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Sporadic-E Plasma Irregularities under an Electron Temperature Rise in the Layer

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Possible changes in sporadic-E plasma irregularities resulted from an electron temperature rise in the layer are considered in this report. The increase in the electron temperature T_e may be caused by the action of powerful radio wave on sporadic-E. We supposed that the action was not too strong and too long to change parameters of the neutral atmosphere noticeably. It was regarded that the sporadic-E in question is formed by a vertical shear of neutral zonal wind and is situated below the turbopause level. Hence, its mean features and irregular structure are mainly controlled by neutral atmospheric turbulence. It is known that an electron temperature rise has to result in the enhancement of ambipolar diffusion. It means that D_A, the ambipolar diffusion coefficient, becomes larger than ν, the coefficient of kinematic viscousity of neutral gas. In terms of the theory of passive scalar convection the diffusion Prandtl number $\mathrm{Pr} = \nu/D_A$ becomes smaller than 1. To estimate consequence of an electron temperature rise for the sporadic-E plasma irregularities we derived formula for the spectrum of plasma density fluctuations generated by neutral turbulence in the layer that takes condition $D_A \neq \nu$ into account. The formula was obtained in the framework of macroscopic description of three-component sporadic-E plasma. It allows us to write corresponding analytic expressions for $\langle (N_1/N_0)^2 \rangle$, the mean-square level of relative plasma density fluctuations, and for σ, the radar backscatter cross-section per unit volume. The obtained formulae were applied to calculate possible changes in the sporadic-E irregular structure when the layer was situated in the mid-latitude ionosphere at the height of 97 km, and the ratio of the electron temperature to the neutral gas one T_e/T_0 took value from 1 to 10. The parameters of the layer were: an electron-density peak $N_0 = 7.6 \times 10^{10}\,\mathrm{m}^{-3}$, a thickness of 2 km, the neutral gas temperature $T_0 = 200$ K, and the ratio of the ion gyrofrequency to ion-neutral collision frequency of 0.019 (it was supposed that the mean ion mass in the layer was about 51 a.u.m.). The mean rate of turbulent energy dissipation (the basic parameter of neutral turbulence) was 0.01 $\mathrm{m}^2\mathrm{s}^{-3}$ in our calculations. It was shown that the electron temperature rise results in a decrease in both the rms fluctuation level and the backscatter cross-section, and also changes the form of plasma irregularity spectrum. In the considered case under increasing in T_e/T_0 from 1 to 10, the level $\langle (N_1/N_0)^2 \rangle^{1/2}$ (for plasma irregularities smaller than 400 m) has decreased from 0.097 to 0.085, and σ from 9.7×10^{-9} to $6.0 \times 10^{-9}\,\mathrm{m}^{-1}$ for the radar frequency of 5 MHz or from 9.6×10^{-12} to $5.9 \times 10^{-12}\,\mathrm{m}^{-1}$ for 50 MHz; at same time the spectral slope has increased, when it was approximated by a power law k^{-p} then the power index p took values from 2.9 to 3.5. These changes are explained by decreasing in the cutoff wavenumber (or the Obukhov-Corrsin wavenumber) in the irregularity spectrum because of increase in D_A, the corresponding length-scale has increased from 21.6 to 77.5 m in our case.