DYNAMIC SPECTRAL STUDY OF Pc 3–5 MAGNETIC PULSATIONS OBSERVED IN THE NORTH POLAR CUSP REGION

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Abstract: Dynamic spectral characteristics of magnetic pulsations in the frequency range from Pc 3 to Pc 5 are examined on the basis of simultaneous observations at Cambridge Bay in the north polar cusp region and Fort Smith in the auroral zone. Both stations are located at almost the same longitude. In the dynamic spectra observed at both stations two predominant spectral bands are generally seen in the frequency ranges of Pc 3 (20–80 mHz) and Pc 4/5 (3–10 mHz). Although spectral peaks in the Pc 3 and Pc 4/5 bands are shown at almost the same frequencies for both stations, sharpness (Q value) of the peaks is very different between the stations. The spectral peaks at Fort Smith are much sharper than those at Cambridge Bay. These observed features are discussed in the light of propagation and resonance mechanism of Pc 3 and Pc 4/5 waves in the magnetosphere.

1. Introduction

Field line resonance structure of Pc 3–5 magnetic pulsations has been clarified well by recent observations in the magnetosphere and on the ground. The dynamic spectral study of Pc 3–4 waves observed at geosynchronous orbit (L=6.6) gave the first clear evidence for the harmonic structure of standing shear Alfvén waves in the magnetosphere (TAKAHASHI and MCPHERRON, 1982). Further, strong evidence for the harmonic structure of Pc 3–5 waves observed on the ground has been provided by extracting coherent oscillations from magnetic pulsation data recorded at a conjugate pair in the auroral zone ($L \simeq 6$) and then calculating the phase difference of the H component between the conjugate points (TONEGAWA and FUKUNISHI, 1984). These results indicate that Pc 4/5 spectral band observed in the frequency range ~3–10 mHz is the fundamental mode of standing shear Alfvén waves near L=6, while the Pc 3 band with multiple harmonic structures observed in the frequency range ~20–100 mHz is the higher harmonics.

Source mechanisms of the Pc 3 and Pc 4/5 pulsations are possibly different from each other. TONEGAWA *et al.* (1984) showed that switching of activity between the Pc 3 and Pc 4/5 bands was frequently observed on magnetically quiet days. They suggested that the Pc 3 and Pc 4/5 bands are excited by different external sources, and the switching events may be caused by a sudden change of solar wind parameters if the Pc 3 and Pc 4/5 pulsations are excited by different energy sources with different dependencies on the solar wind parameters. This idea is consistent with the results of statistical studies on the relationship between the power of magnetic pulsations and the solar wind parameters by WOLFE *et al.* (1980), WOLFE (1980), WOLFE and MELONI (1981), and WOLFE (1982). They have represented the evidences of frequency dependencies in the interplanetary source mechanisms for hydromagnetic energy production in the magnetosphere, and also concluded that different interplanetary source mechanisms contribute to the dayside ground power of magnetic pulsations in different frequency bands.

The surface waves excited at the magnetopause by the Kelvin-Helmholtz instability are a possible driving source for Pc 4/5 pulsations. CHEN and HASEGAWA (1974) and SOUTHWOOD (1974) gave the linear resonance theory based on the idea of resonance coupling between the surface wave excited at the magnetopause and the shear Alfvén wave at a local field line. This theory well explains frequency, amplitude, polarization, and phase characteristics of observed Pc 4/5 pulsations. On the other hand, a possible driving source for Pc 3 is compressional waves excited near the bow shock, as suggested by TAKAHASHI *et al.* (1984). They concluded that the Kelvin-Helmholtz instability is unsuitable, since the phase velocity estimated from the phase differences between two geosynchronous satellites was much higher than the bulk velocity of the solar wind plasma in the magnetosphere when projected on the magnetopause.

In order to clarify generation and propagation mechanisms of Pc 3–5 pulsations in more detail, it is important to observe magnetic pulsations in both the polar cusp region and the auroral zone. In the auroral zone the standing Alfvén waves excited by source waves could be observed as Pc 3–5 pulsations on the ground. In the cusp region it is expected that the source waves, bow-shock associated waves (Pc 3) and magnetopause associated waves (Pc 4/5) are directly observed, as illustrated schematically in Fig. 1. However, there are few observations of Pc 3–5 pulsations in the cusp region (*e.g.*, KATO, 1977).

In this paper, we examine dynamic spectral characteristics of Pc 3–5 magnetic pulsations simultaneously observed at Cambridge Bay in the cusp region and at Fort

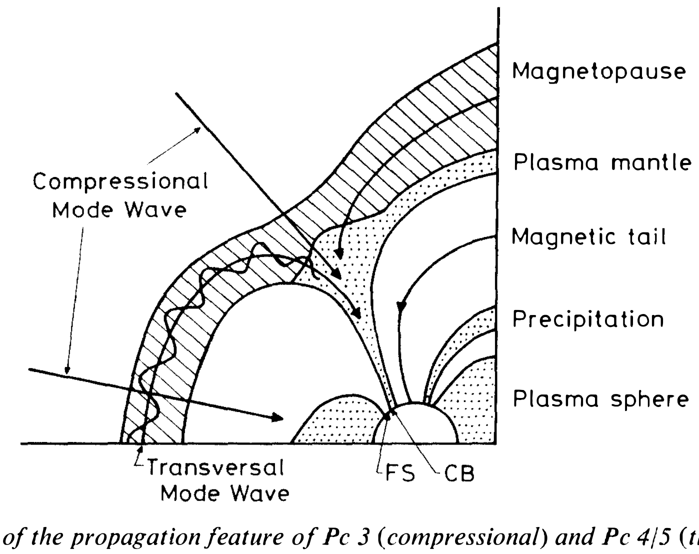

Fig. 1. Sketch of the propagation feature of Pc 3 (compressional) and Pc 4/5 (transverse) wave in the magnetosphere. Relative locations of Fort Smith and Cambridge Bay are represented as FS and CB, respectively.

Smith in the auroral zone. The geomagnetic locations of Cambridge Bay and Fort Smith are 76.8°N, 299.6°E and 67.3°N, 300.0°E, respectively. Figure 2 is a schematic representation of the situation of each station. Cambridge Bay is located inside the cusp region in the interval from 1030 to 1500 local time. KATO (1977) reported that the activity of magnetic pulsations is more intense at Cambridge Bay in the cusp region than at Fort Smith in the auroral zone.

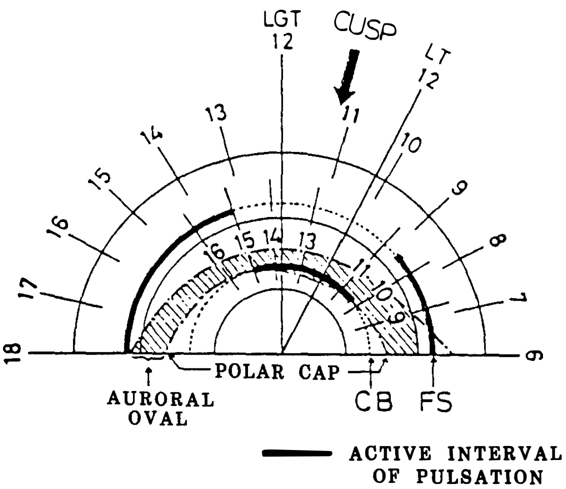

Fig. 2. Schematic representation of the situation of Cambridge Bay in the cusp region and Fort Smith in the auroral zone. Cambridge Bay is located in the cusp region during the interval from 1030 to 1500 LT (after KATO, 1977).

2. Pc 4/5 and Pc 3 Magnetic Pulsations Simultaneously Observed in the Cusp Region and the Auroral Zone

The magnetic pulsations were observed by an induction magnetometer at each station and recorded on analog magnetic tapes. An example of time-amplitude record of the magnetic pulsation observed at both stations is shown in Fig. 3. The analog data were converted to digital data with sampling period of 2 s in order to calculate power spectra. Dynamic power spectra are calculated by using the maximum entropy method (MEM) with the thirtieth order prediction error filter and for a time

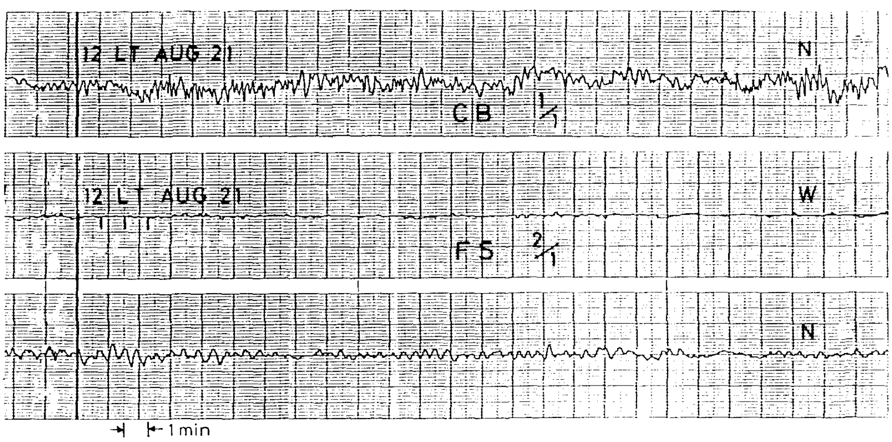

Fig. 3. An example of waveforms of magnetic pulsations observed simultaneously at Cambridge Bay and Fort Smith.

widow of 20 min which is successively shifted by 10 min.

Presented in Figs. 4 and 5 are dynamic spectra of the H component observed at Cambridge Bay and Fort Smith on August 20 and 21, 1974, respectively. The power relative to the background power level is displayed with a gray scale. Two predominant spectral bands are seen in the dynamic spectra at both stations, one in the Pc 3 ($\sim$20–100 mHz) range and the other in the Pc 4/5 ($\sim$3–10 mHz) range. However, it should be noted that the band structure is more clearly seen in the dynamic spectra at Fort Smith than at Cambridge Bay. Figure 6 shows time-averaged power spectra at both stations for the interval of 11–12 LT on August 20 and 21, 1974. Although spectral peaks are shown at almost the same frequencies for both stations, the Q values are very different between the stations, *i.e.*, the spectral peaks at Fort Smith are much sharper than at Cambridge Bay. This observed feature is discussed in the next section.

The similar spectral structure as shown at Fort Smith has been found in dynamic spectra observed at auroral zone stations near $L=6$ by TONEGAWA and FUKUNISHI (1984). From examination of the phase relationship of Pc 3–5 magnetic pulsations

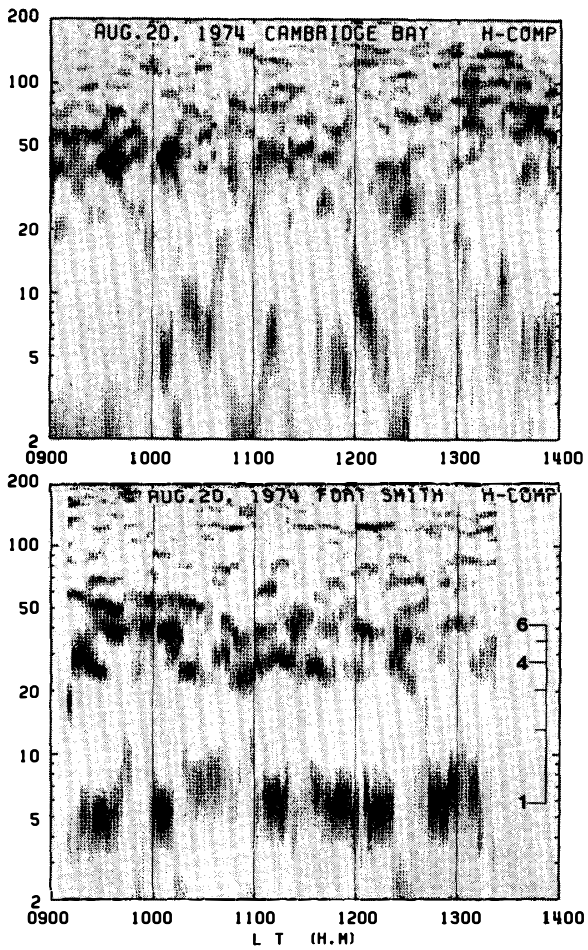

Fig. 4. Dynamic power spectra of the H component observed at Cambridge Bay and Fort Smith in the interval from 0900 to 1400 LT on August 20, 1974.

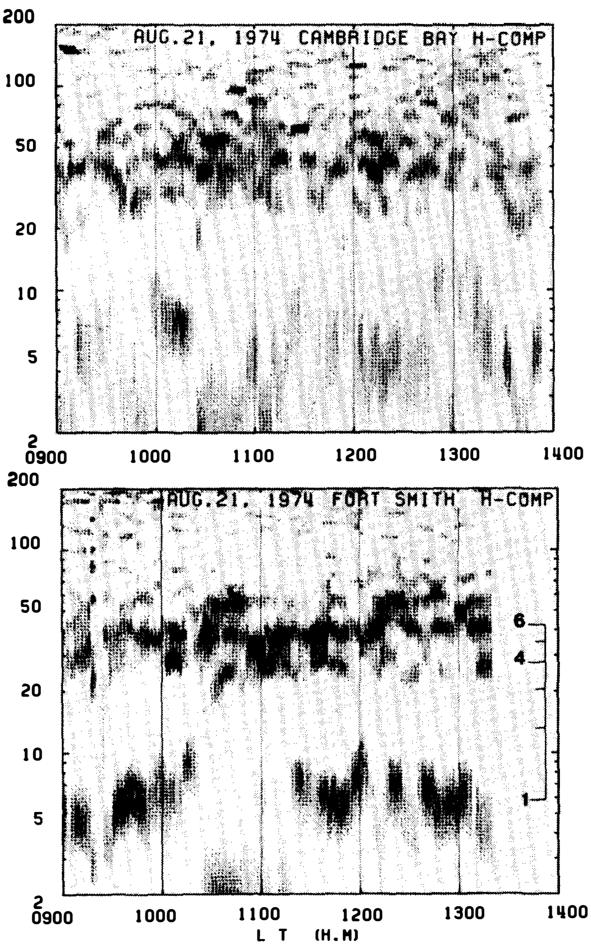

Fig. 5. Same as Fig. 4 but for August 21, 1974.

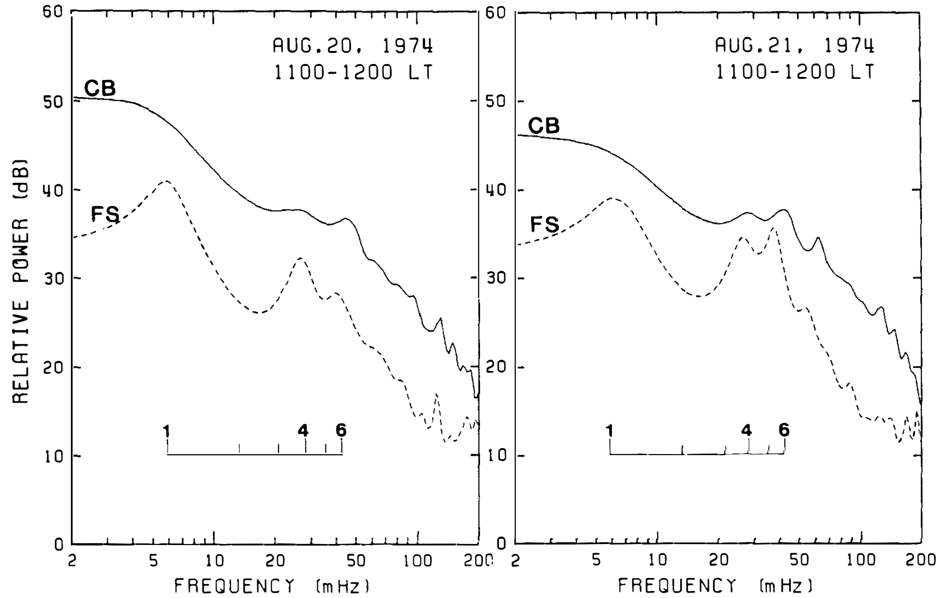

Fig. 6. Time-averaged power spectra of the H component observed at Cambridge Bay and Fort Smith for the intervals of 11–12 LT on August 20 and 21, 1974.

observed at the Syowa–Husafell conjugate pair, they have revealed that the Pc 4/5 band is the fundamental mode of the standing shear Alfvén wave and the Pc 3 band is the higher harmonics. In order to examine the harmonic relation for the present dynamic spectra at Fort Smith, we present a harmonic scale which indicates a relation of eigenfrequencies of standing shear Alfvén waves in Figs. 4, 5 and 6. The scale is based on the theoretical estimation given by CUMMINGS *et al.* (1969). The estimated ratio of the eigenfrequencies weakly depend on the plasma distribution model and the wave mode (toroidal or poloidal), but not on the plasma density and the resonant L value. The ratio used here is estimated by assuming the radial dependence of the plasma density as r^{-4} and the toroidal mode wave. From Figs. 4, 5 and 6 with the harmonic scale it is evidenced that the Pc 3 bands correspond to higher harmonics of the Pc 4/5 band.

3. Discussion

From the dynamic spectral analysis of magnetic pulsations observed simultaneously at Cambridge Bay and Fort Smith, it has been found that two predominant spectral bands in the frequency ranges of Pc 3 and Pc 4/5 basically exist in both the polar cusp region and the auroral zone. However, individual spectral peaks in the Pc 3 and Pc 4/5 bands observed at Cambridge Bay in the cusp region are much broader than those observed at Fort Smith in the auroral zone as shown in Fig. 6. Especially, the spectral peak in the Pc 4/5 range is obscure at Cambridge Bay. The Pc 4/5 pulsation observed on the ground is thought to be a toroidal standing oscillation excited at the resonance point where the frequency of the toroidal oscillation coincides with that of the source wave excited on the magnetopause by the Kelvin-Helmholtz instability. Therefore, the Pc 4/5 wave is obscure at Cambridge Bay located in the Cusp region.

On the other hand, the upstream wave generated at the bow shock front is a possible source of Pc 3 pulsations (*e.g.*, WOLFE *et al.*, 1980). This source wave propagates through the magnetopause and magnetosphere as the first (compressional) mode (YUMOTO and SAITO, 1983), and excites higher harmonics of the standing Alfvén wave in the auroral zone (TONEGAWA and FUKUNISHI, 1984). It may be possible that the Pc 3 source wave propagates to the cusp region directly without the process of the field line resonance. In this case the power spectrum of the observed Pc 3 pulsation is to be broad, because the bandwidth of Pc 3 source wave has to be broad enough to excite multiple higher harmonics simultaneously. The spectral characteristics shown in Fig. 6 coincide well with the feature mentioned above.

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