

ON THE QUESTION OF MAGNETOSONIC RESONANCES IN THE EXOSPHERE

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Abstract

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GEOFYSICS

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ON THE QUESTION OF MAGNETOSONIC RESONANCES IN THE EXOSPHERE

(Presented by Academician B. P. Konstantinov, 20 VII 1966)

According to modern concepts, stable oscillations of the geomagnetic field with periods from several seconds to several minutes are attributed to the existence in the Earth's magnetosphere of resonant hydromagnetic waves excited as a result of the interaction of the solar corpuscular stream with the outer parts of the magnetosphere. The propagation of hydromagnetic disturbances may occur both in the form of Alfvén waves and in the form of magnetosonic waves.

In the first case, stable oscillations may be associated with the occurrence of standing Alfvén waves along a field line, which is usually regarded as an elastic string fixed at the ends. The fundamental period of the resulting stable oscillations is then equal to twice the transit time of an Alfvén wave along the field line between conjugate points.

In the second case, stable oscillations are associated with the occurrence of standing magnetosonic waves in a resonator formed by the outer boundary of the magnetosphere and the well-conducting ionosphere. The period of the oscillations arising in this case must be determined by twice the transit time of a magnetosonic wave over the shortest distance between the walls of the resonator.

In both the first and the second cases, the period of oscillations depends substantially on the distribution of the Alfvén speed in the magnetosphere, since, neglecting gas pressure inside the magnetosphere, both waves propagate with the same speed V_A . Usually, in calculating the periods of geomagnetic pulsations, the profile of the Alfvén speed obtained by Dessler ⁽¹⁾ is used. However, the very first calculations showed that the computed fundamental periods of magnetosonic oscillations of the magnetosphere are substantially larger than the observed ones. This fact indicates that the velocities of hydromagnetic waves are taken to be lower than those existing in nature.

According to modern satellite measurement data ⁽²⁾ and observations of whistling atmospherics ⁽³⁾, it has apparently been established that in the magnetosphere, at an equatorial distance $R \approx 4R_e$, there is a sharp decrease in the plasma density (the so-called "knee"). The plasma concentration n_e ,

Fig. 1

Figure 1: Fig. 1

according to the data of ^(2,3), at these distances drops sharply from ~ 100 to $\sim 1 \text{ cm}^{-3}$.

In Fig. 1 the solid line shows an approximate profile of the Alfvén speed in the magnetosphere, taking into account the effect of the plasma-density “knee” and assuming a dipole magnetic field. The presence of a second maximum of V_A at altitudes of $4\text{-}4.5 R_e$, in contrast to the Dessler profile shown in the figure by the dashed line,* is noteworthy.

An estimate of twice the transit time of hydromagnetic waves between two maxima of V_A ($T \approx 20 \text{ sec.}$) shows that it agrees satisfactorily with the observed periods of stable oscillations. Analysis

* This fact was noted by J. Dungey in his lecture at the Institute of Physics of the Earth, Academy of Sciences of the USSR.

resonances in the region between the two maxima appears especially important because the boundaries of this region are characterized by a sharp change in V_A , by approximately a factor of 3-10. At the same time, the low values of the density of the magnetospheric plasma ρ_i at distances greater than $5\text{-}7 R_e$, close to the density of the solar wind ρ_e , lead to the fact that, under certain conditions, the outer surface of the magnetosphere is not a sharp boundary for hydromagnetic waves.

Fig. 1

For example, if the isotropic part of the external pressure plays the main role, then from the equilibrium condition at the boundary of the magnetosphere ($p = H^2/8\pi$) there follows an approximate equality of the Alfvén velocity inside the magnetosphere $V_A = H/\sqrt{4\pi\rho_i}$ and the speed of sound outside the magnetosphere $V_s = \sqrt{2p/\rho_e}$ for $\rho_e \approx \rho_i$, since $V_s^2 \approx 2p/\rho_e = H^2/4\pi\rho_e \approx V_A^2$.

Owing to the insignificant difference between V_A and V_s , the coefficient of reflection from the outer boundary is very small.

Consequently, magnetosonic resonances must be predominantly associated with two regions: 1) from $R \approx 4.5 R_e$ to $R \approx 1.5 R_e$, with antinodes of the electric field E at the boundaries, so that the fundamental period can be estimated from twice the transit time ($T_1 \approx 20 \text{ sec.}$), and 2) from $R \approx 1.3 R_e$ with an antinode of E to the boundary of the conducting ionosphere with a node of E ; in this case the fundamental period is determined by four times the wave transit time ($T_2 \approx 10 \text{ sec.}$ ⁽⁴⁾).

The mutual coupling between the resonators should lead to the appearance of additional difference beat frequencies. For example, for $T_1 = 15 \text{ sec.}$ and $T_2 = 10 \text{ sec.}$, oscillations will appear with

$$T_3 = \frac{1}{1/T_2 - 1/T_1} = 30 \text{ sec.}$$

In addition, the possibility of resonance between the outer boundary of the magnetosphere and the “knee” region should be taken into account.

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