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GLOBAL WEATHER-FORMING ULF ELECTROMAGNETIC NONLINEAR VORTEX STUCTURES IN THE SHEAR FLOW DRIVEN IONOSPHERE PLASMA

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Summary: *In the present article the dynamics of generation and propagation of planetary global weather-forming ultra-low frequency (ULF) electromagnetic wave structures in the dissipative ionosphere are given. These waves are stipulated by spatial inhomogeneous geomagnetic field. The large-scale waves are weakly damped. The waves generate the geomagnetic field from several tens to several hundreds nT and more. It is established, that planetary ULF electromagnetic waves, at their nonlinear interaction with the local shear winds, can self-localize in the form of nonlinear long-lived solitary vortices, moving along the latitude circles westward as well as eastward with velocity, different from phase velocity of corresponding linear waves. The vortex structures transfer the trapped particles of medium and also energy and heat. The nonlinear vortex structures represent can be the structural elements of strong macroturbulence of the ionosphere main drivers of the electromsgnetic weather at ionospheric level.*

Key words: *ultra-low frequency electromagnetic wave, geomagnetic field*

1.Introduction

Increasing interest to large-scale planetary weather-forming ultra-low frequency (ULF) wave perturbations is caused by the fact, that ionospheric phenomena like superrotation of the Earth atmosphere (Rishbeth,1972), ionospheric precursors of natural processes (Hayakawa, 1999), ionospheric response on the anthropogenic activity (Shaefer et al.,1999) fall into the range of these waves. Large-scale wave structures play important role in the processes of general energy balance and circulation of the atmosphere and ocean. It was supposed, that at natural conditions planetary waves are generated in the tropo-stratosphere and reach the ionospheric altitudes. But, theoretical investigation of the wave processes, as the basis for energy transfer from the lower atmosphere to the upper one, shows, that the system of the stable zonal winds screens (especially in summer) the upper atmosphere from the influence of large-scale planetary waves, generated in the tropo-stratosphere (Charney and Drazin, 1961). Conditions, most favorable for an upward propagation of only very long planetary waves are created during equinoxes, when the zonal winds change their direction (Dickinson, 1969). Nevertheless, a large amount of observational data has been stored by now (Zhou et al., 1997). These data verify the permanent existence of ULF electromagnetic planetary-scale perturbations in the ionosphere.

At natural conditions these weather-forming perturbations are revealed as the background oscillations. The forced oscillations of this type, as it is shown by the observations, are generated by impulse action on the ionosphere from above – during magnetic storms (Hajkowicz, 1991) or from below – as the result of earthquakes, volcanic eruption or artificial explosions (Shaefer et al.,1999). In the last case the perturbations are revealed as the solitary vortex structures.

The last theoretical investigations show (for example, Aburjania et al., 2003, 2004), that above mentioned planetary ULF electromagnetic waves' source exists in the ionosphere itself and such source is spatial inhomogeneous geomagnetic field.

2. **Model Equation**

According to the ground-based and satellite observations, at different layers of the ionosphere there permanently exist weather-forming zonal winds (the flows), having inhomogeneos velocity along the meridians (Khantadze, 1973). The considered waves are interacting with the inhomogeneos (shear) wind (a flow) in the ionosphere, where a favorable condition for formation of the nonlinear stationary solitary wave structures is created.

From model equation of Aburjania et al, 2004 after simple transformations the following nonlinear equation should be obtained:

$$J\left(\psi - \int_{-\infty}^{y} \bar{V}(y)dy + Uy, \nabla_{\perp}^{2}\psi - \frac{\partial \bar{V}}{\partial y} + \left(\beta' + \frac{\mu_0}{\alpha^2 \rho}U\right)y\right) = 0, \qquad (1)$$

where (in nondissipative stage, $\Lambda = 0$) in the form $\Psi = \Psi(\eta, y)$ is a stream function, $A = A(\eta, y)$ - magnetic induction, $b_z = b_z(\eta, y)$ - perturbed magnetic field, $\eta = x - Ut$ - automodel variable, i.e. aolution should be sought in the form of the stationary solitary waves, propagating along *x*-axis (alng the parallels) with velocity *U=const* without changing its' shape.In avoidance of mess it should be mentioned, that under the nonlinear solitary wave here we understand a perturbation, localized even if for one coordinate. We will consider also, that waves are propagated on a background of the mean horizontal wind with zonal shear of velocity $\bar{V}(y)$. Stream function Ψ in this case is equaled to

$$\Psi = \psi - \int_{-\infty}^{y} \bar{V}(y)dy, \qquad (2)$$

where ψ - deriation of stream function from average value.

In order to simplify further investigation, we will seek a class of solutions, for which $\Psi = -\alpha b_z / \mu_0$ and $\nabla_{\perp}^{2} A = \partial b_y / \partial x - \partial b_x / \partial y = f(y)$, where f is an arbitrary function of its argument, and further it wil be assumed a function, fastly decreasing at infinity.

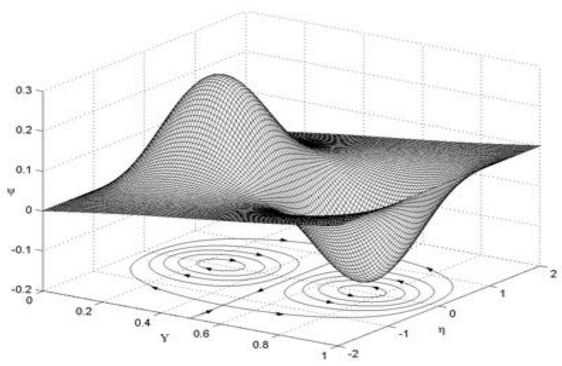
Let's mention that the linear electromagnetic waves, investigated by us in the section 3, basically are zonal, i.e. for them the direction along a parallel (on an axis x) is primary. Therefore, for perturbations of such polarization it is more adequate consideration of nonlinear wave structures, which are longer on an axis x, i.e. the scale on an axis x is much greater of the scale on an axis y.

3. Discussion of the Results and Conclusion

The self-localization of the planetary electromagnetic waves in the non–dissipative ionosphere is proved in the basic of the analytical solution of the nonlinear dynamic equations (2), the wave is localized along the Earth surface (η, y).

The generated nonlinear vortex structures represent monopolistic (solitary) cyclon and/or anticyclon (the fig. 1) or the cyclon – anticyclon pair, connected in a sirtain manner and/or the pure dipole cyclon – anticyclon structure of equal intensity (fig. 1) and/or the vortex chain (fig. 2), rotating in the opposite direction and moving along the latitudinal circles (along the parallels) agains a background of the mean zonal wind.

The nonlinear large-scale vortices generate the stronger pulses of the geomagnetic field than the corresponding linear waves. Thus, the fast vortices generate the magnetic field $b_v^f \approx 10^3\ nT$, and the slow vortices form magnetic field $b_v^s \approx 10^2\ nT$. The formation of such intensive perturbations could be related to the specific properties of the considering low frequency planetary structures. Indeed, they trap the environmental particles, and the charged particles in E- and F-regions of the ionosphere are completely or partially frozen into the geomagnetic field. That's why, the formation of these structures indicates at the significant densification of the magnetic force lines and, respectively, the intensification of the disturbances of the geomagnetic field in their location. Since, the number of the trapped parcels is the order of the passed-by (transient), the perturbation of the magnetic field in the stronger faster vortices would be the same order as of the background field. On the earth surface located $R_0(\sim(1 \div 3) \cdot 10^2$ km) below the region of the researching wave structure, the level of the geomagnetic pulses would be less by $exp(-R_0/\lambda_0)$ factor. λ_0 is the characteristic length of the electromagnetic perturbations. Since $\lambda_0 \sim (10 \div 10^2)R_0 >> R_0$ the magnetic effect on the earth would be less then in E- and F-regions, but in spite of this they are easily registered too.



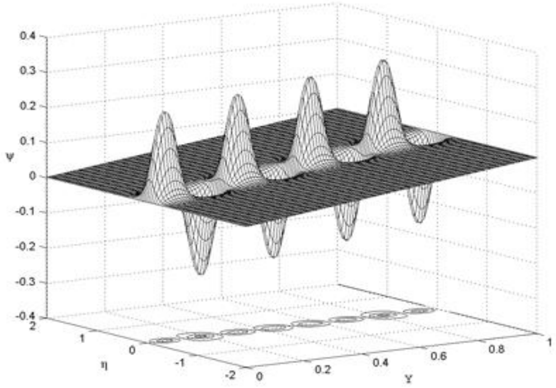


Fig. 1 Anti-cyclone Fig. 2 Vortex chain with eight vortices

The motion of medium particles in studied nonlinear vortex structures is characterized by nonzero vorticity $\nabla\times\boldsymbol{V}\neq 0$, i.e. the particle rotate in vortices. The characteristic velocity of this rotation U_c is of order of the vortex velocity U, $U_c \geq U$. In this case the vortex contains the group of trapped particles (the number of these particles is approximately the same as the number of transit particles); rotating, these particles move simultaneously with the vortex structure. Therefore, being long-lived objects, non-linear planetary-scale electromagnetic vortex structures may play an important role in transporting matter, heat, and energy, and also in driving the macroturbulence of the ionosphere (Aburjania, 1990). In particular, the vortex structures that play the role of "turbulent agents" can be treated as elements of the horizontal macroscopic turbulent exchanges in global circulation processes in the ionospheric E and F-layers. This estimate (which can be regarded as an upper one) shows that, in the global exchange processes between high and low latitudes, the meridional heat transport from north to south in the ionospheric E and F-layers should be of macroturbulence nature (recall that, in the ionosphere, the polar regions are warmer than the equatorial region).

Thus, it can be said, that here investigated wave structures can play important role in the ionospheric electromagnetic weather forming processes.

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