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Modeling ULF Magnetic Pulsations in Southern Hemisphere with Kinetic Alfvén Waves

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Abstract

The main goal of this paper is to study the Ultra Low Frequency-ULF magnetic pulsations (magnetic micropulsations) in the magnetosphere due to disturbances produced possibly by different mechanisms such as magnetic storms and/or substorms, energetic electron beams and so on. These pulsations are seen as electromagnetic ion cyclotron/kinetic Alfvén waves with a broad spectrum of frequencies, in contrast with the very well known Kelvin-Helmoltz mode conversion that excites monochromatic magnetospheric magnetic pulsations.

Here our interest is to relate the continue micropulsations data in the range of 0.2 s to 600 s, with the kinetic/fast Alfvén waves in the region of the Earth magnetosphere.

Keywords:

ULF magnetic pulsations, kinetic Alfvén waves, earth magnetosphere

1. Introduction

There are different mechanisms capable to generate waves into the magnetospheric cavity. The ULF waves for instances, are specifically kinds of waves which frequencies excited in plasma depend not only on the wave modes but also on the boundary conditions.

Wave generation is one kind of magnetospheric phenomenon, which source of energy comes principally from the solar wind or the own ionosphere. Kelvin-Helmoltz instability can be the mechanism responsible for the surface waves compressing the magnetosphere and generating on the same time compressional waves propagating into the magnetosphere and observed on the ground. The theory of field-line resonance of the ULF waves have been developed to describe the effective process of surface waves propagating inside the magnetosphere [1-5]. On the other hand when the sources of energy are related with storms or even substorms, energetic particle are injected into the cavity and different kinds of resonance with a specific polarisation between waves and particles may occur. Consequently a different process of coupling energy take place and also a different kind of wave can be recorded from ground observations by magnetometers or in the space by satellite recording the electric and magnetic fields and others plasma parameters.

2. Analysis

The data of the Southern Hemisphere Magnetic Observatory recorded by magnetometers located at Vassouras-RJ which geomagnetic coordinates are: latitude −11°54′ and longitude +23°54′; while the geographic coordinates are: latitude +22°24′S and longitude +43°39′W, have been analysed and suggested as a signature of the Pc5 micropulsation, modelled by

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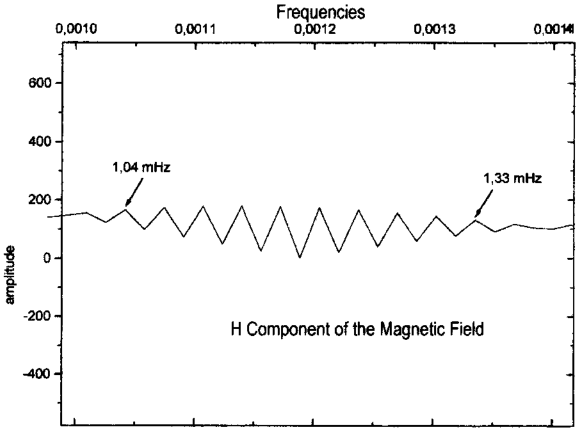

Fig. 1 The spectrum of frequencies (Hz) of the ULF magnetic pulsations at the Vassouras magnetic observatory in Rio de Janeiro-Brazil.

kinetic Alfvén waves (KAW) [6,7]. The Fig. 1 shows a quasi-monochromatic spectrum of frequencies in the range of 1.04–1.33 mHz, with regular amplitude what means an ULF spectrum of waves and described as continuous pulsations.

Kinetic Alfvén wave is a kind of local excitation, so a local observation or a satellite measurement is necessary [8,9]. To consider a kinetic mode as responsible for the presence of ULF waves on the ground observations, could be taking into account the presence of KAW in the magnetosphere by different processes of excitation, such as, energetic electron beams as a source of free energy into the plasma or by resonant mode conversion of a fast magnetosonic or superficial wave [4]. In both cases, to justify the presence of this mode on the ground, it has been considered the local disturbances propagating as parallel as perpendicular through the field line, and by mode conversion process changing into electromagnetic waves that are measures in the Earth surface by magnetometers.

3. Basic Equations

The kinetic Alfvén wave here is derived from the general dispersion relation, considering in this case, the referring corrections to the Larmor radius of the ions and the inertia of the electrons. Besides have been considered in the tensor elements some standard approximations, such as the low frequency turbulence, that means in this case, $\omega << \Omega_i$, as well as, $k_\parallel << k_\perp$ and $k_\parallel \alpha_s << \Omega_i$, where $\Omega_s = (q_s B_0/m_s c)$ and $\alpha_s = (2KT_s/m_s)^{1/2}$ are respectively the cyclotron frequency and the thermal speed for each specie s (ions and/or electrons). Using these approaches, the summarised dispersion relation of the kinetic Alfvén wave can be written as follows [10],

$$N^2 = \frac{k^2 c^2}{\omega^2} = \frac{\varepsilon_{xx}}{\dfrac{k_\parallel^2}{k^2} + \dfrac{k_\perp^2}{k^2}\dfrac{\varepsilon_{xx}}{\varepsilon_{zz}}}, \tag{1}$$

where $N^2 = k^2c^2/\omega^2$ is the refractive index and the tensor elements of relevance is condensed and also can be written in an accomplished style as

$$\varepsilon_{xx} = \sum_S \frac{\omega_{PS}{}^2}{\omega^2}(\mu_S - 1) + \sum_S \sum_{-l}^{+l} \frac{\omega^2{}_{PS}}{\omega^2} \frac{l^2 \Lambda_l(\lambda_S)}{\lambda_S} \mu_S \, \xi_S \, Z(\xi_S) \tag{2}$$

and

$$\varepsilon_{zz} = 2\sum_S \frac{\omega^2{}_{PS}}{\omega^2}\left[\left(\frac{\omega}{k_\parallel \alpha_{\parallel S}}\right)^2 + \frac{1}{2}(\mu_S - 1)\frac{k_\perp^2}{k_\parallel^2}\right] + 2\sum_S \sum_{-l}^{+l} \frac{\omega_{PS}{}^2}{\omega^2} \Lambda_S \, Y_S \, \bar{\xi}_S \, Z(\xi_S) \tag{3}$$

where $\mu_S = (\alpha_{\perp S}^2/\alpha_{\parallel S}^2)$, is the rate between perpendicular and parallel thermal speed for each specie s (ions and/or electrons). The other terms found in the two first equations are expressed by: $\lambda_S = (\alpha_\perp^2 \alpha_{\perp S}^2/2\Omega_S)$; $Y_S\,(\omega - l\Omega_S)/(k_\parallel \alpha_{\parallel S})$; $\Lambda_l\,(\lambda_S) = \exp(-\lambda_S) I_l(\lambda_S)$; $\xi = (\omega - k_\parallel u_{\parallel S} - l\Omega_S)/(k_\parallel \alpha_{\parallel S})$; $\bar{\xi}_S = [\omega - k_\parallel u_{\parallel S} - (1 - \mu^{-1}{}_S) l\Omega_S]/(k_\parallel \alpha_{\parallel S})$ and $\omega^2{}_{PS} = (4\pi n_S q_S/m_S)$, where l means the number of harmonics necessary to find the roots of the equation, $I_l(\lambda_S)$ is the modified Bessel function and finally $Z(\xi_S)$, is the well-know plasma dispersion function [11].

Finally using appropriately the expressions above, the dispersion relation for the KAW can be written in terms of the wave frequency as

$$\omega^2 = k_\parallel^2 v_A^2 \left[\frac{k_\perp^2 \rho_i^2}{1 - I_0(k_\perp^2 \rho_i^2)\exp(-k_\perp^2 \rho_i^2)} + \frac{T_e}{T_i} k_\perp^2 \rho_i^2\right]. \tag{4}$$

4. Conclusions

The presence of ULF magnetic pulsations in the Southern Hemisphere is a well known phenomena in space physics. There are several observatories distributed in the world, many of that in the same latitude or longitude. Any time is possible to get information of any observatory inside this net to check the recorded results and looking for a global or local phenomenon [7,12]. Although the importance of this work is on the nature of the model used to describe the phenomenon. It is new but very consistent the proposal of modelling the ULF magnetic pulsations with kinetic Alfvén waves. This is a good and interesting issue.

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References

[1] L. Chen and A. Hasegawa, J. Geophys. Res. **79**, 1024 (1974).

[2] J.W. Dungey, Pennsylvania State University Ionosphere Research Laboratory Report **69** (1954a).

[3] J.W. Dungey, Pennsylvania State University Ionosphere Research Laboratory Report **57** (1954b).

[4] A. Hasegawa, H.K. Tsui and A.S. de Assis, Geophys. Res. Lett. **10**, 765 (1983).

[5] M.G. Kivelson and D.J. Southwood, J. Geophys. Res. **91**, 4345 (1986).

[6] M. Tanaka, T. Sato and A. Hasegawa, Phys. Fluids B1, 825 (1989).

[7] K. Yomoto, Y. Tanaka, T. Oguti, K. Shiokawa, Y. Yoshimura, A. Isono, B. J. Fraser, F.W. Menk, J. W. Lynn, M. Seto and 210 (deg) MM magnetic meridian observation group, J. Geomag. Geoelectr. **44**, 261 (1992).

[8] L. Chen and A. Hasegawa, J. Geophys. Res. **96**, 1503 (1991).

[9] L. Chen and A. Hasegawa, J. Geophys. Res. **99**, 179 (1994).

[10] A.S. de Assis, PhD Thesis, Campinas State University, SP, Brazil (1988).

[11] T.H. Stix, Waves in Plasmas. American Institute of Physics (1992).

[12] K. Yomoto and 210 (deg) MM magnetic observation group, J. Geomag. Geoelectr. **48**, 1297 (1996).