ON THE POSSIBILITIES OF HORIZONTAL PROPAGATION
OF Pc1 PULSATIONS IN THE IONOSPHERE

KAREL PRIKNER
Geophysical Institute, Czechosl. Acad. Sci., Prague*)

VLADIMÍR VAGNER
Foreign Trade Computer Centre, Prague**)

Summary: The vertical distribution of the contribution of the energy flux density due to the Alfvén (ordinary) wave, guided by the geomagnetic field (and propagating through the ionosphere to the Earth's surface) in the horizontal direction is demonstrated in the mechanism of the horizontal propagation of the Pc1 signal. The distribution with height is shown of the variations of the polarization characteristics of the propagating wave (e.g. the rotation of the polarization plane, changes in ellipticity, attenuation, etc.), which are the result of coupling in the denser layers of the low ionosphere in which also suitable isotropic (extraordinary) modes are generated. The results obtained using the method described in [4, 13] are demonstrated on a model of the daytime ionosphere under incidence of ordinary L-modes, frequency $f = 0.3 \text{ Hz}$, and various meridional angles at the ionosphere.

1. INTRODUCTION

In general it is assumed that ordinary waves of the Alfvén type play a dominant part in the Pc1 pulsation signal, generated in the plasmapause, which propagates along the geomagnetic lines of force to the Earth's surface (where the signal is recorded). As these waves enter the denser layers of the ionosphere ($F$- and $E$-regions), however, these waves (L-modes), left-handed in the Northern Hemisphere, may partly be transformed into right-handed waves, unguided by the geomagnetic field, so-called R-modes [1].

Whereas the guided L-modes are strongly attenuated in the dense layers of the ionosphere (particularly in the $E$-layer) [3], the "isotropic" [1] R-modes propagate easily through the ionosphere to large distances. Moreover, these R-modes may be channelled in the horizontal ionospheric waveguide [2] between the conducting Earth's surface and the Alfvén wave velocity.
maximum at altitudes of roughly 3000 km. The centre of the waveguide is the region of the maximum concentration in the ionospheric F-layer. The \( \text{Pc1} \) signal, transformed in this manner, may propagate from the "ionospheric source region" at high geomagnetic latitudes to large horizontal distances especially in the meridional N-S direction into mid and lower latitudes [1].

We shall also demonstrate the dependence on altitude of the generated horizontal components of the propagating pulsation energy, with which the wave, propagating downwards through the ionosphere to the Earth’s surface and subject to intermodal transformation (intermodal coupling) in the ionosphere, contributes to the horizontal direction. The algorithm described in [4], which enables the “instantaneous” local characteristics, amplitude and energy, to be determined at any altitude in the form of intermediate results, was used for the computations.

2. METHOD

The method of numerical modelling of ionospheric filtration of \( \text{Pc1} \) signals, presented in [4 - 6], enables vertical profiles of the “instantaneous” local characteristics of the individual characteristic wave modes LD, RD (L- and R-modes propagating downwards) and LU, RU (L- and R-modes propagating upwards), to be determined as part of the recurrent computation procedure. The linear combination of the LD- and RD-modes are also determined quantitatively at each level which produces the compound D-wave propagating through the ionosphere to the Earth’s surface.

Based on [4, 5], the solution of the plane wave field at any altitude \( z \) (the \( z \)-axis of the Cartesian coordinate system points vertically upwards from the Earth’s surface, the \( y \)-axis to the north in the plane of the geomagnetic meridian, and the \( x \)-axis to the east) is formally expressed as

\[
\mathbf{f}(z) = Q(z, z_0) \mathbf{f}(z_0), \quad \mathbf{f} = \begin{bmatrix} E_x \\ E_y \\ B_x \\ B_y \end{bmatrix}
\]

where \( z_0 \) is the altitude at which the primary (LD or RD) natural wave modes is incident (Fig. 1). \( Q(z, z_0) \) is the (4 x 4) integral transformation matrix for transforming the “local total” field \( \mathbf{f}(z_0) \) of the wave through the transition layer of the altitude-varying ionosphere from altitude \( z_0 \) to altitude \( z \). The field quantities \( E_z \) and \( B_z \) are obtained by solving 2 linear algebraic equations [4].

The wave solutions can be expressed in terms of a linear combination of four characteristic wave modes. At the level of incidence \( z_0 \) and at the general altitude \( z \) it holds that

\[
(2a, b) \quad \mathbf{f}(z_0) = f_0 = \mathbf{V}_0 \mathbf{c}_0, \quad \mathbf{f}(z) = f_z = \mathbf{V}_z \mathbf{c}_z,
\]

\[
(3a, b) \quad \mathbf{c}_0 = \begin{bmatrix} 1 & u_0 \\ 2u_0 \\ d_0 \\ 2d_0 \end{bmatrix}, \quad \mathbf{c}_z = \begin{bmatrix} 1 & u_z \\ 2u_z \\ d_z \\ 2d_z \end{bmatrix}
\]