HM-WAVE FILTRATION IN A HORIZONTALLY STRATIFIED EARTH'S MAGNETOSPHERE

Part II. The Model for the Lower Magnetosphere

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Summary: The model of filtration of a linearly polarized HM-wave in a system of three homogeneous layers, limited by two halfspaces and treated in [1], is generalized. The wave attenuation is considered in all inner layers of the system and the model is applied to the filtration of HM-waves in the lower layers of the magnetosphere, i.e. in the ionosphere. The nature of the changes of the functional dependences is studied, i.e. of the "amplitude coupling factor" on the frequency under variation of the fundamental parameters, defining the filtering medium. Filtration models are demonstrated and discussed for the periods of maximum and minimum solar activity during daytime and at night. The relation between the properties of filtration and the possibilities of observing geomagnetic pulsations on the Earth's surface is pointed out.

1. INTRODUCTION

In Part 1 of this paper [1] we dealt particularly with the resonance of a plane linearly polarized HM-wave in a horizontally stratified Earth's magnetosphere. The model of 3 homogeneous layers, restricted by 2 halfspaces, assumed wave attenuation in one layer (the ionosphere as a whole). This approach was adopted with a view to studying resonances in the low-frequency range of geomagnetic pulsations. The results, obtained from this model, are only a very rough approximation of the real pulsation mechanism. The model is founded on the assumptions in [2] and in geometry it comes close, to a certain extent, to the model in [3, 4]. However, the actual topology of the magnetosphere as a resonator is so complicated that within the studied range of characteristic lengths of the wave process of geomagnetic pulsations the presented model may only be considered as semi-quantitative, providing only tentative results with regard to the positions of the resonances.

Insiste of the indicated drawbacks, the use of the model is prospective. It can be used to study the filtration of HM-wave amplitudes through a limited region of the magnetosphere, adjacent to the Earth's surface. The region of the ionosphere may be considered a plane layer with respect to the propagating wave front and it can be represented by a system of layers in which the physical parameters vary discretely. The computation of the coupling factor \( |H_T/H_F| \) [1] illustrates the amplitude filtration of the wave on its passage through the system of layers. This system, representing the ionosphere, is not considered a resonator in the range of geomagnetic pulsation frequencies studied (no peaks occur in the \( |H_T/H_F| \)-pattern). However, it may play the role of a resonator for the higher frequencies.

In order to be able to apply this model to the study of HM-wave filtration through the ionosphere, it is convenient to generalize it in particular by introducing attenuation in all layers of the system. In this more general form the model can, of course, be used to treat problems analogous to those in [1].

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2. FORMULATION OF THE PROBLEM

The problem of filtration of a plane linearly polarized HM-wave in a horizontally stratified medium of the upper atmosphere was already formulated in [1]. In generalizing it further we shall retain the fundamental assumptions. We assume the propagation of an isotropic HM-wave through 5 regions: a system of layers composed of 3 layers restricted by 2 halfspaces (Fig. 1). The external magnetic field \( H^{(0)} \) in the layers is homogeneous. The bottom halfspace (denoted with the index 0) represents the solid Earth’s body, adjacent immediately to the ionosphere. In analogy with the assumptions in [2] we ascribe metallic properties to the Earth halfspace in relation to the propagation of HM-waves \( (k_0 \to \infty) \). With a view to the frequency range of the HM-waves being studied, we have neglected the region of the so-called “plasmatic vacuum” between the Earth's surface and the ionospheric layers (a region of roughly 100 km in height). The individual layers are numbered from below 1, 2, 3.

In the inner layers of the system, as well as in the upper halfspace (the region of the incident wave, denoted with the index 4) we also assume constant Alfven velocities \( V_j \) and constant collision frequencies of ions and neutral particles \( v_{in,j}, j = 1, 2, 3, 4 \). The attenuation of HM-waves in the ionosphere is associated in particular with the collision frequency of the ions. In contrast to the formulation of the problem in [1], we assume that \( v_{in} \) is not negligible in any of the inner layers of the system and that the assumption, applied in [1], \( \omega \ll v_{in} \) is no longer valid. In general, therefore, we assume a complex wave number \( k_j = \alpha_j + i\beta_j, j = 1, 2, 3 \) in the inner layers of the system. We can still assume that the medium in the upper half-space, from which the HM-wave are incident at the system, is collisionless.

Consider a clockwise co-ordinate system \((x, y, z)\) (Fig. 1), such that the x-axis is pointing north, the y-axis east and the z-axis upwards. The origin is located on the boundary between regions 0 and 1, representing the “Earth’s surface”. The external homogeneous magnetic field \( H^{(0)} \) is considered to point north, i.e. \( H^{(0)} \parallel x \). The waves propagate along the z-axis \((k \parallel z)\). In this case the vector of the electric field of the wave \( E \parallel y \) and the vector of the magnetic field of the wave \( H \parallel x \parallel H^{(0)} \).

It is also true that \( H \perp k \) and \( E \perp k \). As shown in [1], the conditions of computation do not change even in the second possible configuration of the propagation of the linearly polarized, purely transverse Alfven wave, i.e. if the external magnetic field \( H^{(0)} \parallel z \) and \( k \parallel z \), \( H \parallel x \), \( E \parallel y \).