Abstract

The thesis addresses the dynamics of low-frequency planetary electromagnetic (EM) waves and nonlinear solitary structures (vortices and zonal flows) in the Earth's weakly ionized ionosphere of the E- and F-layers.

The propagation of EM inertio-gravity waves in the partially ionized ionospheric E- and F-layers is considered in the shallow water approximation. Accounting of the field-aligned current is the main novelty of the investigation. Existence of two new eigen-frequencies for fast and slow EM waves is revealed in the ionospheric E-layer. It is shown that in F-layer slowly damping new type of inertial-fast magnetosonic waves can propagate. Slowly damping low-frequency oscillations connected with the field-aligned conductivity are found. Broad spectrum of oscillations is investigated.

Existence of the new type of coupled EM ULF waves in the Earth's ionospheric E-layer is revealed. It is shown that in the weakly ionized E-layer along with the prevalent effect of Hall conductivity the latitudinal inhomogeneity of both the Coriolis parameter and the geomagnetic field becomes essential for the ULF waves under the consideration. Action of these effects leads to the coupled propagation of EM Rossby and Khantadze modes on the one hand and coupled propagation of Rossby, Alfvén and Khantadze modes on the other hand. As a result the new type of dispersive Alfvén waves is revealed. Linear propagation properties of such coupled waves are given in detail. Possibility of existence of the other new coupled Internal-gravity and Alfvén EM planetary waves in the weakly ionized ionospheric E-layer is shown. Under such coupling new type of Alfvén waves is revealed.

Simplified set of nonlinear equations describing the dynamics of mentioned coupled EM modes in the conductive weakly ionized E-layer is obtained: 1) spatially 2D equations in case of coupled Rossby-Khantadze and coupled Internal-gravity-Alfvén, and 2) spatially 3D equations in case of coupled Rossby-Alfvén-Khantadze modes, respectively.

The possibility of self-organization of Rossby-Khantadze modes turbulent state into the nonlinear solitary vortical structures of dipole type in the non-dissipative ionosphere is shown analytically. Conditions for such self-organization are given. It is revealed that nonlinear large-scale vortices may generate the stronger pulses of the geomagnetic field (of the order of (10^4 - 10^5 nT)) than the corresponding linear waves.

Nonlinear instability of short wavelength turbulence of mentioned coupled Rossby-Khantadze, Internal-Gravity-Alfvén, and Rossby-Alfvén-Khantadze EM planetary modes

with respect to the excitation of low-frequency and large-scale perturbations of sheared zonal flow and magnetic field is revealed. The nonlinear mechanism of the instability is driven by the advection of vorticity and is based on the parametric excitation of zonal flow by four finite-amplitude coupled modes leading to the inverse energy cascade toward the longer wavelength. The corresponding driving forces along with the Reynolds stresses are stipulated by Maxwell's stresses also. The growth rates of the corresponding instability and the conditions for driving them are determined. The possibility of generation of the intense mean magnetic field (of the order of $(10^2 \text{-} 10^3)$ nT) is shown.

Obtained results undoubtedly will be useful for the interpretation of different observations on vortical motions, sheared zonal flows and magnetic field disturbances in laboratory and astrophysical plasmas.