POLARIZATION STUDY OF Pc1 AND Pc1-2 BAND PULSATIONS AT CONJUGATE STATIONS

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Abstract: Polarization analyses were made on Pc1 and unstructured Pc 1-2 band pulsations observed at a conjugate pair, Husafell, Iceland and Syowa Station, Antarctica, in August and September 1977. It was found that *L* mode is predominant at Syowa Station, while *R* mode is at Husafell. From the comparison with the polarization at these stations, it was concluded that these two stations would not be in the conjugate relation in a strict sense at this time.

1. Introduction

It has been generally accepted that Pc1 micropulsations are generated at or near the plasmapause as left-handed (*L*) circularly polarized ion cyclotron waves which are propagated back and forth along geomagnetic field lines. When the *L* waves are incident to the ionosphere, mode coupling would occur with the right-handed (*R*) waves (ALTMAN and FIJALKOW, 1968, 1980). The resultant *R* wave may be propagated through the ionospheric duct centered on the F_2 layer crossing the field lines around the Pc1 source region. ALTMAN and FIJALKOW (1968, 1980) investigated the transmission of Pc1 pulsations to the ground through the ionosphere and the atmosphere. They showed that the *L* waves can reach the ground near the Pc1 source region, but as the distance from the source region increases the waves will be gradually replaced by the *R* waves.

Several reports of the Pc1 polarization characteristics using data from auroral and also from mid-latitude sites have appeared in literature (HEACOCK and HESSLER, 1967; CAMPBELL, 1968; HEACOCK, 1970; FRASER and SUMMERS, 1972; FRASER, 1975; ALTHOUSE and DAVIS, 1978). In these measurements, both *R* and *L* waves were observed at the high and middle latitudes, and the polarization sense changed in a complex way not only with time but also from event to event. Hence the appearance of *R* and *L* waves has not been experimentally well understood.

The investigation of the polarization characteristics at conjugate sites, however, has been rather few other than that by GOCHBERG *et al.* (1967), though it would be

useful for understanding propagation and coupling process of Pc1 waves. They showed, using the data recorded at Sogra and Kerguelen, that both of the R and L polarizations existed and that the sense of the polarization with respect to the field line coincided between conjugate sites.

The purpose of the present paper is to study the polarization characteristics for both Pc1 and unstructured Pc1-2 band pulsations observed at the conjugate stations in the auroral region (Syowa Station in Antarctica and Husafell in Iceland). The characteristics of the unstructured pulsations have not been well known yet. They are, as far as our investigations are concerned, observed on the dayside and have the wider band spectrum without a structure such as Pc1. Comparison of the polarization characteristics of these two kinds of pulsations is also another purpose of the present paper. Although the unstructured pulsation appeared in slightly different frequencies at conjugate stations, major differences were not found in the polarization characteristics between them. The polarization sense at Syowa Station was found to be predominantly L mode (clockwise rotation when looking down the H-D plane) while at Husafell it showed R mode (counterclockwise). These results are discussed by invoking theoretical prediction of ALTMAN and FIJALKOW (1968, 1980).

2. Data Analysis

The analysis was made on three unstructured Pc1-2 band pulsation events and four Pc1 events, which are listed in Table 1 with their occurrence times and their average periods. The Pc1 events were selected by the criterion that they had not only structured spectrum but also having a narrow band spectrum so as to avoid the beating effects between the subsequent bands in the fine structure and hence, to make easier the determination of the polarization parameters. Hereafter the Pc1 events thus selected will be referred to merely as Pc1. The dynamic spectra of these events are shown in Fig. 1.

The analogue data of $\dot{H}$ and $\dot{D}$ components were digitized with a sampling period of 0.3 s in the real time and the polarization parameters were calculated every 211.2 s using FFT method. The orientation angle of the ellipse major axis as well

Table 1. Occurrence times and average periods of polarization analysis.

Unstructured Pc1–2 band pulsation	Aug. 8, 1977 0900–1030 UT	Period 3.5–5.0 s
	Aug. 9, 1977 1000–1300 UT	3.5–5.0
	Aug. 26, 1977 0840–1130 UT	3.5–5.0
Pc1	Aug. 10, 1977 1250–1330 UT	2.0 s
	Aug. 14, 1977 1600–1720 UT	6.4
	Aug. 15, 1977 1300–1600 UT	5.0
	Sep. 2, 1977 0800–0900 UT	2.2

as the ellipticity of the waves observed at each station were determined to the values at the frequency band where the maximum peak exists in the power spectrum. Figs. 2a and 2b show an example of the plot of the orientation angle and the ellipticity for the Pc1 event on August 15. The orientation angle was measured from north to east with the plus sign for both stations. The polarization sense of R and L was

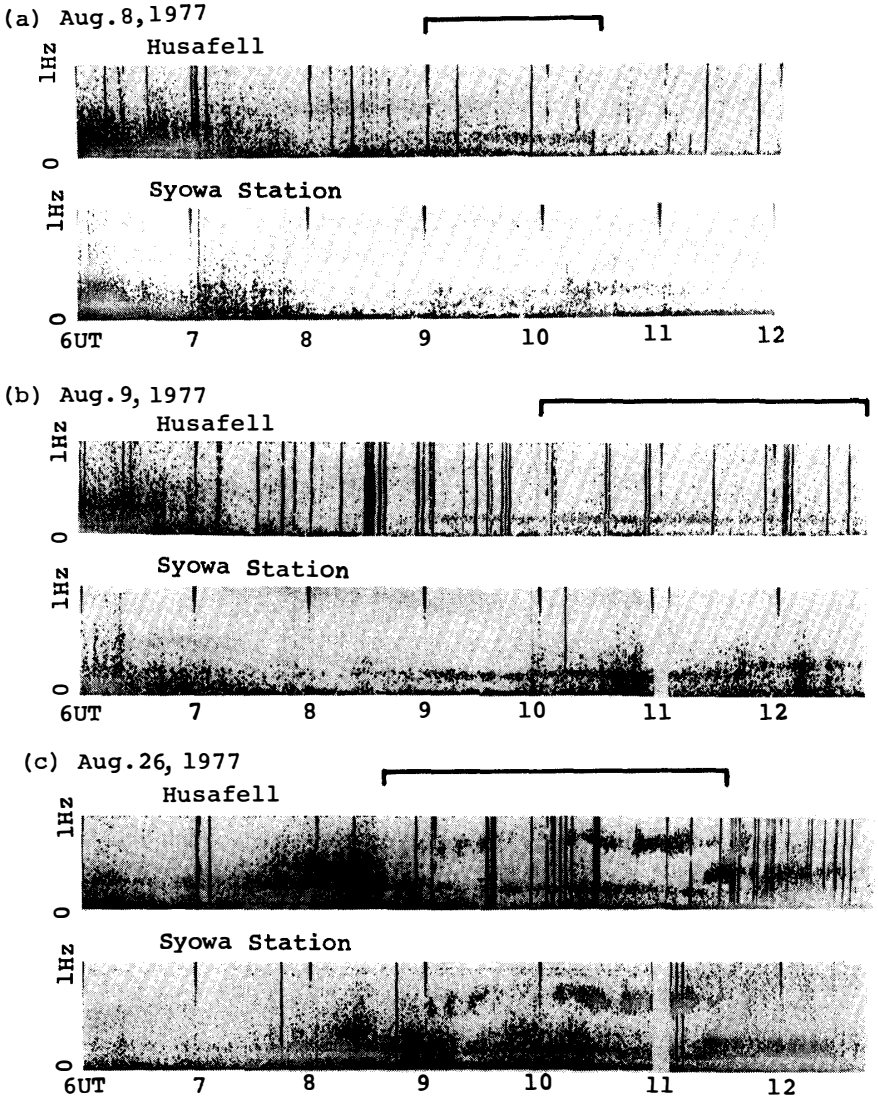

Fig. 1. Dynamic spectra of unstructured Pc1-2 band pulsations (a)~(c) and Pc1 (d)~(g) analyzed in this study. The polarization analysis on the ellipticity and also on the orientation angle of the ellipse major axis was made in the data period denoted in the upper part of each spectrum by horizontal bar. In the event (c) the analysis was made on the waves seen in the lower trace with the center frequency of 0.2 Hz, and in the event (d) it was made on the upper trace with the center frequency of 0.5 Hz.

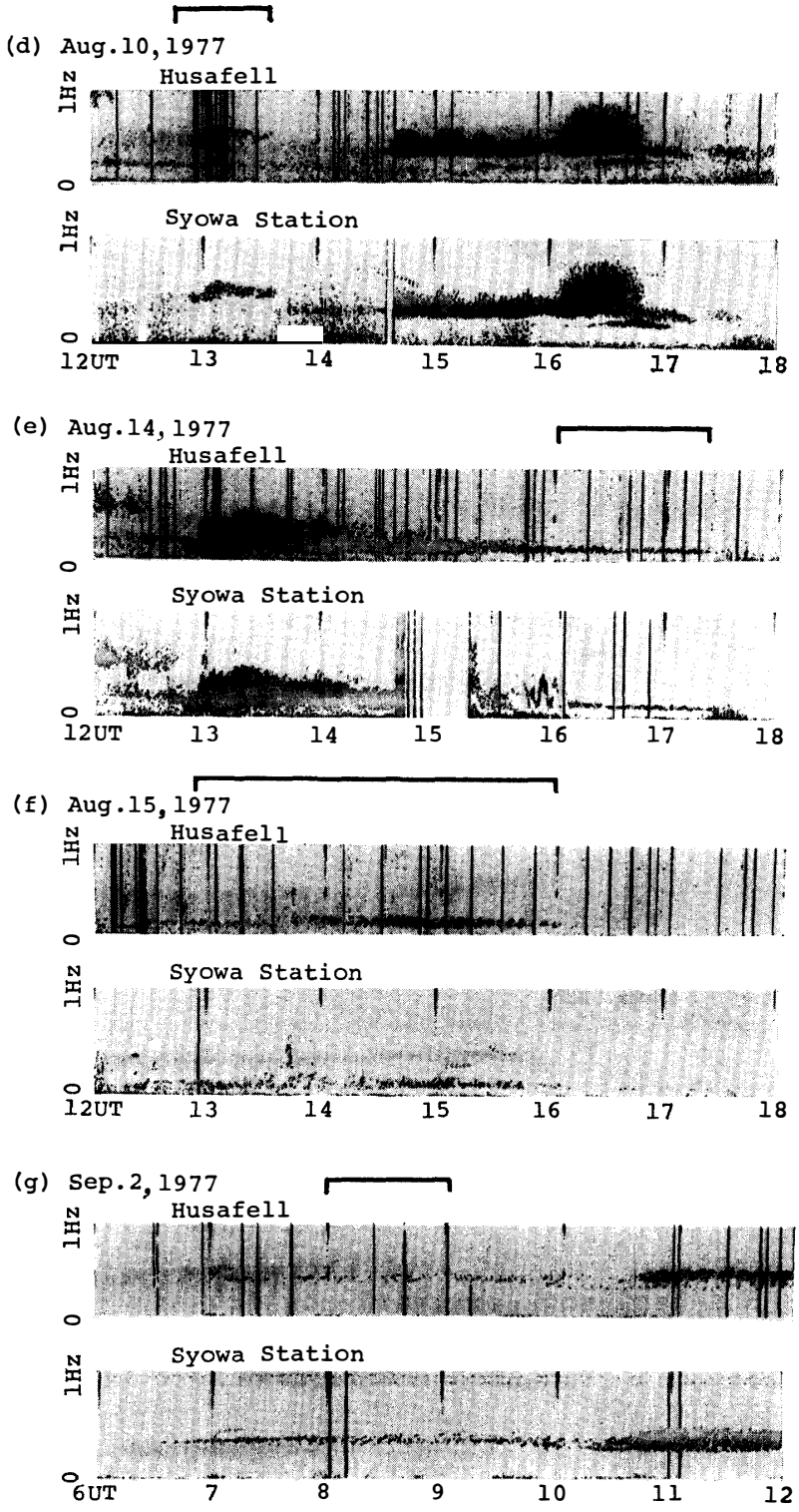

Fig. 1. (continued).

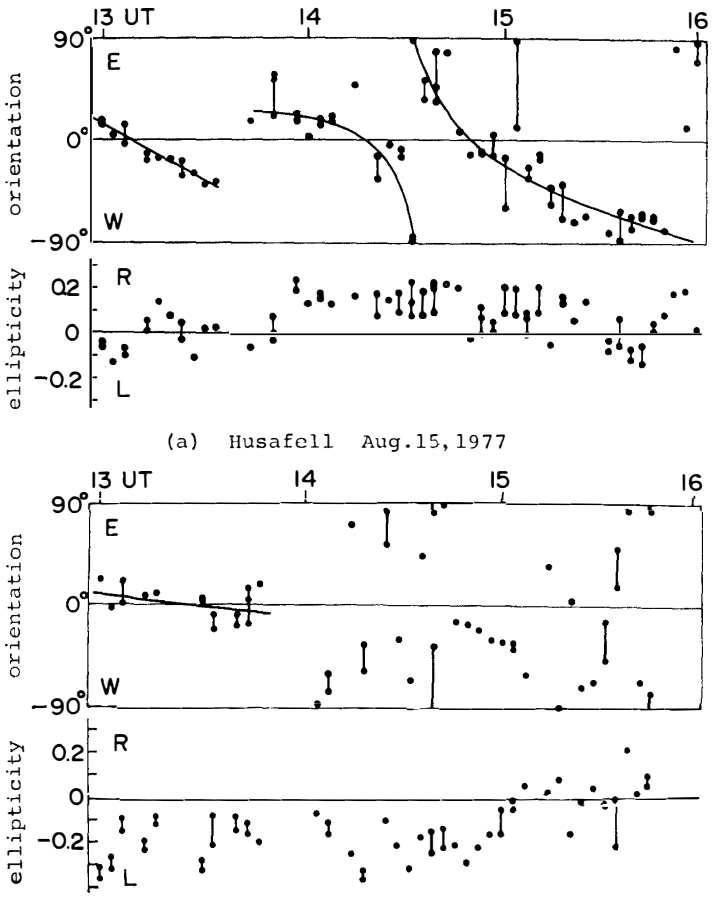

Fig. 2. Plots of orientation angle and ellipticity of the Pc1 event (the center frequency of 0.2 Hz, see Table 1) on August 15, 1977 at Husafell (a) and at Syowa Station (b).

defined with respect to the magnetic field direction, which is indicated in Fig. 2 by the sign of ellipticity; the plus sign corresponds to the *R* mode polarization and the rotation sense is defined as CW at Husafell and CCW at Syowa Station when looking down the *H-D* plane. This definition might be convenient when we consider the wave polarization at conjugate pair stations, as the direction of the magnetic field line has already been taken into account; that is, the wave polarization of electron and ion resonance modes are defined as *R* and *L*, respectively.

Although Fig. 1 indicates that the dynamic spectra of each event are very similar between the two stations, it can be seen in Fig. 2 that the time changes of the orientation angle and the ellipticity are quite different between them. The event on August 15, 1300–1600 UT, seems to continue throughout that period when looking at the dynamic spectrum, but it can be recognized from the polarization characteristics

shown in Figs. 2a and 2b that the event rather consists of two series of pulsation (1300–1340 and 1340–1600) possessing different properties. In the first series of pulsation between 1300–1340 UT, the orientation at Husafell (Fig. 2a) changes linearly with time from north to north-west, while at Syowa Station (Fig. 2b) it is directed constantly to the north. The polarization at Husafell is found to be approximately linear but at Syowa Station it is left-handed polarized. In the second series of pulsation between 1340–1600 UT, the orientation at Husafell starts to rotate in the CCW sense. The rotation angle of the major axis amounts up to approximately 270°. On the other hand, at Syowa Station the orientation is scattered and it dose not indicate any systematic change with time. The polarization at Husefell is always *R* mode throughout two series of pulsation, but at Syowa Station it is *L* mode in the first period of the event (1400–1500 UT) and is followed by the linear mode polarization, which is indicating an increasing *R* mode power after 1500 UT.

Comparing with these analyses at Husafell and Syowa Station, the polarization

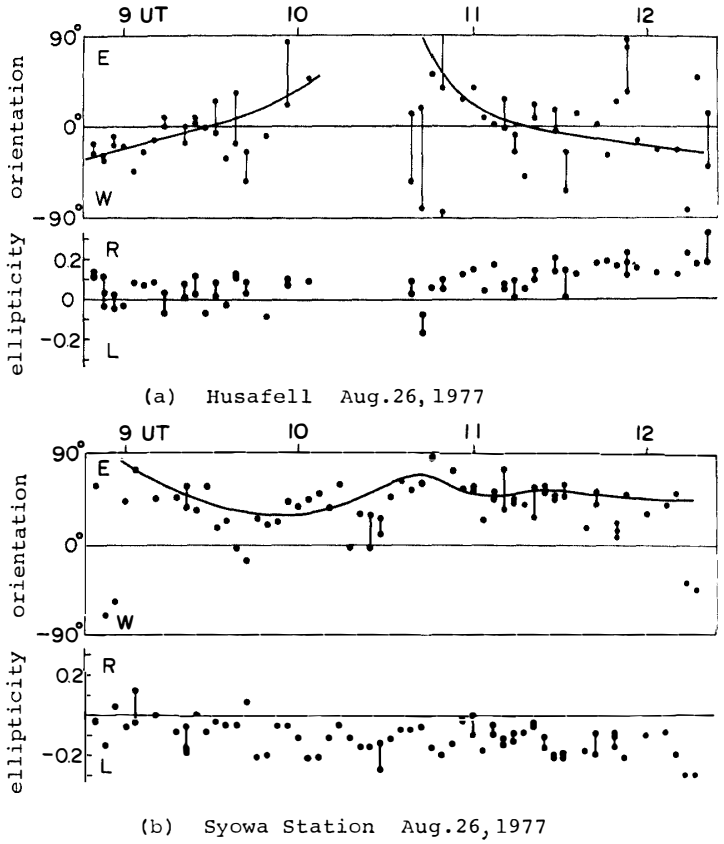

Fig. 3. Plots of orientation angle and ellipticity of the unstructured Pc1-2 band pulsation event (the center frequency of 0.2 Hz, see Table 1) on August 26, 1977 and Husafell (a) and at Syowa Station (b).

characteristics are revealed to be quite different between them except for a similar pattern observed in the orientation angle during 1300–1340 UT.

Figs. 3a and 3b show another example for the unstructured Pc1-2 band pulsations on August 26. The orientation at Husafell rotates similarly to the Pc1 event at Husafell on August 15 (Fig. 2a), but the rotation sense of the orientation reverses from CW to CCW after around 1020 UT. The polarization sense at Husafell is *R* mode almost throughout the period of this event (Fig. 3a). At Syowa Station the orientation is directed constantly to the north-east, and the polarization sense is always *L* mode. In this event there is no resemblance in the orientation and in the ellipticity between two stations. The analyses about the time changes of the orientation angle and the ellipticity on the other five events of Pc1 and the unstructured Pc1-2 band pulsations were also made in the same way as in Figs. 2 and 3. Some features of the polarization parameters are summarized as follows.

Concerning the polarization sense there is a tendency that the *R* mode is dominant at Husafell while the *L* mode is at Syowa Station. To show this, histograms of the number distribution of the ellipticities calculated every 211.2 s are indicated in Fig. 4 for each event. Since in an event which continued for several hours as shown in Fig. 2a as an example, the ellipticity tends to vary from *L* to *R* or *vice versa*

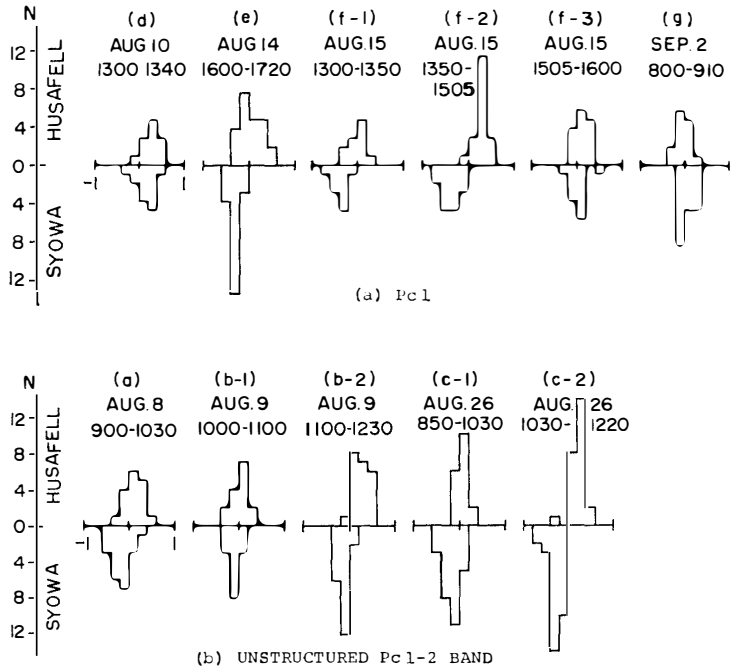

Fig. 4. Histograms of number distribution of ellipticity for the unstructured Pc1-2 band pulsation events (a)~(c) and the Pc1 events (d)~(g). Ellipticities are calculated every 211.2 s by FFT method. Plus and minus signs represent the polarization sense of L and R, respectively.

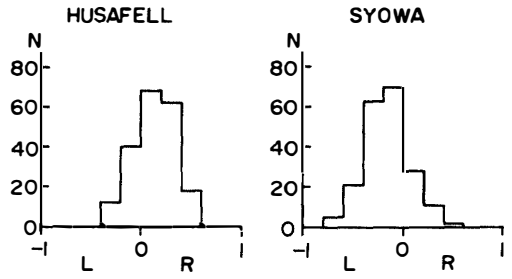

Fig. 5. Total number distribution of ellipticity by summing up all histograms shown in Fig. 4.

during a time period of 1.0~1.5 hour, the long-term event was divided into several blocks with a time duration of 1.0~1.5 hour, and a histogram was made for each block. The result is indicated in Fig. 4a for the unstructured Pc1-2 band and in Fig. 4b for Pc1, respectively. It could be seen that the location of the peak at Husafell always deviates toward *R* mode, while that at Syowa Station does toward *L* mode. Fig. 5 shows the distribution of the ellipticity by summing up all histograms from Fig. 4. It is clear that at Husafell the polarization is mostly *R* mode while at Syowa Station it is *L* mode.

From the analysis of the orientation of the polarization ellipse it is found that there is no prevailing direction of the orientation at both stations. This may be partly because the orientation undergoes a large change with time, and also because the feature of the time change differs from event to event (Figs. 2 and 3), which is true for both Pc1 and the unstructured Pc1-2 band pulsations. Further analysis using more data including another period of time would be required to specify the changes of the orientation.

3. Discussion

The polarization parameters were analyzed using seven days data of Pc1 and the unstructured Pc1-2 band pulsations observed at conjugate stations of Husafell and Syowa Station in August and September 1977. The *R* mode polarization was predominantly observed at Husafell, while the *L* mode at Syowa Station was found from the present analysis. This characteristic is common to both Pc1 and unstructured Pc1-2 band pulsations.

Theoretical credence has been given by ALTMAN and FIJALKOW (1968, 1980) that the *R* mode waves are generated in the ionosphere by the *L*-*R* coupling process when the *L* mode waves are propagating down through the ionosphere. According to their calculation Pc1 waves transmitted to the ground show predominantly *L* mode polarization (ion resonance mode) near a center of the Pc1 wave source. On the other hand, due to the strong *L*-*R* coupling and selective absorption of the *L* mode waves, the *R* mode waves (electron resonance mode) generated in the ionosphere tend to be transmitted to the outer side of the source region. Therefore, the polarization sense

changes from L to R as an observation site moves toward outside of the Pc1 source region. Applying this model to the present investigation, it leads to a supposition that Syowa Station is located close to the source region, while Husafell is on the outer side of that region throughout the observation period. This means that Syowa Station and Husafell were not strictly in the conjugate relation in this period. However, since the number of the events analyzed in the present investigation is small and the period of this analysis is relatively short (about one month), further analysis would be needed to confirm the present conclusion.

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