HAARP Program Office
University of Alaska Fairbanks
Geophysical Institute
2156 Koyukuk Drive
Fairbanks, Alaska 99775
UAF-GI-HAARP@alaska.edu
https://haarp.gi.alaska.edu/
Phone | 907-474-1100
www.facebook.com/pg/UAFHAARP
X | @UAFHAARP

UAF
HIGH FREQUENCY ACTIVE AURORAL RESEARCH PROGRAM
University of Alaska Fairbanks
GEOPHYSICAL INSTITUTE

Date: January 21, 2025
To: Amateur Radio & Radio Astronomy Communities
From: HAARP Program Office
Subject: Notice of Transmission

The High-frequency Active Auroral Research Program (HAARP) will be conducting a research campaign January 27-31 UTC, with operating times specified in the table below. Operating frequencies will vary, but all HAARP transmissions will be between 2.75 MHz and 10 MHz. Actual transmit days and times are highly variable based on real-time ionospheric and/or geomagnetic conditions. All information is subject to change.

This campaign is being conducted in support of research proposals from UAF, the University of Florida, the Naval Research Laboratory, Los Alamos National Laboratory, Cornell University, Dartmouth College, Embry-Riddle Aeronautical University, and the University of Houston. Research topics for this campaign include VLF generation and ducting, studies on STEVE airglow, and space debris detection. This campaign will also support the GIRAFF rocket launch from Poker Flat Research Range, which is investigating the mechanisms that cause flickering and pulsing within the aurora. More information on GIRAFF is available here: https://sites.wff.nasa.gov/code810/news/story301-36.380%20381%20GIRAFF.html

Note that a number of experiments will be conducted based on the critical frequency ($f_0F2$) determined by the Gakona ionosonde. The included transmission notice supplement contains information on the frequencies HAARP is authorized to transmit. HAARP transmissions will only occur on our authorized frequencies. **There are no specific data collection requests from funded investigators, but reception reports are appreciated and may be submitted online via our web form at: https://haarp.gi.alaska.edu/form/reception-reports**

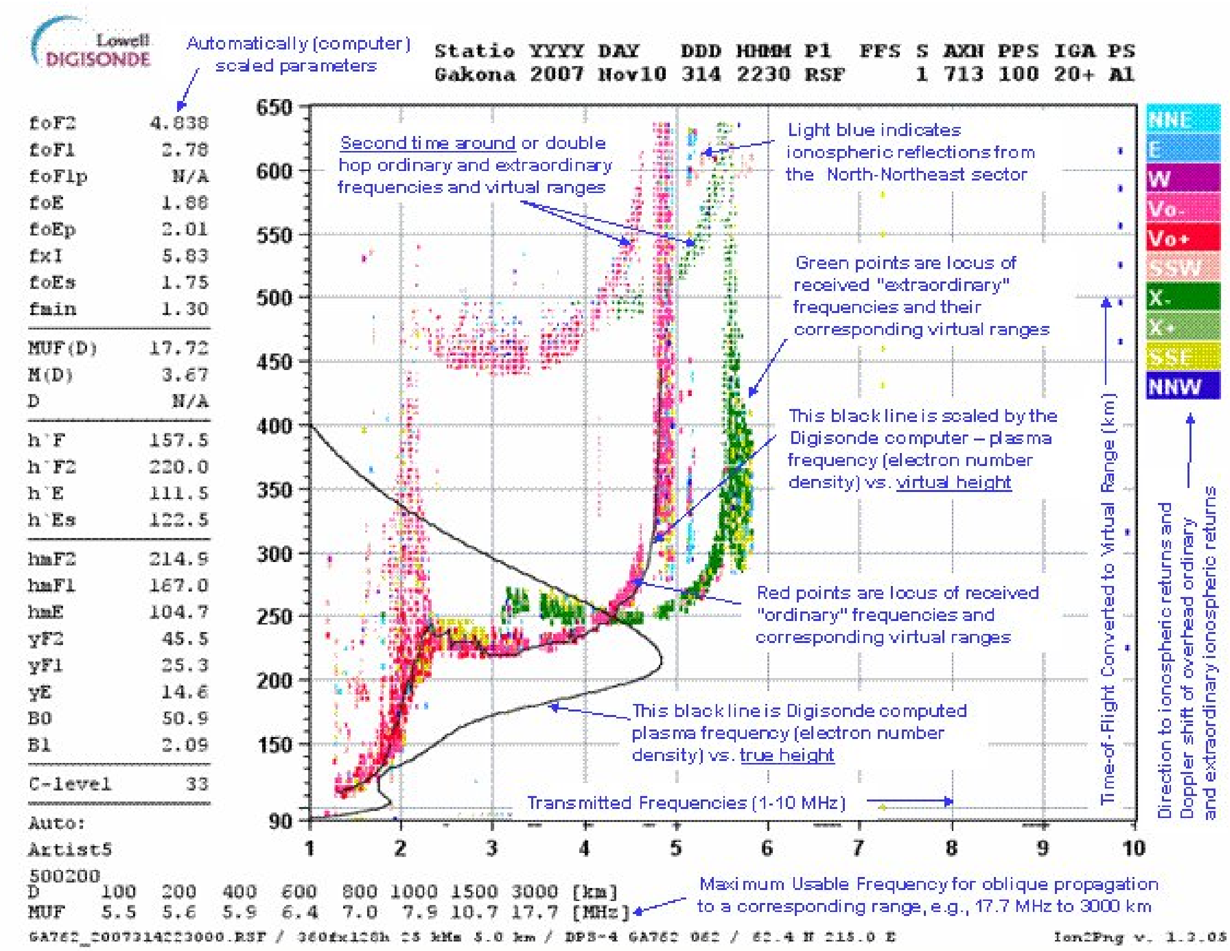
| **Date (UTC)** | Jan. 27 | Jan. 28 | Jan. 29 | Jan. 30 | Jan. 31 |
|---|---|---|---|---|---|
| **Time (UTC)** | 0300-0830 | 0500-1130 | 0300-1030, 2100-2400 | 0000-0330, 2000-2400 | 0000-0330 |
| **Frequency (MHz)** | 3.25, $f_0F2$ | 3.25, $f_0F2$ | 3.25, $f_0F2$ | 3.25, $f_0F2$ | 3.25, $f_0F2$ |
| **Notes** | Frequencies updated based on real-time conditions | Frequencies updated based on real-time conditions | Frequencies updated based on real-time conditions | Continues into UTC day Jan. 31 | Frequencies updated based on real-time conditions |

For updates on ionospheric conditions in Gakona, including $f_0F2$, please consult ionograms from the HAARP Diagnostic Suite: https://haarp.gi.alaska.edu/diagnostic-suite

## Additional Resources for Reading Ionograms

*Understanding HF Propagation and Reading Ionograms* from Bootstrap Workbench:
https://www.youtube.com/watch?v=oTFKNCo3CI8

*Reading Your Ionogram-Keeping It Simple* from John (VE6EY):
https://play.fallows.ca/wp/radio/shortwave-radio/reading-your-ionogram-keeping-it-simple/




The image above is an annotated ionogram from HAARP that describes features that may be of interest. Note that $f_0F2$ is calculated at the top left.

$f_0F2$ is the critical frequency of the F2 layer of the Earth's ionosphere. This is the frequency at which radio signals stop refracting off the ionosphere and begin passing through to outer space. For certain HAARP experiments that deal with interactions in the ionosphere, transmission frequencies below $f_0F2$ are desirable, while for other experiments (such as those involving high-altitude satellites), staying above $f_0F2$ is required.

# Supplement to HAARP Notice of Transmission

**General Information for HAARP Radio Enthusiasts:**

1) The HAARP Ionospheric Research Instrument (IRI) transmits in the frequency range 2.750 to 9.600 MHz, with certain frequencies blocked out as specified in the FCC license for call sign WI2XFX. The frequency authorization chart on the next page shows the HAARP transmission frequencies.
2) The emission bandwidth may be up to 46 kHz; the actual value depends on the frequency, modulation and experiment requirements;
3) The lower frequency transmissions many times are based on a harmonic of the local ionosphere's gyro frequency; the actual frequency depends on the experiment. The fundamental gyro frequency above HAARP varies from roughly 1.5 MHz at lower altitudes to 1.2 MHz at higher altitudes. The $2^{nd}$ or $3^{rd}$ harmonic is often used to heat the ionosphere in conjunction with another frequency to produce low frequency effects;
4) The mid-range frequencies often are used for artificial airglow experiments but, again, the frequencies used will depend on the experiment as well time of day, season, solar activity and sunspot cycle;
5) The higher frequency transmissions many times are based on the critical plasma frequency for the F2 region (foF2) as measured by the Gakona ionosonde (https://haarp.gi.alaska.edu/diagnostic-suite ). The transmission frequencies may be above, below or at the critical frequency depending on the experiment. The critical plasma frequency in the vicinity of HAARP varies widely depending on, among other things, time of day, season, solar activity and sunspot cycle;
6) One or two carriers are transmitted and one or both of the carriers may be modulated. The types of modulation varies with the experiment requirements. Modulation may be AM, FM, or Pulse, including Linear FM (LFM) or a complex waveform or a time sequence of different modulations. LFM is very common. Communications modulations and protocols such as SSB, PSK, FSK, and QAM are never used. A glossary and brief description of the modulation modes is provided at the end of this document;
7) Frequencies and timing are precise to allow synchronization with diagnostics. Both are controlled by locking them to the Global Positioning System (GPS);
8) Most experiments depend on ionospheric and geomagnetic conditions that are mostly unpredictable. The transmission frequencies for a given experiment may change to track changes in those conditions with little or no notice;
9) A scheduled experiment that depends on certain ionospheric or geomagnetic conditions may be rescheduled or cancelled if the required conditions do not occur;
10) Additional information can be found on the HAARP webpage at: https://haarp.gi.alaska.edu/ .

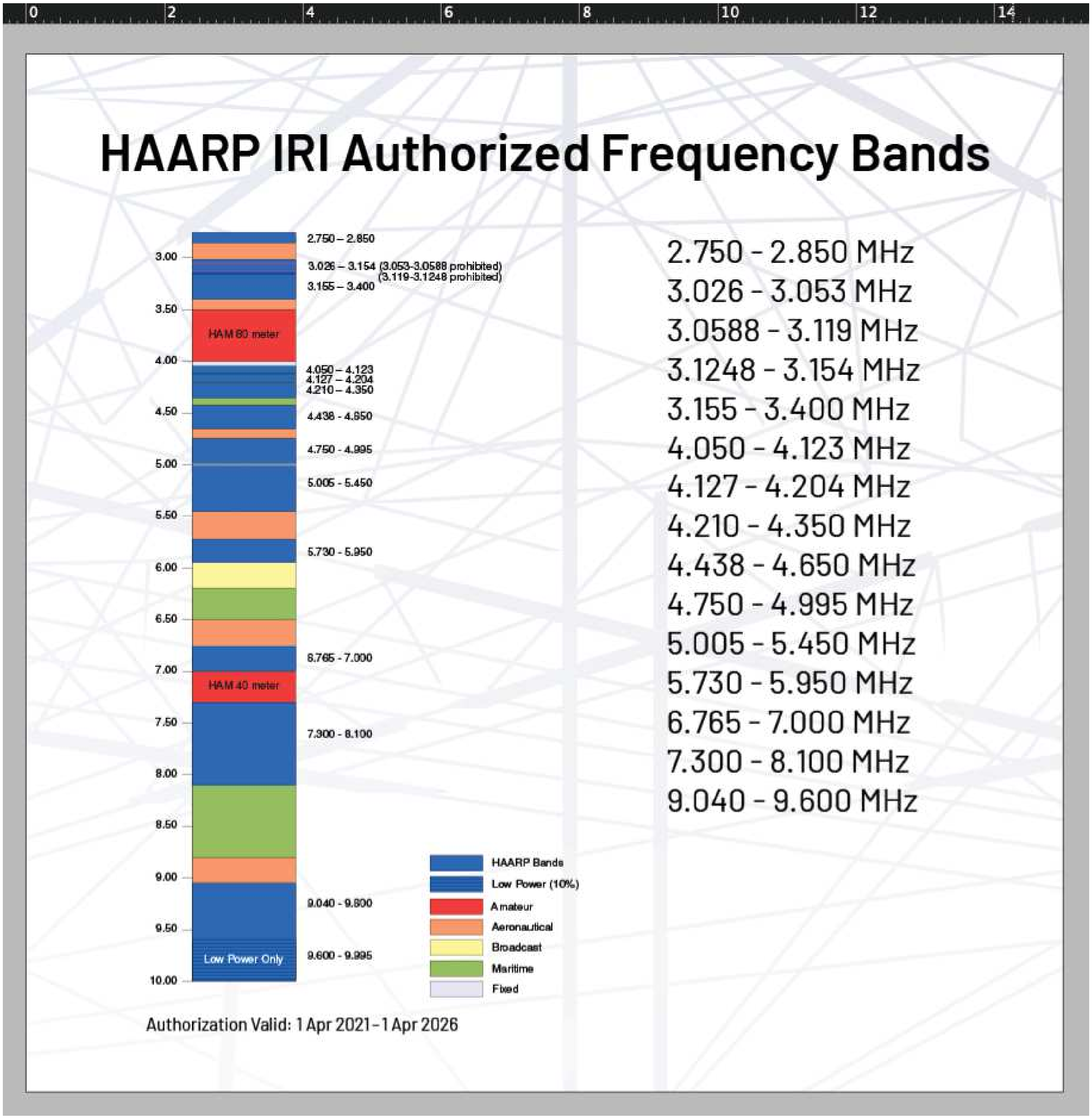



Image courtesy of University of Alaska Fairbanks – Geophysical Institute

**Monitoring HAARP IRI transmissions with a Software Defined Radio Receiver:**

1) Listeners with an SDR receiver capable of 8 MHz bandwidth can monitor the entire frequency band noted above. A center frequency of 6.35 MHz may be used with 8 MHz bandwidth;
2) The HAARP IRI uses Coordinated Universal Time (UTC) for all operations. Transmissions most often are programmed to *Start* at top of the minute, ie, HH:MM:00, but some start at 30 seconds, ie, HH:MM:30. Transmissions usually *Stop* on the 30 second mark, ie, HH:MM:30, to allow time to retune the transmitter/antenna for the next experiment. There may be exceptions to the Start and Stop times;
3) The SDR software should be run on a PC whose real-time clock is synchronized to UTC using the Network Time Protocol (NTP);
4) When a carrier is seen to pop up on the SDR's displayed spectra, listeners can identify the center frequency using the SDR software and then reduce the bandwidth to further analyze the signal;
5) If two SDRs are available, one can be used in a wideband mode to locate the signals and the other can be used in a narrowband mode to analyze specific signals after they are identified;
6) A useful method for locating IRI transmissions that are on or near the ionosphere's critical frequency $f_0F2$, is to view the latest Gakona Ionogram (Ionosonde tab at https://haarp.gi.alaska.edu/diagnostic-suite ). Find the current $f_0F2$, which is labeled in the upper-left corner of the Ionogram, and then tune the SDR to that frequency with a moderate displayed frequency span;
7) SDRs with a 50 kHz bandwidth setting are able to monitor the modulated carrier after it is located. However, the center frequency may be stepped through a range of frequencies or may change according to experiment requirements to another, far removed frequency. Carrier frequency changes > 200 kHz require at least 30 seconds for retuning;
8) Not all experiments use a modulated carrier or the full emission bandwidth, some use only a pure carrier;
9) Some experiments require a transmitter On – transmitter Off cycle. The cycle times and On-Off ratios vary from experiment to experiment but Off times typically are minutes or fractions of a minute. Transmission On times can last from a couple minutes to a few hours;
10) Radio propagation conditions and the IRI beam direction will affect the reception of the IRI transmissions or cause a fadeout at the receiving antenna location. Propagation conditions and beam directions can change significantly and rapidly during an experiment;
11) Some experiments require the IRI beam to be pointed along or near the local magnetic zenith. This means the beam is pointed parallel or nearly parallel to the local magnetic field lines. The magnetic zenith at the HAARP facility is approximately 76° elevation and 16° west of south;
12) Although the HAARP IRI transmits only in the HF range, the transmissions can and some experiments are designed to generate ELF, SLF, ULF, and VLF emissions in the D- and E-regions of the ionosphere. Other experiments may not be designed to generate these low frequency emissions but the emissions are generated as a side effect. Modulated heating of the D- and E-region electrons by the HF transmissions in turn modulates the plasma conductivity, which generates a *virtual antenna* at altitudes between 70 and 85 km. Emissions up to 20 kHz have been demonstrated but most are below a few kilohertz. These low frequency emissions can propagate in the Earth-Ionosphere Waveguide or by other mechanisms, depending on frequency, and conceivably can travel great distances;

13) It is important to remember that the upper frequency limit of the IRI is 9.600 MHz. Any spectral indications at higher frequencies that correlate with the timed IRI transmissions are possibly intermodulation products in the receiver itself or they could be spurious.

**Glossary**

Modulation types mentioned in transmission notice:

AM: Amplitude Modulation, https://en.wikipedia.org/wiki/Amplitude_modulation . The modulation frequency can be 0 – 30 kHz. The AM modulation may be fixed frequency with sine, square, triangle, linear or log ramp, or square-root sine waveforms.

FM: Frequency Modulation, https://en.wikipedia.org/wiki/Frequency_modulation . The modulation frequency can be 0 – 30 kHz with frequency deviation ≤ 100 kHz

LFM: Linear Frequency Modulation is a form of FM in which the carrier is swept at a linear rate. LFM is very common in HAARP experiments and may be combined with AM pulse. FMCW (continuous) also may be used

Pulse: Carrier is pulsed On and Off. Pulse width is ≥ 10 μs and pulse rise time is set to limit transmission spectral width

Frequency bands mentioned in transmission notice:

ELF: Extremely Low Frequency, 3 – 30 Hz
SLF: Super Low Frequency, 30 – 300 Hz
ULF: Ultra Low Frequency, 300 – 3000 Hz
VLF: Very Low Frequency, 3 – 30 kHz
HF: High Frequency, 3 – 30 MHz

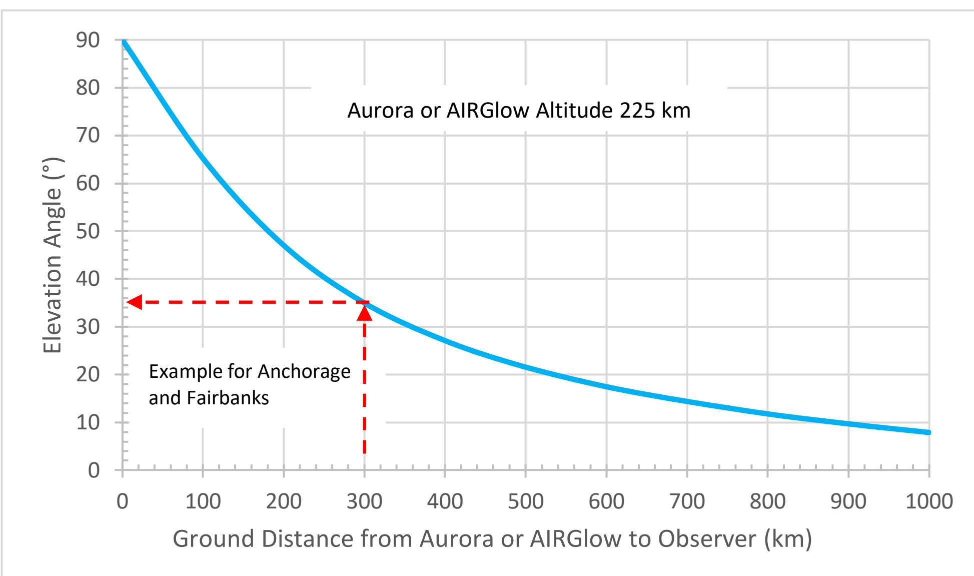
**AIRGlow Observer Guide**

The AIRGlow (*Artificial Ionospheric Reflector with Airglow*) experiments pulse the HAARP transmitters on and off to create radio-induced aurora, also known as airglow and artificial aurora. The on transmissions add energy to, or excite, the gases in the upper atmosphere causing electrons to break free of their atomic bonds, a process called ionization. During the transmission off times, the electrons recombine with the molecules and atoms, and the atmosphere's gases de-excite. The de-excitation produces visible airglow between about 200 and 250 km (120 and 150 miles) altitude.

The artificial airglow can help us learn about the natural aurora and to answer questions such as: What causes the brightest airglow and why does it happen, and how do radio waves interact with ionized gases (plasma) in the upper atmosphere?

The phenomenon, if visible, will appear as a faint, red or possibly green splotch. Because of the way the human eye operates, the airglow might be easier to see when looking just to the side. The Earth's curvature prevents observations of the airglow from greater distances and, of course, the skies must be clear of clouds between the observer and the airglow. It is possible that mountains, buildings or tall trees will obstruct the line-of-sight of an observer toward HAARP. Even bright natural aurora or a bright Moon could wash out the visibility of the artificial aurora.

People within about 500 km (300 miles) of the HAARP facility can try to spot the airglow and even attempt to photograph it. The plot below shows the elevation angle (angle above the horizon) that an observer would look for the airglow. For example, say there are observers in Anchorage or Fairbanks. Both places are about 300 km from HAARP. First, find 300 km on the lower horizontal scale and then look directly above to the intersection with the blue curve. Read the elevation angle directly to the left of that intersection. In this example, the elevation angle is around 35°. Observers within 100 km (60 miles) will look almost straight up. The 500 km limit mentioned above is based on a 20° elevation angle. It is possible that some observers farther away than 500 km could have a clear line-of-sight to the airglow region above HAARP even though the elevation angle is below 20°. The opposite is true of closer observers that have mountains or tall trees in the line-of-sight.




An observer also will need to look toward the HAARP facility near Gakona, Alaska. From Anchorage, the azimuth is approximately north-west, or 60° from True North and 44° from Magnetic North as seen on a compass. An observer in Fairbanks would look south-east at approximately 154° from True North or 138° Magnetic North. Online maps or Google Earth can be used to determine the distances and azimuths for other cities in Alaska and western Canada.