Variation of HF beam parameters in ELF/VLF generation via modulated heating of the auroral electrojet

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The High Frequency Active Auroral Research Program (HAARP) facility located near Gakona, Alaska, is a phased High Frequency (HF, 3-10 MHz) antenna array, capable of generating ELF (300 – 300 Hz) and VLF (3 – 30 kHz) signals, by modulated heating of the lower ionosphere in the presence of the auroral electrojet. The conductivity of the ionospheric plasma is modified due to the absorption of the HF waves, and the ELF/VLF modulation of this conductivity change effectively produces a large radiating antenna in the ionosphere, at frequencies that are extremely difficult to produce with conventional antennae. The HAARP facility has recently completed an upgrade in which the radiated power has increased from 960 kW to 3.6 MW, and in addition, the HF antenna array has been expanded to allow more focusing, increasing the effective radiated power by a factor of more than 20. Such elevated power levels have led to questions regarding the most effective method for generating ELF and VLF waves with HAARP. In particular, the effect of varying the HF carrier frequency, and the width of the beam, could be of critical importance, particularly in light of recent observations of saturation of conductivity changes [Moore et al., 2007]. In this paper, we investigate, experimentally and theoretically, the effect of HF frequency variation, and beam geometry configuration, on the ELF/VLF generation mechanism. Results are presented for detection of signals in the region nearby to HAARP, and for injection of subionospherically propagating signals detected at larger distances. Results are also compared across different diurnal and geomagnetic conditions, utilizing a large enough sample size of transmissions to discuss the possibility that the optimal HF beam parameters may vary in time.