ELF/VLF Generation Experiments at the HAARP Facility

Morris B Cohen*, Umran S. Inan, Marek Golkowski, Nikolai G. Lehtinen, and Denys Piddyachiy
Stanford University STAR Laboratory, Stanford, CA, 94305, http://www-star.stanford.edu/~vlf

The recently upgraded HAARP facility, near Gakona, Alaska, utilizes 3.6 MW of HF (3-10 MHz) power along with an unprecedented ability to steer the HF heating beam over a large area extremely rapidly. In recent decades, HF heating has been successfully utilized to generate ELF/VLF (500 Hz – 10 kHz) radiation, via amplitude modulation of the HF beam. Through the temperature-dependent conductivity of the D-region ionospheric plasma, the lower ionosphere effectively becomes a large radiating antenna in the presence of currents, such as the naturally forming auroral electrojet. A variety of scientific and practical applications would benefit from more effective ability to generate and steer these generated signals, such as magnetospheric injection and study of subsequent wave-particle interactions, ionospheric diagnostics, and long-range communications, especially since additional upgrades to existing HF facilities are difficult. More recently, geometric modulation of the HF beam has been experimentally shown to boost generated amplitudes by 7-11 dB, and/or steer the generated signals along preferred directions in the Earth-ionosphere waveguide. Here, we discuss a set of experimental and theoretical efforts exploring the generation of these ELF/VLF waves, and their coupling to propagating signals in the Earth-ionosphere waveguide, utilizing HAARPs upgraded capabilities and an array of ELF/VLF receivers across Alaska, as well as observations on the DEMETER spacecraft. The theoretical formulation utilizes a 3D model of the HF collisional heating and subsequent collisional electron cooling processes, leading to spatial structure of modulated ionospheric conductivities, the results of which are input into an analytical model of ELF/VLF propagation in the Earth-ionosphere waveguide.