IONOSPHERIC MODIFICATION AND ELF/VLF WAVE GENERATION BY HAARP

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HAARP is a high-power HF transmitter facility which after an upgrade to 3.6 MW power scheduled in 2006 will have an effective radiated power of the order of 2 GW in 2.8–10 MHz range. Facilities such as HAARP are used to study various effects of powerful HF radiation throughout all regions of ionosphere. The powerful emission at 3 MHz causes a significant modification of electron distribution at altitudes of 70–120 km. With modulation at (for example) 2 kHz applied to the HF carrier, the periodic changes in conductivity of the ionosphere modulate the subauroral electrojet currents and lead to emission of ELF/VLF waves into the magnetosphere, which then propagate to a point geomagnetically conjugate to HAARP. In this paper, we report the preliminary results of a fully kinetic model of the nonlinear heating by the HF signal, and the generation of the ELF/VLF signals via the modulation of such heating, with specific application to the parameters of the HAARP facility.

To calculate the modified electron distribution, we use a time-dependent solver of the kinetic equation with harmonically varying electric and static geomagnetic fields. The non-Maxwellian distribution obtained in this way can be characterized in terms of effective elecron temperature defined by the average electron energy. The calculated changes in the effective electron temperature as a function of altitude show some similarities with Maxwellian models with static heating, but also display new features such as nonlinear saturation of the effective temperature at high HF power levels. The electron distribution obtained from the kinetic solver is used to find the conductivity for both HAARP HF radio wave and a low-frequency (approximated as DC) electric field. The modulated DC conductivity results in the modulation of the elecrojet current, while the HF conductivity affects losses during the HF wave propagation. Since the modification of ionosphere affects the propagation of the HAARP radio wave itself, the power flux is calculated self-consistently together with the solution of the kinetic equation at each altitude. We pay specific attention to the highly nonlinear dependence of elecrojet modulation on the applied HF power, and the effects of the geomagnetic field.

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