SATURATION EFFECTS IN THE VLF SCATTERING OFF HF HEATED IONOSPHERE

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Abstract

The HAARP ionospheric HF heating facility modifies the electron-neutral collision frequency in the *D*-region ionosphere, which creates a disturbance in the conductivity of this region. The VLF waves from Navy transmitters scatter off this disturbance, which results in a perturbation of the VLF amplitude and phase of the narrow-band signal of the VLF transmitter. This perturbation may be detected both by ground-based receivers and satellites with VLF instruments. For small disturbances of conductivity, the Born approximation may be used, which neglects the scattered field inside the disturbance compared to the incident VLF field. This method was previously used in combination with the Stanford Full-Wave Method (Stanford FWM), e.g., for calculations of scattering off lightning-created *D*-region disturbances [*Lehtinen et al.*, 2010, doi:10.1029/2009JA014776], and may be used in the case when HF power of the heater is small and the resulting change of the conductivity in *D*-region is also small. However, when for high HF power heating, the disturbance in the conductivity may be strong and therefore strongly affect the propagation of the VLF wave, so that the scattered field inside the disturbance region may be of the same order as the incident wave, which renders the use of the Born approximation invalid. In order to tackle with this problem, we introduce a novel computational technique which combines the Stanford FWM with the method of moments (MoM). This novel technique may be used for general problems of calculation of scattering on spatially localized strong perturbations in stratified media. In MoM, one solves the discretized version of an integral equation which represents the scattered field is as a convolution of the Green's function with the electric current source. The current in this case is due to the change in the conductivity of the *D*-region acting on the total electric field consisting of both incident and scattered fields. The Green's functions in the present case are to be calculated for the Earth-atmosphere-ionosphere system which is represented as a stratified medium, which is solved by application of the Stanford FWM. On the contrary to the use of the Born approximation, the MoM allows us to calculate the effects of the total field and thus may be applied to situations with any level of perturbation. We show how the field measured on the ground and at a satellite deviates from that calculated previously in the Born approximation, which in most cases overestimates the scattering by strong disturbances. In this way, we demonstrate the saturation effects in the VLF perturbations for strong HF heating.