The High Frequency Active Auroral Research Program

HAARP

Purpose and Objectives of the HAARP Program

As stated in the Environmental Impact Statement

The High-frequency Active Auroral Research Program (HAARP) is a congressionally initiated program jointly managed by the U.S. Air Force and U.S. Navy. The program's goal is to provide a state-of-the-art U.S. owned ionospheric research facility readily accessible to U.S. scientists from universities, the private sector and government. This facility would be the most advanced in the world and would attract international scientists and foster cooperative research efforts. The program's purpose is to provide a research facility to conduct pioneering experiments in ionospheric phenomena. The data obtained from the proposed research would be used to analyze basic ionospheric properties and to assess the potential for developing ionospheric enhancement technology for communications and surveillance purposes.

The layer of the earth's atmosphere called the ionosphere begins approximately 30 miles above the surface and extends upward to approximately 620 miles. In contrast to the layers of the atmosphere closer to the earth, which are composed of neutral atoms and molecules, the ionosphere contains both positively and negatively charged particles known as ions and electrons. These ions and electrons are created naturally by radiation from our sun.

The ionized gas in the ionosphere behaves much differently from the neutral atmosphere closer to the earth. A major difference is that although radio signals pass through the lower atmosphere undistorted, the signals directed through the ionosphere may be distorted, totally reflected or absorbed. For example, communication links from the ground to earth-orbiting satellites can experience fading due to ionospheric distortion; an AM radio signal sometimes can reflect, or "skip", off the ionosphere and be heard at locations hundreds of miles distant from the broadcasting radio station; the characteristic fading on the high-frequency (HF) or "shortwave" band is due to ionospheric interference. Because of its strong interaction with radio waves, the ionosphere also interferes with U.S. Department of Defense (DOD) communications and radar surveillance systems, which depend on sending radio waves from one location to another.

Ionospheric disturbances at high latitudes also can act to induce large currents in electric power grids; these are thought to cause power outages. Understanding of these and other phenomena is important to maintain reliable communication and power services. HAARP is needed to continue and expand basic research efforts on the properties and potential uses of the ionosphere for enhanced communications and surveillance. To meet the project's research objectives, the HAARP facility would utilize powerful, high frequency (HF) transmissions and a variety of associated observational instruments to investigate naturally occurring and artificially induced ionospheric processes that support, enhance or degrade the propagation of radio waves.

Investigations conducted at the HAARP facility are expected to provide significant scientific advancements in understanding the ionosphere. The research facility would be used to understand, simulate and control ionospheric processes that might alter the performance of communications and surveillance systems. This research would enhance present civilian and DOD capabilities because it would facilitate the development of techniques to mitigate or control ionospheric processes.

Civilian applications from the program's research could lead to improved local and world-wide communications such as satellite communication. Furthermore, and possibly more significant is the potential for new technology that could be developed from a better understanding of ionospheric processes.

A potential DOD application of the research is to provide communications to submerged submarines. These and many other research applications are expected to greatly enhance present DOD technology.

There are several HF transmitters located throughout the world which conduct research similar to that proposed by HAARP. However, no facility, located either in the U.S. or elsewhere, has the transmitting capability needed to address the broad range of research goals which HAARP proposes to study. The most capable HF transmitters currently operating are located in Russia and Norway and have effective radiated powers (ERP) of roughly one billion watts (1 gigawatt). One gigawatt of ERP represents an important threshold power level, allowing significant radio wave generation and analysis of key ionospheric phenomena. The HAARP facility is designed to have an ERP above one gigawatt. This would elevate the United States to owning and operating the world's most capable ionospheric research instrument.

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Page updated November 17, 2007

What Are the Effects of HAARP on the Ionosphere?

Overview of Active Ionospheric Research

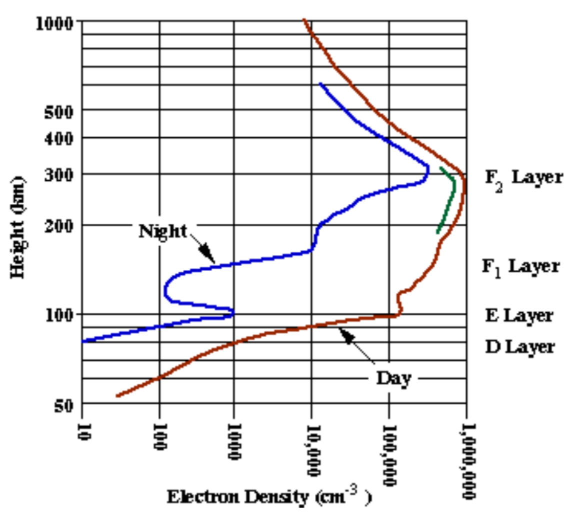
In the field of geophysics, the use of high power transmitters, such as the one located at the HAARP facility, to study the upper atmosphere is called "active ionospheric research." The HAARP facility will be used to introduce a small, known amount of energy into a specific ionospheric layer for the purpose of studying the complex physical processes that occur in these naturally occurring plasma regions that are created each day by the sun. The effects of this added energy are limited to a small region directly over the HAARP observatory ranging in size from 9 km in radius to as much as 40 km in radius.

It is important to realize that HAARP interacts **only** with charged (or ionized) particles in a limited region of the ionosphere directly over the facility. Interaction occurs because a charged particle (electron or positive ion) will react to an external electric field. HAARP does not interact with the neutral atoms and molecules that make up the bulk of the gas at all atmospheric heights.

When the HAARP HF transmitter is shut down at the end of an experiment, any ionospheric effects rapidly dissipate, becoming imperceptible over time frames ranging from fractions of a second to minutes. Extensive research conducted over many years at other active ionospheric research facilities around the world has shown that there are no permanent or long term effects resulting from this research method. The following sections discuss these points in greater detail.

How Ionization Varies Naturally

The following chart [1] shows the degree of ionization measured in number of electrons per cm^3 as a function of height in kilometers for a typical case. The chart also shows the generally accepted positions for the most important ionospheric regions: the D, E, F_1 and F_2 layers. The red curve in this chart shows the level of ionization that is typical during the daytime and the blue curve, the ionization during the evening hours. (The actual ionization levels and ionospheric layer heights will vary substantially over the 11 year solar cycle as well as for different geographic locations and in different seasons of the year.)



It is quite apparent from this chart that the ionosphere undergoes a dramatic change in ionization from day to night. The D layer, for example, disappears entirely as soon as the sun sets. The electron (and ion) density in the E-layer decreases by a factor of 200 to 1 and in the F_1-layer by nearly 100:1. For all practical purposes, the lower layers disappear during the evening hours as the sun's radiation is no longer creating new ions and the recombination process depletes the existing ion supply. The density of neutral (non-ionized) particles, on the other hand, does not vary from day to night.

How is the Ionosphere Affected by HAARP?

During active ionospheric research, a small, known amount of energy is added to a specific region of one of the ionospheric layers as discussed previously. This limited interactive region directly over the facility, will range in size, depending on the frequency of operation and layer height, from as little as 9 km in radius to as much as 40 km in radius and may be as much as 10 km in thickness. The interactions occur only with ionized particles in the layer; neutral (non-ionized) particles, which outnumber ionized particles by 500:1 or greater, remain unaffected.

Effects produced by HAARP are thermal in nature and do not result in new ionization. HAARP is not able to produce artificial ionization for the following two reasons.

1. The frequencies used by the HAARP facility are in the High Frequency (HF) portion of the spectrum. Electromagnetic radiation in the HF frequency range is *non-ionizing* - as opposed to the sun's ultraviolet and X-ray radiation whose photons have sufficient energy to be *ionizing*.
2. The intensity of the radiation from the completed HAARP facility at ionospheric heights will be too weak to produce artificial ionization through particle interactions. The power density produced by the completed facility will not exceed 3 to 4 microwatts per cm^2, about two orders of magnitude below the level required for that process.

We have provided a separate page that allows you to calculate the diameter of the affected ionospheric region and the power density that can be produced in that region by HAARP for any frequency and any layer height. The calculator also allows selection of various array sizes up to the full 180 element, completed array.

What Effects Are Produced By HAARP?

A portion of the energy contained in the high frequency radio wave transmitted by HAARP can be transferred to existing electrons or ions making up the ionospheric plasma through a process called **absorption**, thus raising the local effective temperature. As an example, the typical electron temperature at a height of 275 km (the peak of the F_2 region) may be on the order of 1400°K. [2]. Work at other active ionospheric research facilities has shown that it is possible to raise this temperature by as much as 30% within a small, localized region during an experiment. The affected region would then temporarily display electrical characteristics different from neighboring regions of the layer. Sensitive scientific instruments on the ground can then be used to study the dynamic physical properties of this region in great detail.

As the electrons (and ions) acquire additional energy, their temperature increases, their kinetic energy increases and they begin to move more rapidly. In the F layer, this increased movement or expansion results in a decrease in the electron density (electrons move into adjacent undisturbed regions). Experience at other active ionospheric research facilities [3] has shown that electron densities in the small, affected region may be reduced by 10% to 20%. This reduction in electon density is shown in the above chart by the dark green line.

Natural ionization in the F layer may produce an electron and ion density during the daytime of 1,000,000 cm^{-3}, about 0.2% of the total gas present. Active ionospheric research using the HAARP HF transmitter (interacting *only* with the ionized particles and not the neutral gas) could suppress this electron density in a localized region to 800,000 cm^{-3}. Compare this with the decrease in electron density that occurs naturally through a large portion of the nighttime F region (shown in the blue curve) of 500,000 cm^{-3} or less and it is clear that active ionospheric heating cannot duplicate what happens naturally, even within the small affected region directly over the facility.

For ionospheric layers below about 200 km in altitude (the "D" and "E" layers, for example), the electron density may actually **increase** as a result of active heating because of the suppression of recombination processes. Compare this with the natural depletion that occurs after sunset every evening when the E-layer electron density **falls** by as much as 200 times to levels of 1,000 cm^{-3} over almost the whole nighttime hemisphere.

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References

[1] Davies,Kenneth, **Ionospheric Radio**, Peter Peregrinus Ltd.:London, 1990, p-57.

[2] Kelley, M. C., **The Earth's Ionosphere**, Academic Press, Inc:San Diego, 1989.

[3] Davies,Kenneth, p-518.

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Page updated June 3, 2011

Technical Information

The HAARP Ionospheric Research facility will be a major Arctic facility for conducting upper atmospheric research. The facility will consist of two essential parts:

1. A high power transmitter and antenna array operating in the High Frequency (HF) range. The transmitter is capable of delivering up to 3.6 million Watts to an antenna system consisting of 180 crossed dipole antennas arranged as a rectangular, planar array.

2. A complete and extensive set of scientific instruments for observation of both the background auroral ionosphere and of the effects produced during active research using the transmitter system. Output from these instruments is readily available world-wide in near real time over the Internet.

During active ionospheric research, the signal generated by the transmitter system is delivered to the antenna array, transmitted in an upward direction, and is partially absorbed, at an altitude between 100 to 350 km (depending on operating frequency), in a small volume a few hundred meters thick and a few tens of kilometers in diameter over the site. The intensity of the HF signal in the ionosphere is less than 3 microwatts per cm^2, tens of thousands of times less than the Sun's natural electromagnetic radiation reaching the earth and hundreds of times less than even the normal random *variations* in intensity of the Sun's natural ultraviolet (UV) energy which creates the ionosphere. The small effects that are produced, however, can be observed with the sensitive scientific instruments installed at the HAARP facility and these observations can provide new information about the dynamics of plasmas and new insight into the processes of solar-terrestrial interactions.

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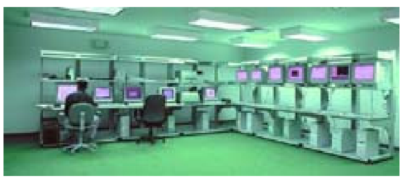
Page updated December 1, 2007

HAARP Diagnostic Instruments

The HAARP program has developed an extensive set of scientific research instruments useful for monitoring the Earth's geophysical and electromagnetic background. Information available from these instruments descibes physical conditions in the ionosphere and magnetosphere that affect communication and navigation systems.



These instruments serve an essential, diagnostic role during active ionospheric research, providing knowledge of local ionospheric conditions prior to, during and after research periods. Data collected from these instruments are processed and displayed at the site, allowing scientists to monitor results of ongoing experiments in real time.

Monitoring the outputs from these instruments on a day-to-day basis provides insight into the correlation between radio propagation conditions and certain geophysical processes. Currently available data products can be found on our Data Index page which provides a convenient access to some of these results. All of the following instruments are installed either at the HAARP Research Station or elsewhere in Alaska.

- All sky Riometer About
- Imaging riometer 8 X 8 Array
- Fluxgate Magnetometer
- Induction Magnetometer About
- Digisonde About
- Optics
  - All-sky imager
  - Telescopic imager
  - Photometers
  - 14 ft Optical Dome Photo
- Tomography Chain
  Cordova -> Kaktovik
- VHF Radar (139 MHz)
- MUIR (Modular UHF Ionospheric Radar Photo
- Ionospheric Scintillation Receivers
  - SATSIN (offsite)
  - GPS-NOVATEL
  - Total Electron Content
- Radio Background Receivers
  - Broadband ELF / VLF Receiver network.
  - SEE Receiver string.
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