Spectral characteristics of HF-enhanced ion-line signals detected during the initial response, and extended heating phase at the HAARP facility

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The HAARP ionospheric modification facility, and UHF diagnostic radar, at Gakona, Alaska have been used in a high time-range resolution mode to study the spectral characteristics of HF-enhanced ion-line signals observed in the F-region ionosphere. The results presented here have utilized HF frequencies from about 3 to 6 MHz with O-mode polarization and full HF power (about 3.6 MW).
The UHF diagnostic radar was operated with 600 meter range resolution, and ion-line Doppler spectra are presented as a function of altitude, with a time resolution of 10 milli-secs. We have been able to observe the ion-line temporal behavior during the response to HF turn-on during the first 100-150 milli-seconds. After this initial response phase signals disappear for about 1 second then re-appear continuously during the time that the HF power is on. The altitude of the signals during the extended heating phase decrease with time in response to large-scale heating and modification of the ionospheric structure. Experiments with varying HF power levels show that the rate of descent is dependent on the HF power level. The rate of descent is maximized when the HF frequency is near the third gyro harmonic but not at the third gyro harmonic, and also when the HF interaction altitude is close to the F-region peak altitude.
Spectral characteristics during the extended heating phase suggest that the parametric decay instability dominates the oscillating two-stream instability. When the HF frequency is 4.50 MHz (a little above the 3rd gyro harmonic) the ion-line spectra adopt a unique asymmetric character that indicates ion-acoustic waves propagating downward-only over a height range of a few km, and below that height the data show upward-only ion acoustic waves. This feature is not power-dependent but is observable at all HF powers with useful signals.
During the initial response phase (to about 120 milli-secs) the ion-line signals are spread closer to zero Doppler and differ significantly from pulse to pulse (ie every 10 milli-secs); this suggests plasma processes are operating on much faster time scales than we are able to resolve.