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HYDROMAGNETIC SPECTROSCOPY OF THE MAGNETOSPHERE WITH Pc3 GEOMAGNETIC PULSATIONS

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1. Introduction

The typical feature of wave activity in the magnetosphere is the large variety of possible sources of geomagnetic pulsations in any particular frequency range. Usual application of Pc3-4 ULF ground data for diagnosis of the solar wind and the magnetosphere relied mainly on determination of the pulsation frequency. However, the selection of a proper frequency can be uncertain due to complicated spectral forms of pulsations. So, the hydromagnetic diagnosis of the outer space in fact reduces to the problem which may be called the hydromagnetic spectroscopy, i.e the physical interpretation of spectral peaks of the recorded ULF waves. A reliable interpretation of ground-based data cannot be done by just analyzing spectral features of some component only. The physical nature of particular spectral peaks can be revealed with the use of additional information about spatial or polarization structures of ULF signals (*Baransky et al.*, 1995). This approach will be illustrated by the analysis of the ULF data from mid-latitude stations along the 210^0 meridian.

2. Variations of ULF spectra along a meridian

From the network along the meridian 210^0 we have chosen the mid-latitude stations: MGD ($L \approx 2.85$), PTK ($L \approx 2.1$), MSR ($L \approx 1.60$) - in the northern hemisphere and ADL ($L \approx 2.13$), BSV ($L \approx 1.57$) - in southern hemisphere. The identical flux-gate magnetometers at each station recorded three-component magnetic variations in the range 0–0.5 Hz with flat frequency response (*Yumoto et al.*, 1995). In contrast with quasi-static variations, the ULF oscillations have a non-monotonic latitudinal distribution. Even visual inspection of magnetograms reveals essential variations of amplitude and apparent period of ULF signals from station to station. A variety of the ULF response of the magnetosphere to an external source of wave energy is determined by relationship between the spectral features of an external pulsation source and the local resonant frequencies.

2.1 Band-limited noisy source

One class of the meridional distribution is caused, probably, by wide-band disturbance without a pronounced central frequency. The power spectrum density of non-resonant D-component gradually decreases with frequency as $f^{-\alpha}$ with $\alpha = 3$ in the range 20–100 mHz. Signal coherency between the D-components at different stations is low. For more clear elucidation of the spectra fine structure the background slope of spectral curve has been compensated by multiplication of H-component spectra $H(f)$ by factor f^3. After elimination of an average spectrum slope the fine structure of $H(f)$ comprises specific pronounced spectral peaks. Their frequencies systematically change with latitude: from 35 mHz at $L \approx 2.85$ (MGD) to 45-50 mHz at $L \approx 2.1$ (PTK/ADL), and further to 85 mHz at $L \approx 1.6$ (MSR/BSV). These frequencies correspond to local eigen frequencies of Alfven oscillations of field line. Additional argument in favor of this suggestion is the fact that the signal coherency between the nearly-conjugated stations: PTK-ADL and MSR-BSV, increased at these frequencies. At the same time signals at the stations of the same hemisphere correlate poorly.

2.2 Source with central frequency

The principal feature of another class of ULF events is the enhanced power spectral density in the D-component at certain frequency throughout the network: $D(f)$ has a common maximum at 45–65 mHz at all stations. The signal coherency between stations in the band 50–90 mHz is rather high, $\gamma > 0.5$.

In contrast with the previous example, the spectral content of the H-component varies with latitude in more complicated way for this class of ULF events. At the "common" frequency ~ 50 mHz, which probably corresponds to the central frequency of an ULF source, wide spectral maxima have been observed at

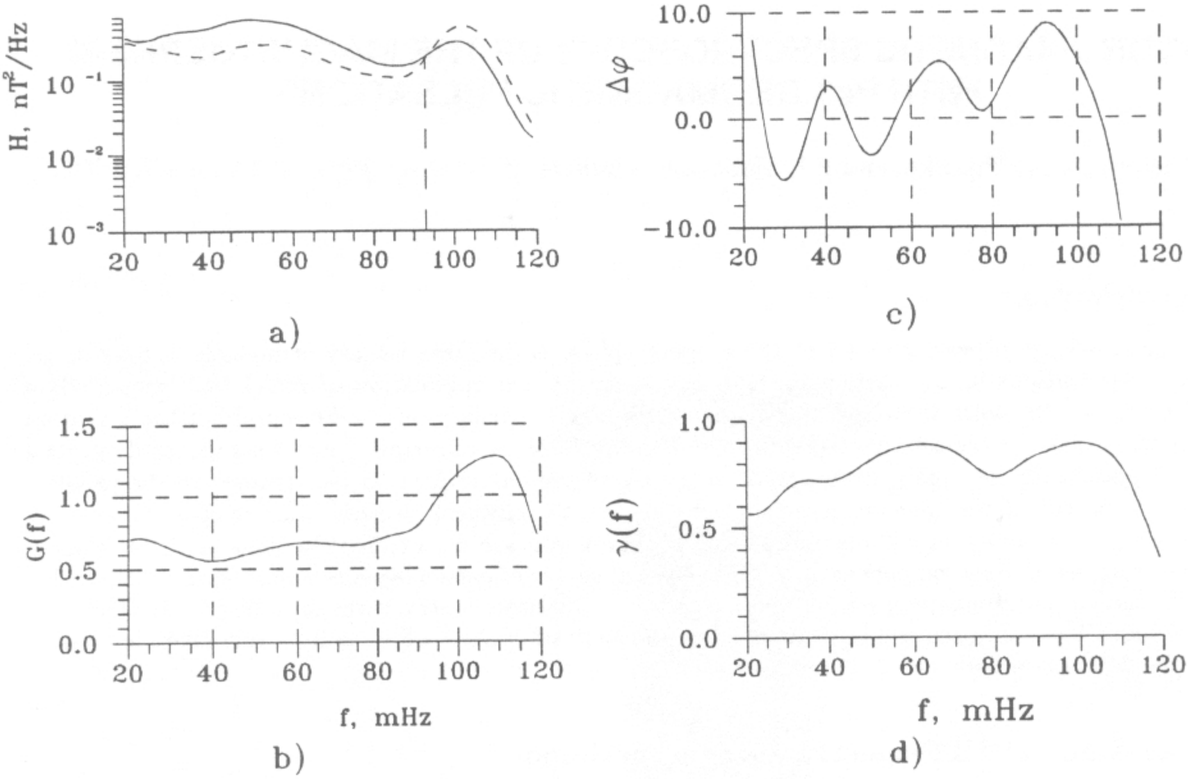

Fig.1. The results of the quasi-gradient analysis of the ULF waves recorded on 14.10.92, 0:23-0:41 UT at near-conjugated stations MSR and BSV: a) H-component spectra; b) spectra ratio $G(f)$; c) phase difference $\triangle\varphi(f)$ and d) coherency $\gamma(f)$. The resonant frequency of a field line between the stations is marked by the arrow.

$L \approx 2.85$ (MGD) and $L \approx 1.6$ (MSR/BSV). At this frequency signals at far stations MGD and MSR are highly coherent both in the H and D-components and have no pronounced phase shift. At the same time at the "common" frequency a "gap" at $L \approx 2.1$ (PTK-ADL) emerges in the meridional profile of spectral density. The effect of local decrease of the H-component amplitude at $L \approx 2.1$ cannot be explained by local geoelectrical conditions or by appearance of a cavity-mode node, and it is possibly caused by influence of resonance somewhere within $L = 1.6 - 2.1$.

At $L \approx 1.6$ (MSR/BSV) two frequencies, which are about 50 mHz and 100 mHz, dominate in the spectra $H(f)$. In principle, these peaks could be interpreted in two ways: a). 50 mHz is the fundamental resonant frequency and 100 mHz is its second harmonic; b). a high-frequency peak corresponds to the local fundamental frequency, while a low-frequency peak is a non-resonant response. To resolve this ambiguity a modification of the gradient method has been applied to the data from the nearly-conjugated stations at $L \approx 1.6$ (MSR and BSV). The mismatch in latitude between them is about 0.7^0 ($\Delta L = 0.03$). The quasi-gradient analysis reveals the transition of the ratio between power spectra of H-components at both stations $G(f)$ over 1 and the extreme value of the phase difference $\triangle\varphi(f)$, typical for a resonance region, only in the region of high-frequency peak (Fig.1). Hence, the amplitude and phase gradients definitely indicate the $\sim$ 100 mHz peak as a resonant one, while low-frequency spectral enhancement has a non-resonant nature. This conclusion has been supported by examination of $H(f)/D(f)$ ratio at each station, which also increased in the region of high-frequency spectral peak. The above interpretation is also supported by phase relationships among signals at conjugated stations.

In total we have analyzed 60 Pc3 events with duration of 10-35 min recorded in October, 1992. Statistical distributions prove the existence of particular frequencies with enhanced $H(f)$, which are specific for each station. It is natural to relate these frequencies with local frequencies of resonant shell oscillations at particular latitudes. This assumption is supported by similar statistical distribution of spectral peaks in $H(f)/D(f)$ ratio.

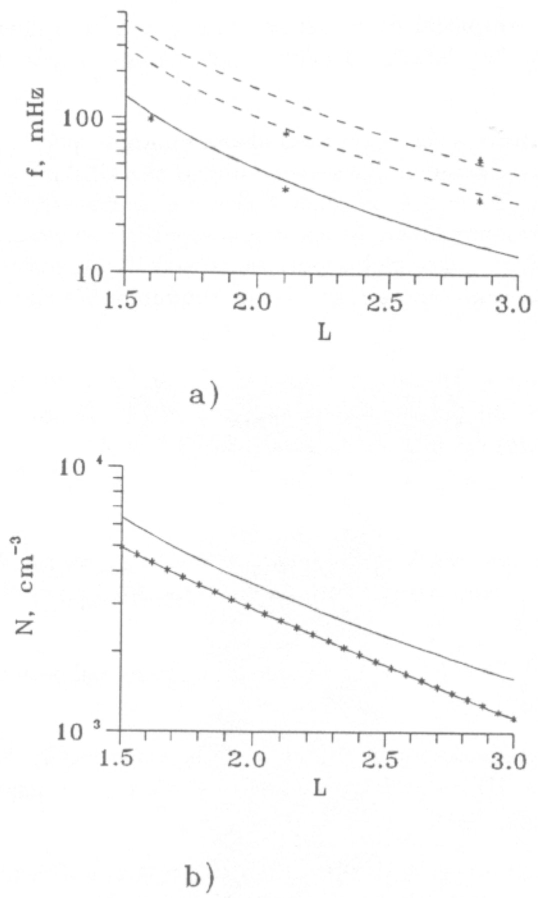

Fig.2. a) Radial profile of latitude-dependent resonant frequencies approximating the experimental data (asterisks) from the meridional network. Solid line corresponds to fundamental mode, dashed line - to 2-nd and 3-d harmonics. b) Corresponding plasma density distribution in the equatorial plane of the magnetosphere. Interpolation of CA model is shown by asterisks.

3. Numerical modeling of the magnetospheric plasma distribution

The experimentally determined values of local resonant frequencies $f_R(L)$ have been used for the restoration of plasma density profile in the magnetosphere. The numerical model of the Alfven resonator has been used, which is based on the integration of the local differential equation along a field line, which determines spectral properties of the Alfven continuum, with the boundary condition in the approximation of thin ionosphere. For the power-law plasma distribution $N(L) = N_0(L/L_0)^{-p}$ the best agreement between the numerical profile $f_R(L)$ and experimental data was achieved for the following parameters: $N_0 = N(L = 3) = 1,6 \times 10^3$ cm^{-3} , $p = 2.0$ (Fig.2). Good accordance between the frequencies of the fundamental mode and its harmonics is given by the value of the parameter m, which characterizes plasma distribution along a field line, equal to 3.0. The empirical model by *Carpenter-Anderson* (CA) (1992) of electron plasma density in the equatorial plane of the magnetosphere, after its extrapolation into the region $L < 2.2$, fits well with the resultant meridional profile $N(L)$ (Fig.2).

Knowledge of instant values of local resonant frequencies $f_R(L)$ is important not only for hydromagnetic diagnosis of the magnetosphere, but for correct interpretation of the results of the magnetotelluric sounding (MTS) as well. Near the resonant frequencies distortions of MTS curves above low-conductive layers could be misinterpreted as features of the crust structure (*Pilipenko and Fedorov*, 1994). To avoid this misinterpretation a preliminary estimation of $f_R(L)$ is necessary. For this purpose a special semi-empirical model has been elaborated. The PC version of this model enables a user to render the profile $f_R(L)$ for different geophysical parameters. For middle latitudes ($\Phi > 40^0$) the model is based on CA model. Extension of the CA model to lower latitudes relies on the presented above results. The model has been realized as an PC program with a graphical presentation, and it can be applied for express analysis of $f_R(L)$ distribution in a given area. Any interested person may request a free copy of the program from the authors.

In contrast with the problem of hydromagnetic diagnosis of the magnetospheric plasma, the study of correlative relationships between the parameters of the solar wind and the ULF pulsations requires monitoring of the central frequency of a source. To do this one should either eliminate the resonant distortions of the H-component spectra, or use the D-component, which is less sensitive to resonant effects. The network observations make it possible to discriminate global pulsations with "common" f from local field-line oscillations, and this may help to determine more reliably the frequency of solar wind sources of the ULF waves.

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