VLF signatures of *D*-region disturbances

Nikolai G. Lehtinen*[1], Morris B. Cohen[1], Kevin Graf[1], and Umran S. Inan[2]

[1] STAR Laboratory, Stanford, CA 94305
[2] STAR Laboratory, Stanford, CA 94305; Koç University, Rumelifeneri Yolu, 34450 Sariyer, Istanbul, Turkey

Powerful high-frequency (HF) electromagnetic radiation from a ground-based facility heats the *D*-region of the ionosphere, modifying the electron energy distribution function. This leads to the change in the electron-neutral collision frequency, and therefore to the change in the conductivity of the disturbed region. The conductivity change affects the propagation of the HF wave which is calculated self-consistently. The disturbed region scatters the narrowband electromagnetic waves, which are radiated by VLF transmitter and propagate in the Earth-ionosphere waveguide. We apply the recently developed Stanford FWM (full-wave method) model to the calculation of scattering of the VLF transmitter radiation by ionospheric disturbances caused by HF heating. We use Born approximation technique by assuming that the scattered wave is negligible compared to the incident wave inside the perturbed region and understanding the scattered wave as being emitted by the currents due to the perturbation of conductivity. This new method allows us not to use other approximations, such as WKB approximation which was used in similar calculations in the past works. The values of the scattered wave magnetic field on the ground are found to be higher during daytime, due to higher electron density in the *D*-region. Beside steady-state heating, we also investigate the scattering on ELF/VLF frequency-modulated HF-heated regions. The scattered wave is expected to demonstrate cross-modulation between VLF transmitter and modulation frequencies. We search for this effect in the experimental data. From comparison of calculation results with the experimental data, we infer the constraints on relative magnitudes of the steady-state and modulated changes in the effective electron temperature. For both cases of steady-state and modulated heating, we analyze the validity of Born approximation and conditions when the second Born approximation calculation is required.