The High Frequency Active Auroral Research Program

HAARP

Effects in the Ionosphere

As stated in the Environmental Impact Statement

The HAARP transmissions would interact with the charged particles in the ionosphere. The interaction of the IRI transmissions with the ions would cause temporary increases in temperatures and decreases in electron densities within the ionosphere lasting from a few seconds to several hours and possibly continuing through a polar winter night [1]. The temporary changes in ionospheric properties, caused by the IRI transmitted radio waves, would be many orders of magnitude less than those changes caused by variations in the sun's energy output.

The IRI would transmit radio waves over the frequency range 2.8 to 10 MHz. The transmitted radio wave beam would occupy a conical volume roughly 30 miles in diameter at an altitude of 300 miles. The transmitted radio waves would have up to 3.3 MW of power, only slightly higher than waves transmitted by radio and television stations.

Even if all the transmitted power from the IRI was absorbed by the ionosphere it would take more than 33,000 HAARP-scale IRIs, transmitting simultaneously to account for just 1 percent of the auroral ionosphere's energy budget. Another way of showing the vast difference between the amount of energy that would be dissipated in the atmosphere by the HAARP transmissions and natural processes is through a comparison of the local dissipation power in terms of power densities. The maximum power density of the IRI transmitted waves would be about 30 milliwatts per square meter (mW/m^2) at 50 miles altitude decreasing to 1 mW/m^2 at 186 miles altitude in the F region. In comparison, the densities of power dissipated by an aurora could exceed 2 W/m^2, or roughly 2000 times greater then the expected maximum dissipation due to the absorption of the HAARP high frequency transmissions in the F region. Even the daily absorption of solar radiation easily exceeds the most intense, low altitude HAARP-ionduced energy deposition rate by a factor of ten.

Temperature Effects

The ionosphere's temperature would be detectably affected within a few milliseconds of initiating IRI transmissions. Within seconds of initiating IRI transmissions the temperature of the affected conical volume of the ionosphere would begin to rise. The magnitude of the temperature rise would be a function of transmitted power and duration, transmission characteristics such as frequency, and perhaps most importantly, ionospheric conditions.

Existing facilities, such as the IRI in operation at Tromsoe, Norway, typically can enhance F region electron temperatures over a small range of altitudes by up to about 80° F, relative to natural ambient temperatures of 1340° F to 1727° F. Elevated temperatures due to the IRI would rapidly return to ambient levels once transmissions are ended. The rapid return to ambient conditions would be the result of the dissipation of the extra heat energy by collisions of heated electrons with ambient ions and neutral particles. In the F region the temperatures would return to ambient levels in a few tens of seconds. The return time to ambient temperature levels decreases with decreasing altitude through the F and E layers and down into the D layer where the neutral gas density is about one million times greater than in the F layer. In the D layer the temperatures would return to background levels within less than a millisecond of terminating transmissions.

Electron Density

Changes in electron density would be associated with high frequency induced temperature increases. IRI transmission induced temperature increases would cause increases in electron densities in the D, E, and F layers below approximately 124 miles above the ground and decreases in electron density in the F layer above approximately 124 miles above ground. Two primary temperature dependent processes would affect electron densities due to IRI transmissions. One process involves the recombination of ions and electrons into neutral molecules (two or more bonded atoms), which make up the troposphere and statosphere. Higher temperatures slow down the recombination rate resulting in higher electron densities. The second process involves the expansion of the ionospheric atmosphere due to heating. The expansion causes the ionosphere electron density to decrease.

Thermal expansion would be inhibited and electron recombination rates would decrease in the D, E, and F layers below approximately 124 miles above the ground. As a result, electron densities within the conical volume of the IRI beam could increase on the order of 20 percent. Above approximately 124 miles, above ground, in the F layer, thermal expansion would prevail over reduced recombination rate effects and the electron density within the affected conical volume of the F layer would decrease. The magnitude of the decrease could range up to 10 - 15 percent over an altitude range of a few tens of miles.

Ionospheric electron densities would return to background levels over time scales similar to, though somewhat longer than, those associated with high frequency induced electron temperature effects. In the D and E layers the electron densities would immediately return to background conditions once the IRI is turned off. The decreased electron densities induced within the affected conical volume of the F layer could last anywhere from a few hours to an entire polar night. However, IRI transmission induced temporal changes to ionospheric electron densities would be insignificant compared to naturally induced changes.

Mitigation

There would be no significant impacts to the ionosphere. Hence no mitigation measures would be necessary.

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