ELF/VLF WAVES GENERATED BY MODULATED HEATING OF THE AURORAL ELECTROJET WITH THE HAARP HF TRANSMITTER

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ELF/VLF broadband recordings acquired at multiple locations during several recent ELF/VLF generation campaigns conducted with the HAARP HF heater are used to determine the amplitude and phase properties and the occurrence statistics of ELF/VLF waves generated by modulated heating of the auroral electrojet. Extensive, continuous data sets were acquired every night for up to 10 hours during two continuous 14- and 24-day nighttime campaigns. A 24-hour period allowing the investigation of ELF/VLF signal generation under daytime conditions, and a 4-day period including multiple power-step sequences allowing the assessment of the heating characteristics at the wave-generating altitude are also discussed. With the relatively large (4.8 by 4.8 m square) magnetic loop antennas utilized, together with a transformer matched differential preamplifier, system sensitivities of as low as several femtoteslas per root Hz are achieved, depending on the noise environment at the measurement site. A large variety of natural magnetospheric signals, including ELF/VLF chorus, auroral hiss, and lightning-generated whistlers are commonly observed in addition to the ELF/VLF signals produced by HAARP.

Artificially generated ELF/VLF signals at all modulation frequencies were observed every night of operation at receivers within 50 km of the HAARP facility. ELF/VLF signals were robustly produced under varying geomagnetic conditions, although the strongest signal levels were observed during geomagnetically active periods. At the closest receiver site, typical signal levels varied from 1 to 10 picotesla, while on two very geomagnetically active days, intensities of up to 70 picotesla were observed. Observed phase differences between ELF/VLF pulses observed at the same site on two orthogonal magnetic antennas indicate the need to take a laterally as well as vertically distributed source region into account for the modeling of received signal amplitudes at ground distances of up to 150 km. Additional observations show that ELF/VLF signals can be generated well during daytime as well as nighttime and that the signal levels generated depend the location of the electrojet currents rather than on daytime or nighttime ionospheric conditions. While observed signal amplitudes at the modulation frequencies varied linearly with the power transmitted during the power-step sequences, harmonic signal level saturation occurred on a regular basis, consistent with a non-linear heating mechanism.

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3. (a)

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