CHARACTERISTICS OF THE MID-LATITUDE IONOSPHERE SUITABLE FOR MODELLING IONOSPHERIC FILTRATION OF ULF WAVES

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Summary: An approximate method of one-dimensional modelling of the plasma of the Earth's ionosphere is demonstrated for purposes of studying the ionospheric filtration of ULF waves (micro-pulsations). Apart from the basic local parameters, characterizing the plasma, also derived local characteristics have been defined, i.e. the mass of the so-called effective ion $\tilde{m}_i$ and its effective collision frequency $\tilde{v}_i$. Drawing on existing empirical models of the mid-latitude ionosphere, vertical profiles ($50 \text{ km} \leq h \leq 1000 \text{ km}$) of the characteristics $N_e \approx N_i$, $v_e$, $\tilde{m}_i$ and $\tilde{v}_i$ for the daytime and nighttime mid-latitude ionosphere under low and enhanced solar activity, which can be used to study the ionospheric ULF filter.

1. INTRODUCTION

A micropulsation signal (ULF), recorded at the Earth's surface, is a signal transformed in the process of propagation of MHD and electromagnetic waves through the rarified magneto-active plasma of the Earth's magnetosphere and ionosphere. This medium in itself is considerably complicated and variable in its structure and dynamics. It is described by a whole series of inter-related local characteristics. A signal, propagating through the inhomogeneous, anisotropic and absorbing medium of the ionosphere, is strongly deformed, it is subject to interference [1] and attenuated.

The fundamental methodological problems of two-dimensional numerical modelling of ionospheric filtration of a ULF micropulsation signal in the Pc 1-type pulsation frequency range were treated in [2–4]. The developed method enables the filtration effect of the denser layers of the ionosphere on the signal, propagating from the magnetosphere to the Earth's surface, to be modelled. The medium of the ionosphere is represented by a plane, inhomogeneous, anisotropic (magneto-active) and absorbing transition layer between the homogeneous, anisotropic and collisionless magnetosphere and the Earth's surface with a finite conductivity. The numerical matrix method [2, 3] represents a recurrent procedure of computing wave parameters in the medium of the transition layer, finely stratified into elementary homogeneous layers. Under these circumstances, the medium of the real ionosphere can be modelled one-dimensionally, practically vertically, by an empirical profile of the required complexity.

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For the purpose of the method in question, the multi-component ionospheric plasma may be simplified. In the ULF wave range ($f < 5$ Hz) being considered, the MHD approximation is quite sufficient. It is possible to consider the ionosphere plasma as two-component (electrons and positively charged simple ions) and quasineutral. The component of the neutral particles is implicitly included in the effective collisions of the charged particles and plays an important part in the damping of waves, particularly in the low layers of the ionosphere. The anisotropy of the ionosphere is associated with the existence of the external geomagnetic field (this is responsible for the cyclotron motion of the particles, anisotropy of conductivity, etc.) which is considered to be homogeneous in the elementary layers.

A whole series of papers has now been published, which deal with the theoretical as well as empirical modelling of the physical composition of various regions of the real ionosphere. The purpose of this paper is not to create new models, but to construct vertical profiles in the existing models, of a suitable form of ionospheric characteristics which could be used directly for modelling the ionospheric filtration of ULF waves using the methods described in [2–4].

2. FUNDAMENTAL PARAMETERS OF IONOSPHERIC PLASMA

In the simple two-component plasma of the ionosphere, we consider the occurrence frequency of the charge ($Z_e = -1$, $Z_i = +1$) and the mass of the electron $m_e$ and the mass of a certain type $X^+$ of the positive ion, $m_i(X^+)$, to be the fundamental local parameters. The existence of negative ions ($X^-$), particularly in low ionospheric layers, has been omitted in these deliberations for their small physical significance with regard to the propagation of waves through the ionosphere. There is also the electron concentration $N_e$ which, assuming quasineutrality of the medium, is equal to the overall concentration of all types of ions in the medium, $N_i = \sum N(X^+) \approx N_e$.

An important dissipative parameter of the medium with regard to the propagation of ULF signals are the effective particle collision frequencies, representing collision frequencies of a particular type of particle with all other types of particles present in the medium. The effective collision frequency of electrons $v_e$ is defined as a local parameter,

\begin{equation}
  v_e = v_{en} + v_{el},
\end{equation}

where

\begin{equation}
  v_{en} = \sum_X v(e, X)
\end{equation}

is the aggregate collision frequency of electrons with neutral particles of all kinds ($X$) at a given point of the medium. The importance of this component increases with decreasing altitude, in the low dense layers of the ionosphere. The quantity

\begin{equation}
  v_{el} = \sum_{X^+} v(e, X^+)
\end{equation}

is the aggregate collision frequency of electrons with all types of $X^+$ positive ions at a given point of the medium. A more detailed description of determining and analysing the properties of these parameters can be found in [5].