Connections between whistlers and pulsation activity

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Received: 11 October 1999 / Revised: 15 March 2000 / Accepted: 4 April 2000

Abstract. Simultaneous whistler records of one station and geomagnetic pulsation (Pc3) records at three stations were compared. In a previous study correlation was found between occurrence and L value of propagation/excitation for the two phenomena. The recently investigated simultaneous records have shown that the correlation is better on longer time scales (days) than on shorter ones (minutes), but the L values of the propagation of whistlers/excitation of pulsations are correlated, i.e. if whistlers propagate in higher latitude ducts, pulsations have periods longer than in the case when whistlers propagate in lower latitude ducts.

Key words: Electromagnetics (wave propagation) – Magnetospheric physics (magnetospheric configuration and dynamics; MHD waves and instabilities)

1 Introduction

Whistlers and geomagnetic pulsations from field line resonances are two phenomena which need a certain magnetospheric structure for excitation. Whistlers propagate from one hemisphere to the other in ducts, i.e. in tubes which are elongated approximately along geomagnetic field lines and are bordered by some inhomogeneity in the particle density. The main factors governing whistler activity are propagation conditions from the source (lightning) to the magnetospheric channel and then the existence of appropriate channels in the magnetosphere which lead them to the opposite hemisphere (Maeda and Kimura, 1956; Smith, 1960; Smith et al., 1960; Smith and Angerami, 1968; Helliwell, 1965; Walker, 1976, 1978; Strangeways, 1976, 1982).

Field line resonances are excited by waves/inhomogeneities arriving into the magnetosphere from the interplanetary space. Due to these upstream waves, shells (whether they are of finite or infinitesimal thickness) are excited with a frequency characteristic for the given shell (Orr, 1976; Yumoto, 1986; Cz Miletits et al., 1990). These waves are observed at mid-latitudes at the surface as Pc3 pulsations. Again, the possibility of the excitation of field line resonances depends on several factors which are partly unknown at present. One of these factors is surely a not too high particle density in the magnetosphere, as during solar maximum conditions when particle density exceeds a certain level field line resonances do not occur, or are at least very seldom excited (Verő and Menk, 1986; Verő, 1996).

Even if the two magnetospheric structures are different, both need some kind of inhomogeneity along geomagnetic field lines, in the case of whistlers, linear structures along the field lines, in the case of field line resonances, shell-like structures on surfaces of equal L-values. Such shell-like structures if not infinitely thin may correspond to a series of ducts along this surface (Takahashi et al., 1993). This is the background for a possible correlation of whistler and pulsation activities.

There are several experimental facts which suggest a connection between whistler and pulsation activities. At first, a direct (and for us the only known mid-latitude) study of the whistler and pulsation activities (Verő et al., 1997) has shown two kinds of connections. The spectra of (Pc3-4) geomagnetic pulsations are different in times when whistlers propagate at low and at high L-values. In the latter case periods are longer, corresponding to the resonant period of the field line along which whistlers propagated, in the former case they are shorter. Additionally, a statistical analysis of whistler and pulsation activities has shown that pulsation activity is higher on days when the whistler activity is high and vice versa. Daytime pulsation activity is correlated both with daytime and night-time whistler activities.

This preliminary study was a statistical one in both respects. In the case of the connection between L-value
of the whistler ducts (recorded at the Tihany, THY observatory) and pulsation periods (recorded at Nagy- cenc, NCK, about 120 km away), parameters deduced from whistlers were compared to the pulsation activity of simultaneous 30 min long intervals as found in the NCK pulsation catalogue. Data of about 1700 whistlers were used in this comparison. A strict simultaneity could not be ensured, only the 30 min long intervals of the whistler appearance were the same for the pulsation activity.

In the comparison of whistler occurrence frequency and pulsation activity, the observed number of whistlers (Panska Ves, PAV observatory in the Czech Republic, about 200 km away) in a two-hour long daily and a one-hour long night interval was compared to the NCK daily index of pulsation activity. In this case, the strict simultaneity of data was even less certain, only longer time averages (one day) were used, thus features (whistler ducts and field line shells) persisting for at least one day could be compared.

Recently Smith et al. (1998) found correlation between Antarctic (geomagnetic and VLF/ELF) Pc3 pulsations and whistlers. According to their results, a part of the QP (quasi-periodic) emissions with periods of 10–60 s, known as type I QPs are linked with geomagnetic pulsations and correspond to upstream waves. Type II QPs are uncorrelated with geomagnetic pulsations, and are always accompanied by shorter period (4–6 s) VLF/ELF PEs (periodic emissions).

Another line of evidence suggesting extraterrestrial influences in whistler activity is presented in Fig. 1. It shows the dependence of the observed yearly average number of whistlers per minute (PAV) on the (yearly average intensity of the) interplanetary magnetic field (IMF) based on 11 years of data. In spite of a significant scatter, an influence of IMF is evidently present in whistler activity, perhaps due to an influence on the source mechanism, or due to an effect on propagation (the correlation coefficient is −0.49 between the two sets, the number of whistlers decreases by 0.4 per minute for an increase of 1 nT in IMF scalar magnitude; the averages of the two groups differ according to the Student-test on a level of significance of 0.99).

The aim of the present study of pulsations at three (L’Aquila, LAQ, L ∼ 1.59, Nagyenc, NCK, L ∼ 1.91, Niemegk, NGK, L ∼ 2.29 at a height of 200 km, 1.53, 1.85, 2.22 at the surface) observatories and of whistlers at one station (Tihany, THY, L ∼ 1.86 and 1.80) was to study the connection in detail, i.e. in shorter time intervals. We also had pulsation records from Budkov, but due to malfunction of the recorder, we did not use them.

2 Planning the simultaneous measurements

The task of the selection of the daily time interval for the simultaneous recording of geomagnetic pulsations and whistlers is a difficult one. As the digital whistler recording system in Tihany did not allow us to record in intervals longer than one hour daily, and even this was at the limit of its capabilities, we had to select the most advantageous one hour section of the day. Figures 2 and 3 represent the daily distribution of whistlers and pulsations, in different seasons. On the basis of these distributions, we selected the interval 0300 to 0400 UT, i.e. 4 h to 5 h LT for the recording. During this interval, the number of whistlers is about one third of the

![Fig. 1. Average number of whistlers per minute (n, diamonds) in the years 1971–1979, 1987 and 1990 versus the (yearly average intensity of the) interplanetary magnetic field (B). Medians of the whistler numbers for high and low B values (limit 6.5 nT) are indicated by squares](image)

![Fig. 2. Daily variation of the number of whistlers per minute in different seasons (S summer, May to August, W winter, November to February, Ae equinox, March, April, September, October), at the Observatory Panska Ves, 1971–79, 1987 and 1990. The selected interval for the present study is indicated by arrows. LT is UT + 1 h approximately](image)

![Fig. 3. Daily variation of the average pulsation amplitudes (µV/km) in different seasons (for periods shorter than 2 min), in long-time average from the Nagyenc Observatory (1957–1991). The selected interval for the present study is indicated by arrows](image)