Observations of ELF/VLF Waves Produced Using the HAARP HF Transmitter in Dual-Beam Configuration

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Dual-beam HF heating experiments may now be performed at the High-frequency Active Auroral Research Program (HAARP) HF transmitter in Gakona, Alaska due to recent hardware upgrades. During two thirty-minute periods in July and August 2007, one beam of the HAARP HF transmitter generated ELF/VLF waves (at 1215 Hz and 2430 Hz) by modulated ionospheric heating at 4.5 MHz (X-mode), stepping the peak HF power in 15 distinct log-based steps. The second beam of the HAARP HF transmitter continually and simultaneously heated the same patch of ionosphere at 3.25 MHz (CW, X-mode) for a period of 5-8 minutes. This transmission block was followed by a 5-7 minute 'recovery' period without CW heating (i.e., the first beam continued to modulate at 4.5 MHz while the second beam was OFF). ELF/VLF wave observations at a ground-based receiver indicate that the timescale for electron density change at the altitude of ELF/VLF wave generation may be detected using the ratio of the harmonic amplitude to the fundamental amplitude as a function of time. In some cases presented, the electron temperature change produced by HF heating dominates the ionospheric conductivity change even for minutes-long HF heating pulses. The implications of these observations for other ELF/VLF wave generation experiments are discussed.