Generation of ELF/VLF waves by an ionospheric heater at the geomagnetic equator

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Abstract

The heating of the D-region by a ground-based facility creates change of conductivity, calculated by solving a kinetic equation for electron distribution function, which causes modulation of the auroral electrojet. The resulting current is used to calculate the emission of ELF/VLF waves into both the ionosphere and the Earth-ionosphere waveguide, using a new stable full-wave method [1] for a horizontally-stratified arbitrary anisotropic medium, with arbitrary harmonically-varying current distribution. Unlike heating at high latitudes with significant emission of whistlers, at geomagnetic equator radiation is only into the Earth-ionosphere waveguide.

1. Kinetic model of HF heating

The ground-based high power transmitter facilities operating in the HF frequency range are used to study various effects occurring throughout all regions of ionosphere [2]. We consider heating of the D-region of ionosphere, which can change the electron temperature by more than an order of magnitude. We solve the kinetic equation for electron distribution function using a modified version of a standard software package ELENDIF [3], expanded to include oscillations of the electric field and ambient geomagnetic field. The HF wave propagation is calculated self-consistently by taking into account the modified HF conductivity. Modification of DC conductivity leads to the modulation of the auroral electrojet. The motivation for using a kinetic equation to study the electron heating process is provided by the fact that HF facilities become more and more powerful, and in the future can provide levels of electric field which create electron distributions which are substantially different from Maxwellian. In this paper, we investigate effects which are specific to the geomagnetic equator.

2. Full-wave model of ELF/VLF wave radiation and propagation

The modulated electrojet current radiates ELF/VLF waves both into ionosphere and into the Earth-ionosphere waveguide. For the purpose of calculating this radiation, we developed a finite element method of calculation of electromagnetic field in a horizontally-stratified ionosphere filled with magnetized plasma, with arbitrary harmonically-varying current distribution and the direction of geomagnetic field [1]. This method is based on the idea of recursive calculation of reflection coefficients and mode amplitudes [4] and is proven to be stable against the loss of precision due to "swamping" of useful modes by evanescent waves. The electromagnetic field is calculated both in the Earth-Ionosphere waveguide (at arbitrary horizontal distance and direction) and in the ionosphere. While for heating facilities located at high latitudes (such as HAARP), there is a significant emission of the whistler waves upward into the ionosphere [1], for a heating facility at the geomagnetic equator, there is no emission into ionosphere, and all of the emitted energy goes into the Earth-ionosphere waveguide.

3. References

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