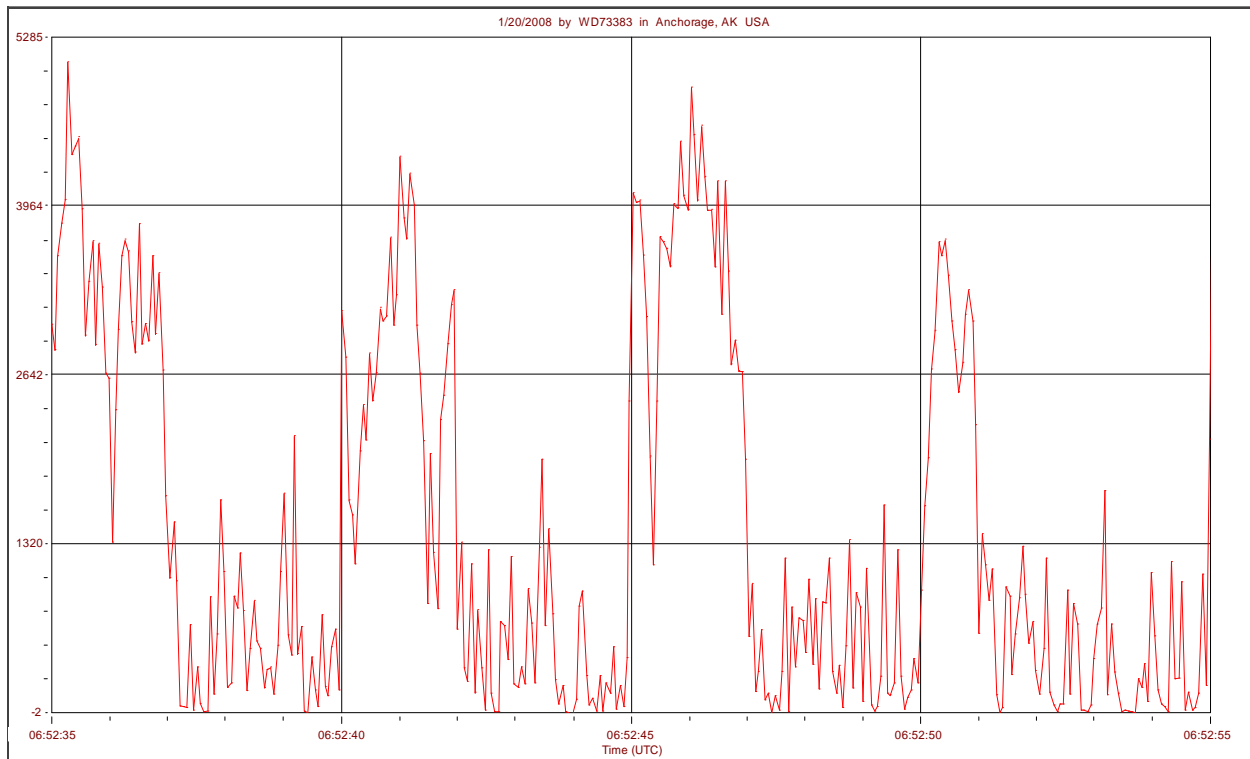


Figure 8B – Snapshot of a trace recording from 0652:35 to 0652:55 on January 20. The trace of the transmitted signals is corrupted due to atmospheric conditions. Reflected signals are not obvious but they can be inferred between the transmitted signals.

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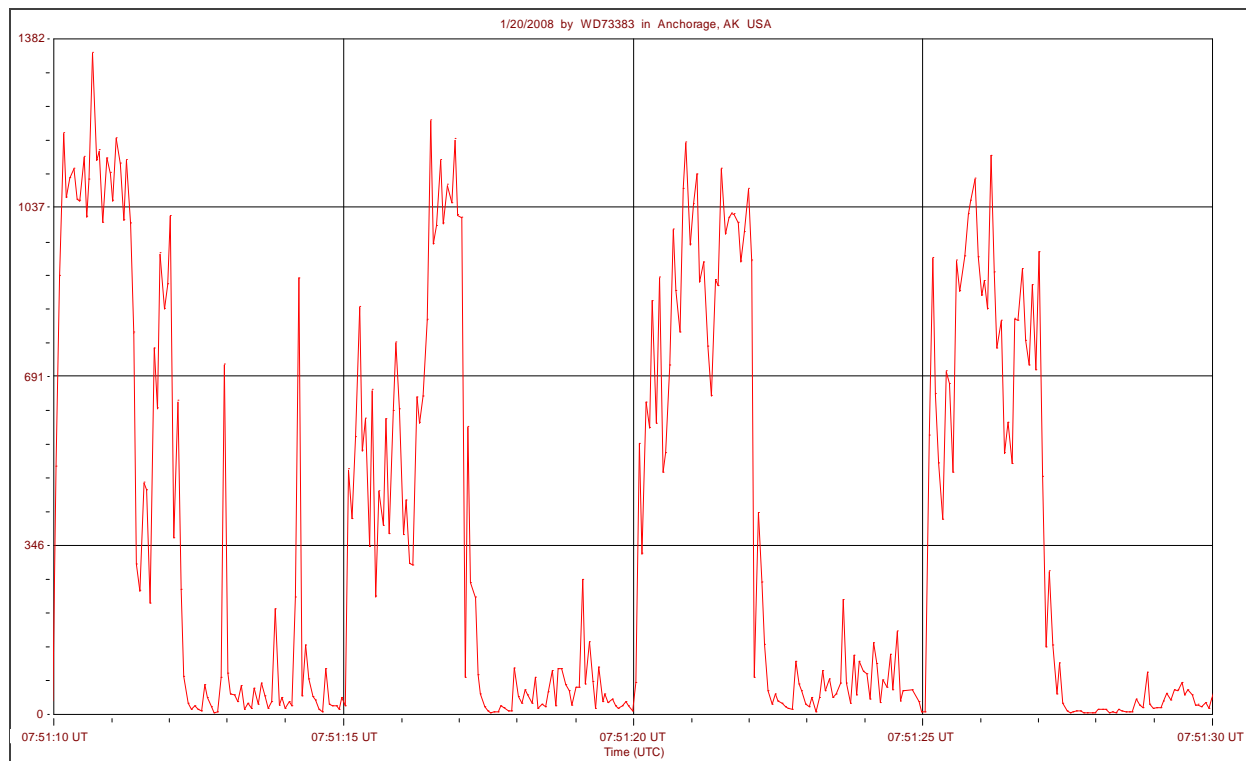


Figure 8C – Snapshot of a trace recording from 0751:10 to 0751:30 on January 20. Vestiges of the reflected signals are visible between the much taller transmitted signals.

Conclusions

Given my haste to setup my receiver and PC for this observing experiment, I was surprised to receive the reflections at all. I wish now I had been better prepared.

Even so, I consider the experiment a success, at least on my part as an observer. It gave me a chance to use some additional capabilities of my receiver station including the SkyPipe software, which I had just obtained for use in the Radio JOVE project. It also gave me a chance to participate in a unique experiment and to monkey around with different antenna configurations, filters and audio frequency (AF) and radio frequency (RF) signal paths. Now that I know what I am doing, and have documented all the setup details, I am ready to do this experiment again and expect to have even better results. All I need now is the cooperation of the HAARP facility.