Conjugacy of ELF-VLF Emissions at Syowa Station and Husafell

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昭和基地—Husafell における ELF-VLF 放射の共役性

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要旨: 昭和基地のほぼ地磁気共役点にあたる，アイスランドの Husafell において，1977 年 7 月 29 日から約 50 日間，ELF-VLF 放射の共役点観側を行った．共役性についていえば，(1) 昼間出現するポーラコーラス，準周期的 (QP) 放射の共役性は良い，(2) バーストタイプのディスクリート放射，オーロラコーラスの共役性は悪く，おもに北半球側が強い，(3) オーロラヒスの共役性は悪く，南半球（冬半球）側が圧倒的に強い．これらの観側結果から共役性の良いポーラコーラス，QP 放射は磁気圏内の赤道面付近で発生し，磁力線に沿って伝搬しているものと理解できる．またオーロラヒス，バーストタイプ放射の非共役性は，電離層内の電子密度，磁場強度，磁力線の伏角等の南北半球での非対称およびこれらの放射の発生領域に依存すると思われる．

Abstract: Conjugate observations of ELF-VLF emissions, magnetic pulsations and auroras were carried out at Syowa Station in Antarctica and Husafell in Iceland from July 29, 1977 to September 18, 1977. Husafell is located at a distance of about 50 km from the conjugate point of Syowa Station. Conjugacies of ELF-VLF emissions depend on emission types, such as polar chorus, quasi-periodic emissions, burst of discrete emissions and auroral hiss. Polar chorus and quasi-periodic emissions are observed simultaneously at the conjugate-pair stations. This suggests that the emissions are generated near the equatorial region in the outer magnetosphere and propagate to the both hemispheres along the field lines of force. Conjugacy of bursts of discrete emissions and auroral hiss is generally low. The emission intensity of auroral hiss is much stronger at Syowa Station (winter hemisphere) than at Husafell (summer hemisphere). Just the opposite tendency is observed for bursts of discrete emissions. The low conjugacy of these emissions may depend on the differences in geophysical conditions, such as the magnetic field, magnetic dip angle and the plasma density and also it depends on properties of the generation region of the emissions.

1. Introduction

The coordinated observations of ELF-VLF emissions and magnetic pulsations have been carried out at Syowa and Mizuho Stations, Antarctica and Husafell, Iceland

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in the two periods of July 29–September 18, 1977 and August 20–September 27, 1978. Locations of Husafell, Reykjavik and the conjugate points of Syowa and Mizuho Stations which were determined by using the 1975 IGRF model are shown in Fig. 1. As apparent in the figure Husafell is located about 50 km north of the geomagnetic conjugate point of Syowa Station. Geographic and geomagnetic coordinates of these stations are listed in Table 1.

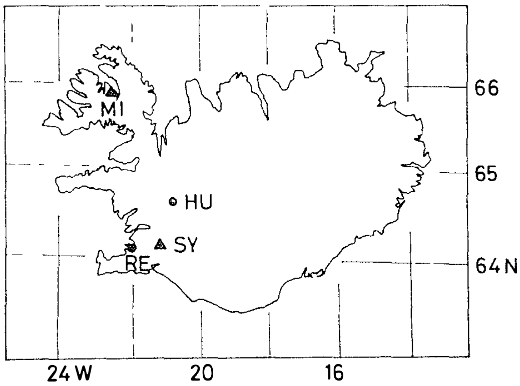

Fig. 1 Locations of Husafell, Reykjavik and the geomagnetic conjugate points of Syowa and Mizuho Stations

Table 1 Position of conjugate-pair stations

Stations	Geographic		Geomagnetic	
	Latitude	Longitude	Latitude	Longitude
Syowa Station	−69 03	39 60	−70 03	79 39
Mizuho Station	−70 70	44 33	−72 32	80 62
Reykjavik, Iceland	64 14	−21 88	69 87	72 41
Husafell, Iceland	64 70	−20 90	70 19	74 24

One of the subjects of this conjugate experiment campaign is to find how ELF-VLF emissions occur at magnetically conjugate points. Studies of conjugacy of ELF-VLF emissions are very limited. HUDSON (1971) found from the ELF-VLF emission data obtained at Great Whale and Byrd ($L\sim 7$) that the polar chorus band usually occurs simultaneously at the conjugate points, while discrete emission occurs randomly at the conjugate points, and auroral hiss exhibits some conjugacy but less than does polar chorus. According to KITAMURA *et al.* (1969), who examined the data from the Great Whale-Byrd conjugate-pair stations, QP emissions associated with magnetic pulsations have seldom shown conjugacy, whereas QP emissions not associated with magnetic pulsations have been frequently observed in a good conjugate relationship. On the other hand, KOROTOVA *et al.* (1975) reported from the intensity records at a fixed frequency band around 2 kHz at two conjugate-pair stations, Sogra-Kerguelen

($L \sim 3.5$) and Dolgoschelie-Herd ($L \sim 4.2$) that QP emissions associated with magnetic pulsations occur often simultaneously at the conjugate points.

In this paper, we study occurrence characteristics of polar chorus, quasi-periodic (QP) emission, auroral chorus and auroral hiss at the Syowa Station-Husafell conjugate pair and also differences in the f–t spectra of these emissions at the conjugate points.

The magnetic pulsation data and the ELF-VLF data used in this study were measured by the same instrument, at Husafell, Syowa and Mizuho Stations. The H and D components of magnetic pulsations in the frequency range below 3 Hz were measured with an induction magnetometer and were recorded on magnetic tape (speed, 3 mm/s) and strip chart (speed, 30 cm/h). ELF-VLF emissions picked up by standard loop antennas were recorded in the three different forms at Syowa Station and Husafell. First, intensities of emissions at selected frequencies (0.75, 1.0, 2.0, 4.0 and 8.0 kHz) measured by Q value of 40 were recorded on the strip chart with a chart speed of 30 cm/h. Second, wide band signals in the frequency range of 0.2–20 kHz were continuously recorded on a magnetic tape. Third, wide band ELF-VLF signals, the H and D components of magnetic pulsations and auroral luminosity (4278 Å) were simultaneously recorded on the same magnetic tape in order to examine correlations between these phenomena.

2. Conjugacy of Polar Chorus and QP Emission

2.1. Polar chorus

A polar chorus band is defined as a continuous quasi-steady noise normally composed of multiple rising tones and having definite upper and lower cut off frequencies. The occurrence of polar chorus has a peak prior to local magnetic noon and also during the local summer (UNGSTRUP and JACKEROTT, 1963; HAYASHI *et al.*, 1968). Good examples of polar chorus emissions and their relations to magnetic pulsations observed at Syowa, Mizuho Stations and Husafell are shown in Figs. 2–3. Fig. 2 shows the intensity records of polar chorus emissions in the 0.75 and 1 kHz bands and also records of magnetic pulsations on August 9, 1977. Polar chorus emissions enhanced suddenly, and occurred simultaneously in the both hemispheres in the time intervals of 1414–1423, 1444–1451 and 1503–1507 UT. The onsets of sudden enhancement of polar chorus were accompanied by positive sudden impulses in the magnetic fields (HAYASHI *et al.*, 1968; SATO, 1978). In this event, abrupt changes of ELF-VLF intensity were also simultaneously observed on GEOS-1 (CORNILLEAU-WEHRLIN *et al.*, 1978). Fig. 3a shows another example of magnetic pulsations and polar chorus emissions in the frequency bands of 1 and 2 kHz observed at Syowa Station and Husafell

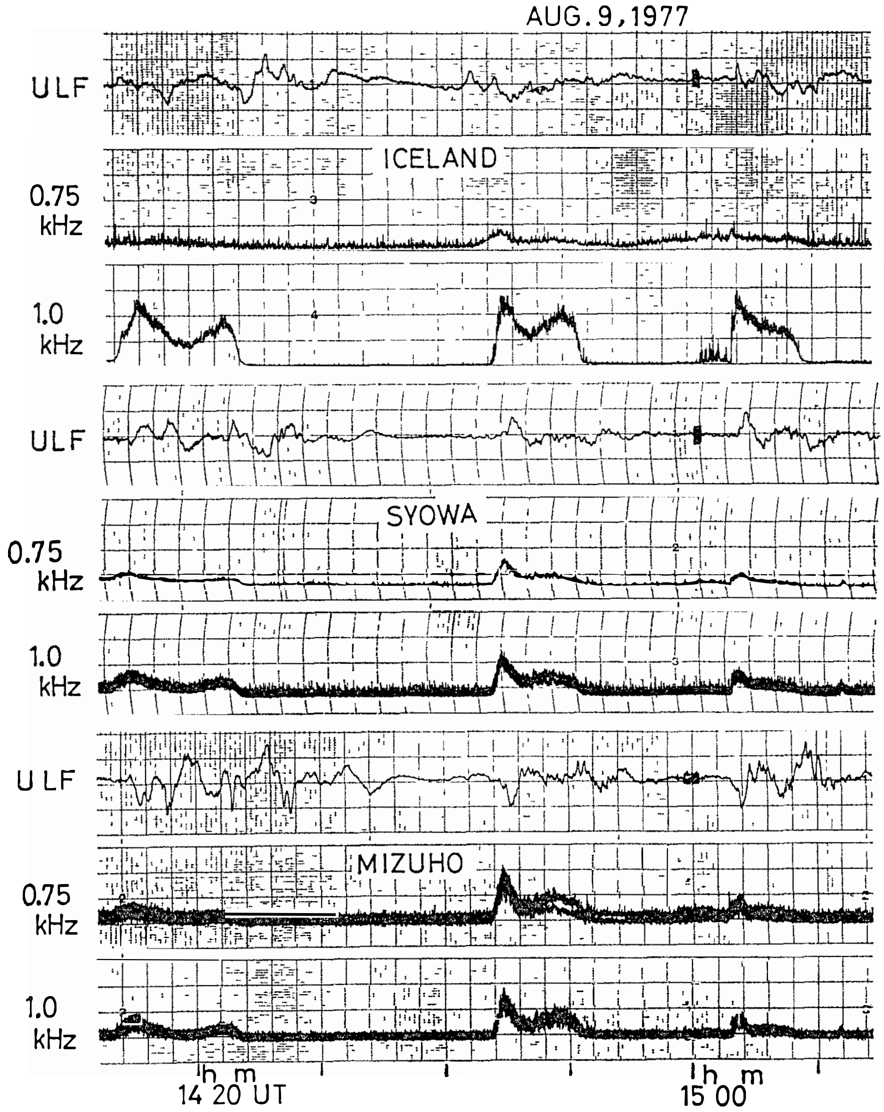

Fig. 2. Intensity records of polar chorus emissions in the 0.75 and 1 kHz bands with records of magnetic pulsations observed at Husafell, Syowa and Mizuho Stations on August 9, 1977.

on August 5, 1977. Emission intensities are modulated with the period of 30–300 sec in the time interval of 1256–1415 UT. It is evident that intensity modulation of ELF emissions and corresponding magnetic pulsations occurred simultaneously at Husafell and Syowa Station. Fig. 3b indicates the frequency-time spectra in the time interval of ~1334–1343 UT on August 5, 1977. It is apparent that the spectra at the conjugate points are quite similar at any given time.

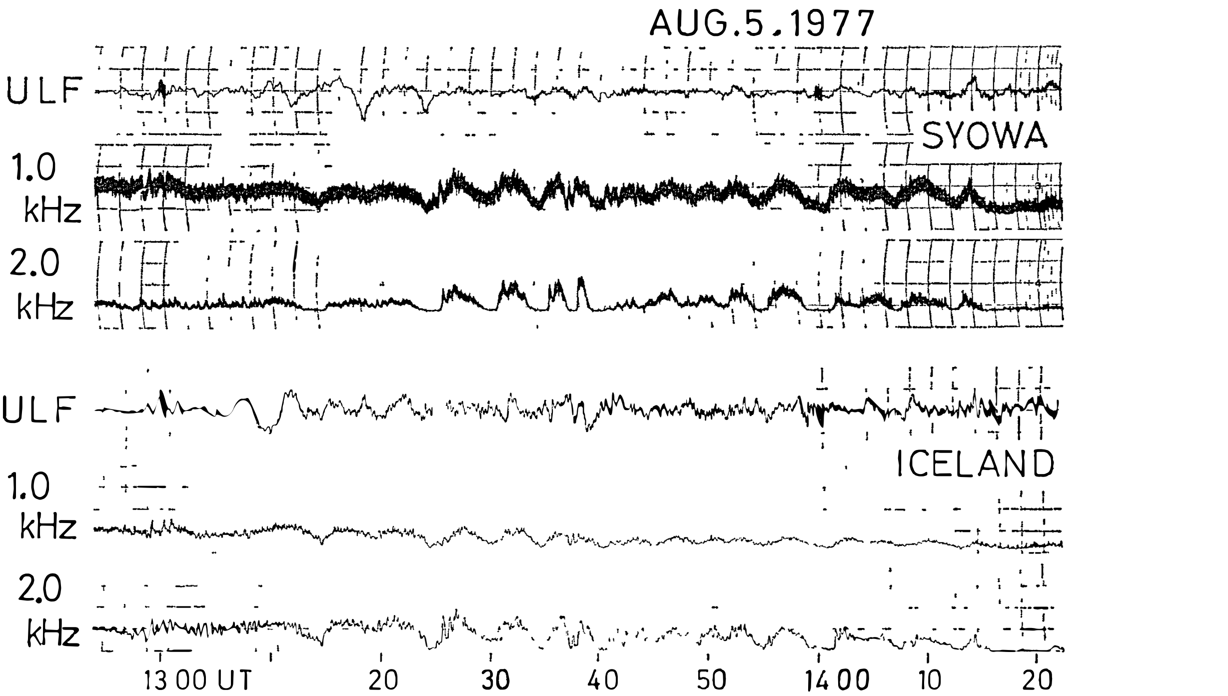

Fig 3a Intensity records of polar chorus emissions in the frequency bands of 1 and 2 kHz observed at Syowa Station and Husafell on August 5, 1977.

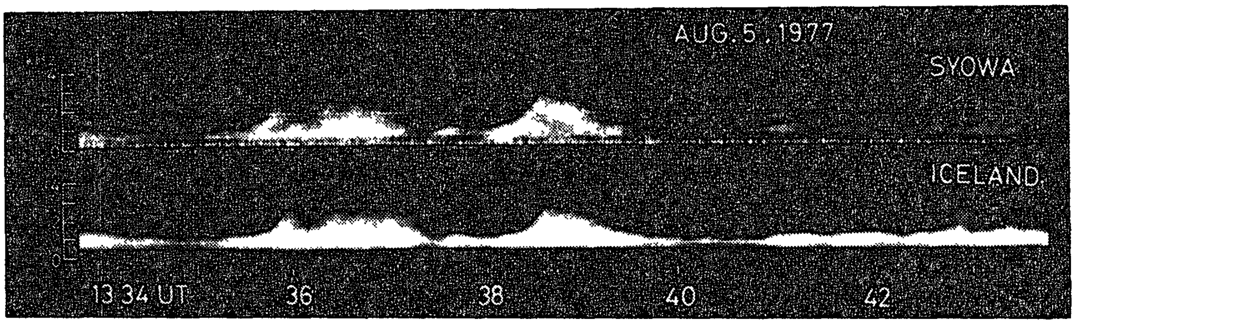

Fig 3b Frequency-time spectra in the time interval of ~1334–1343 UT on August 5, 1977.

2.2. QP emission

Most of Type 1 QP emissions (QP's associated with magnetic pulsations) are observed on the dayside with a maximum occurrence around the noon, and the Type 2 QP emissions (QP's not associated with magnetic pulsations) are observed on the dayside with a maximum around the noon and a sub-peak in the afternoon-evening period (SATO *et al.*, 1974). The period of QP's ranges from 10 sec to a few minutes, mostly around 20–40 sec (CARSON *et al.*, 1965; HELLIWELL, 1965; KITAMURA *et al.*, 1969; SATO *et al.*, 1974). The spectral structure of QP emissions is composed of the polar chorus, diffuse noise, discrete emission and periodic emissions (SATO *et al.*, 1974; SATO, 1978). KITAMURA *et al.* (1969) reported that Type 1 QP's show rarely a good

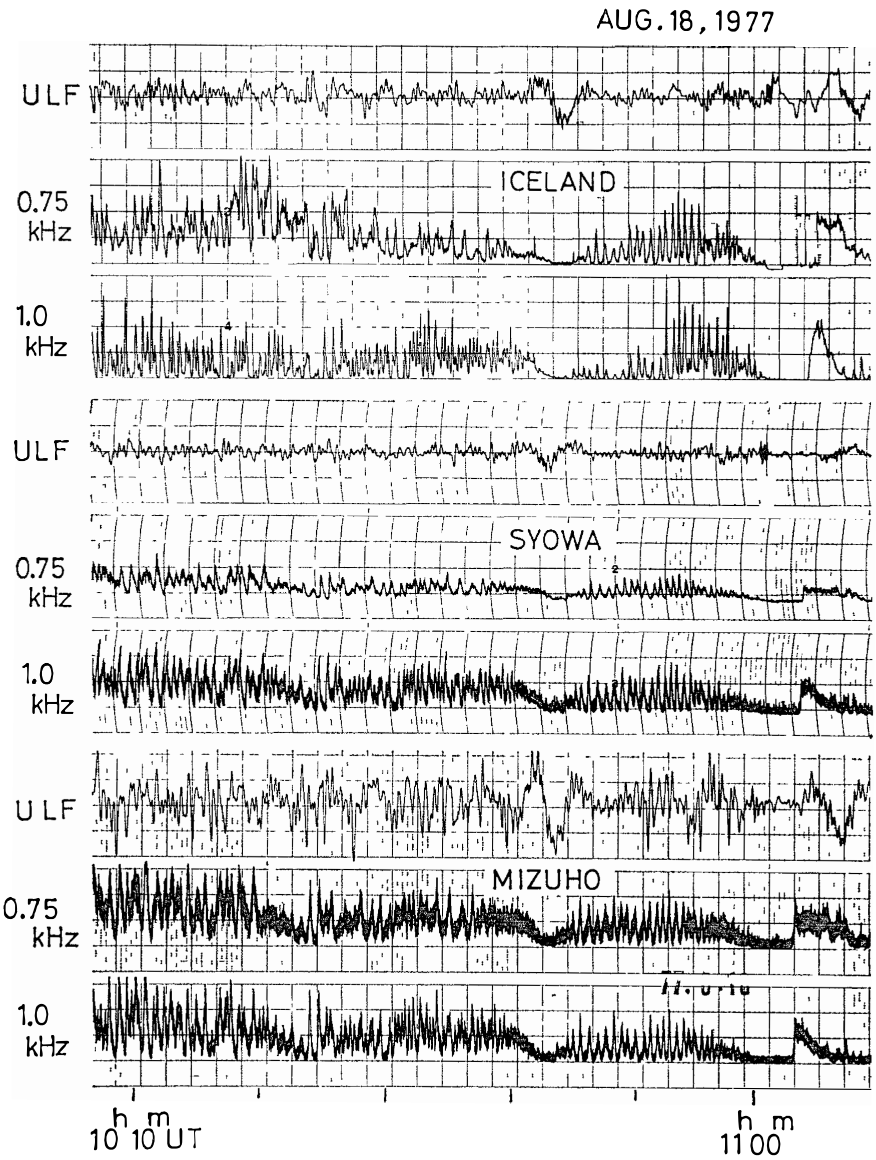

Fig. 4a Intensity records of ELF emissions with time-amplitude records of magnetic pulsations, obtained on August 18, 1977 at the conjugate-pair of stations, Husafell in Iceland, Syowa and Mizuho Stations in Antarctica.

conjugacy. However, a clear conjugacy was observed in Type 1 QP events at the Syowa Station-Husafell conjugate pair. Fig. 4a shows a typical example of Type 1 QP emission on August 18, 1977. It is found that QP emissions are associated with Pc 3 magnetic pulsations in the time intervals of 1006–1045 and 1058–1109 UT. It is also evident that QP emissions and magnetic pulsations occurred simultaneously at Husafell, Syowa and Mizuho Stations. These QP emissions were observed on GEOS-1 as well as on the ground as shown in Fig. 4b (CORNILLEAU-WEHRLIN *et al.*, 1978). Frequency-time spectra of QP emissions in the time interval of 1046–1051 UT on

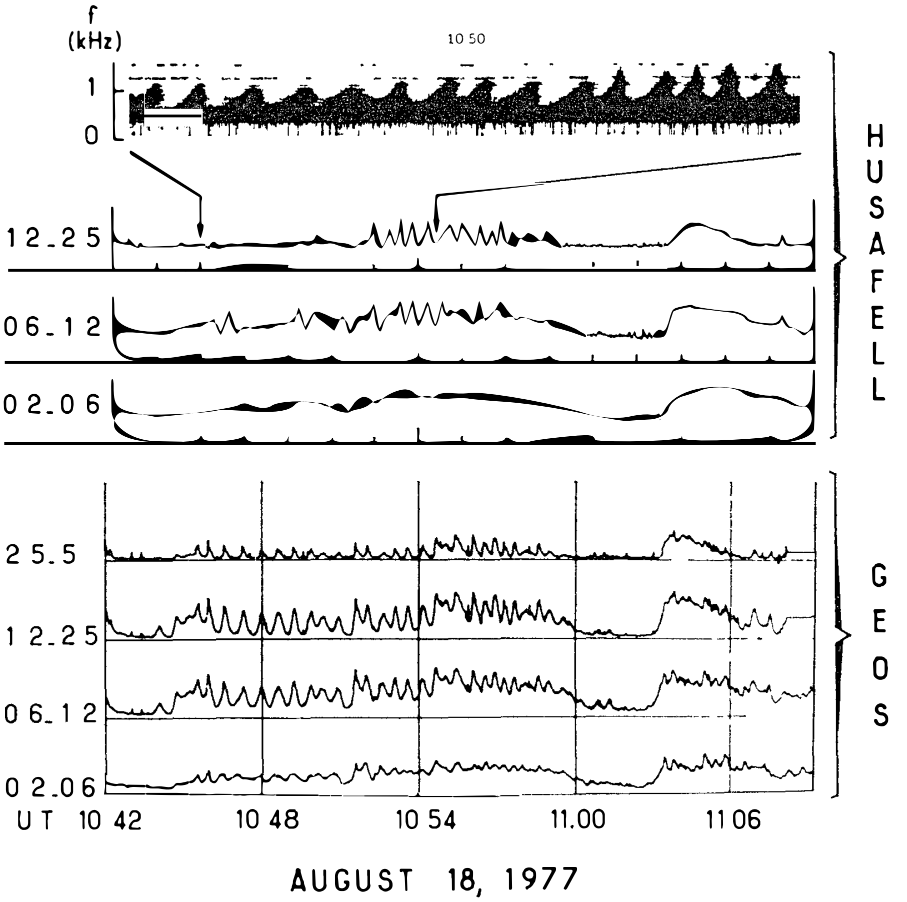

*Fig 4b Quasi-periodic emissions observed simultaneously on GEOS-1 and on the ground during the August 18, 1977 event (*CORNILLEAU-WEHRLIN *et al, 1978).*

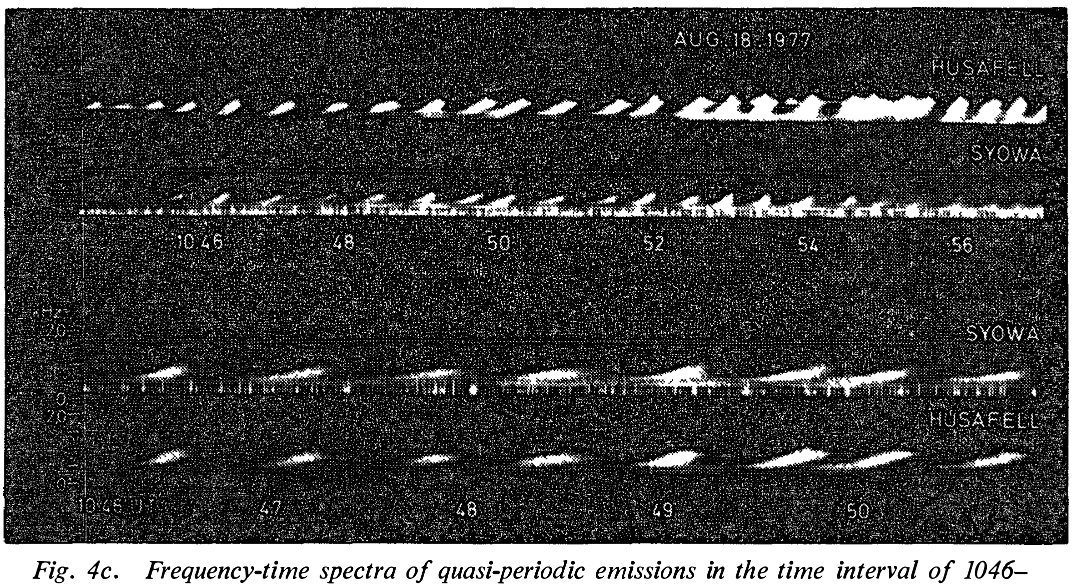

Fig. 4c. Frequency-time spectra of quasi-periodic emissions in the time interval of 1046–1051 UT on August 18, 1977.

August 18 are shown in Fig. 4c, in which the spectral structure of QP emissions is found to be quite similar at the conjugate points

Fig 5 shows an example of Type 2 QP emissions Activity of magnetic pulsations was very low at the conjugate-pair stations, Syowa and Husafell. However, the activity of QP emissions was very high with the same period of 20 sec at the both stations This example shows clearly that Type 2 QP emissions have a good conjugacy. Fig. 6 shows frequency-time spectra of Type 2 QP emissions in the time interval of

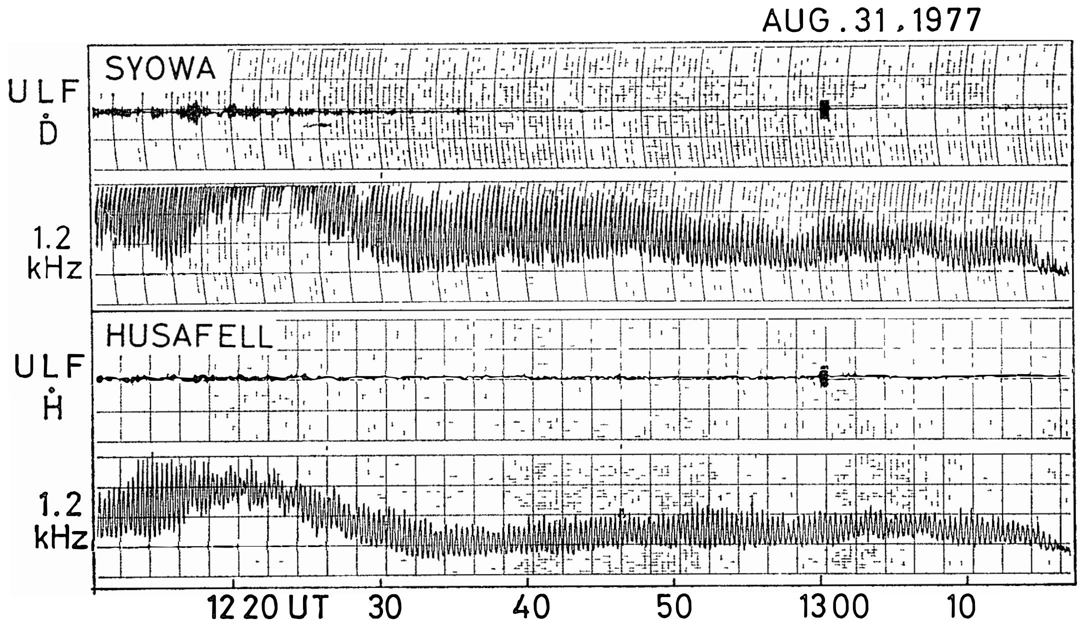

Fig 5 Example of Type 2 QP emissions observed at Husafell and Syowa Station on August 31, 1977. Emission activity of QP's was very strong at both stations On the other hand, activity of magnetic pulsations corresponding to the same periods of QP's (T~30 s) was very weak at both stations.

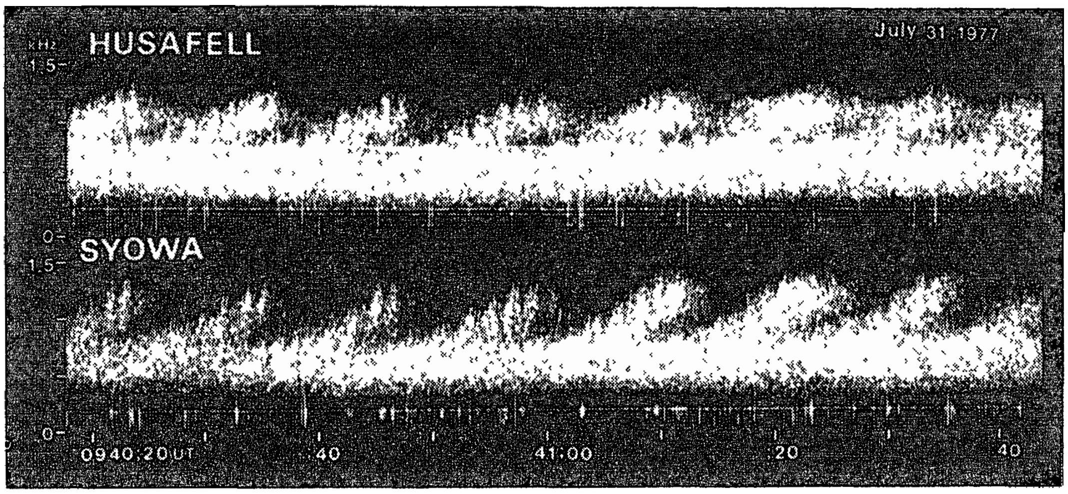

Fig 6 Frequency-time spectra of Type 2 QP emissions in the time interval of 0940·18–0941 43 UT on July 31, 1977.

Table 2. Conjugacy of quasi-periodic emissions

Date	Start time (UT)	Stop time (UT)	QP period (Second)	GP activity at Husafell	GP activity at Syowa	Type of QP emissions	Conjugacy of QP activity
July 31	0855	1046	10–15	M	M	2	yes
31	1820	1840	150	A	A	1	yes
Aug 1	1150	1255	25–35	M	M	1	yes
4	0450	1540	80	A	M	1	yes
4	1155	1220	15–20	M	M	1	yes
4	1300	1350	50–70	W	W	(?)	?
4	1605	1735	25–35	W	W	(?)	?
5	1000	1430	20–60	A	A	1	yes
6	0920	0925	30	A	A	1	yes
6	1340	1520	25–35	A	A	1	yes
8	0920	1000	12–18	W	N	?	yes
8	1105	1300	25–40	A	A	1	yes
9	0900	0930	10–15	W	W	2	yes
9	0950	1030	15–20	W	W	2	yes
10	1330	1340	35–45	W	W	2	yes
16	0850	1140	15–25	W	W	1 and 2	yes
18	0840	1510	20–40	A	A	1	yes
19	0750	0920	25–35	A	A	1	yes
19	1220	1510	30–40	A	A	1	yes
20	0905	0920	35–40	M	M	1	yes
20	1200	1520	50–70	M	M	1	yes
23	1040	1120	30–40	W	W	2	yes
26	0710	0750	10–15	M	M	1 and 2	yes
31	0940	1520	15–25	W	W	2	yes
Sept. 3	0800	1120	15–20	A	A	1	yes
3	1605	1740	50–70	M	M	2(?)	yes
14	0940	1530	20–40	M	M	1	yes
17	1910	2020	25–30	N	N	2	yes

A: Active M: Modelate W: Weak N: Nothing

0940:18–0941:43 UT on July 31, 1977. Rising-tone type QP emissions with a period of 15 sec were simultaneously observed at the conjugate stations with the same *f–t* spectral structure.

QP events on the intensity record at the conjugate-pair stations in the period from July 31 to September 17, 1977 are listed in Table 2. In this period, 28 QP events were observed. Most of QP's occurred in the first half of August, corresponding to high magnetic activity during this period. It is found that most of QP's (including Type 1 and Type 2 QP's) and magnetic pulsations show a good conjugacy except the August 4 event. These results are inconsistent with the result of KITAMURA *et al.* (1969) who suggested from a poor conjugacy of Type 1 QP's that the source of QP emissions may be local. However, the present results indicate that QP emissions are generated near the equatorial region in the outer magnetosphere and propagate to the both hemispheres through the wave duct along the field lines of force.

3. Conjugacy of Bursts of Discrete Emissions

Transient emissions usually with a duration of a few seconds or less, are called discrete emissions. The structure of elements in discrete emissions is classified into rising tone (risers), falling tone, and hooks. Bursts of discrete emissions include riser, triggered emissions, periodic cluster, and quasi-periodic clusters (HELLIWELL, 1965). Bursts of discrete emissions are mostly observed in the early morning during disturbed magnetic activity and are sometimes associated with particle precipitations. ROSENBERG *et al.* (1971) found a one-to-one correlation between bursts of whistler-triggered discrete emissions and bursts of >30 keV X-rays. Recently, HELLIWELL *et al.* (1979) reported a one-to-one correlations between bursts of VLF noise in the ~2–4 kHz range and optical emissions at 4278 Å observed at $L \sim 4.2$. KOKUBUN and SATO (1978) showed that discrete elements of burst types of QP emissions were sometimes associated with Pi 1 or Pi d magnetic pulsations which are correlated with pulsating auroras and electron precipitation bursts (CAMPBELL, 1964; MORIOKA and SAITO, 1971). HUDSON (1971) showed that the discrete emissions occur at random at the conjugate points, but their occurrences were caused by random spherics in the opposite hemisphere suggesting that discrete emissions are triggered by spherics in the opposite hemisphere.

Fig. 7 shows the D component record of magnetic pulsations and the VLF emission intensity records at the center frequencies of 0.5, 1.0 and 2.0 kHz at Husafell and at the frequencies of 0.5, 0.7, 1.0 and 1.3 kHz at Syowa Station on August 10, 1977. After 0950 UT, Pi type magnetic pulsations became active simultaneously at the conjugate-pair stations. Burst type of VLF emissions, typically at the frequency of 1.0 and 2.0 kHz bands, observed at Husafell becomes active associated with Pi type magnetic pulsations in the interval of 0955–1025 UT. However, the emission activity at Syowa Station was very weak during this time interval.

Figs. 8–10 show the frequency-time spectra of bursts of discrete emissions observed at the conjugate-pair stations. It is evident from the f–t spectra in Fig. 8 that separated two frequency bands (0.3–0.7 and 0.9–2.0 kHz) are enhanced at Husafell in the interval of 1136:50–1137:30 on July 31, 1977. On the other hand, only the lower frequency band of 0.2–0.9 kHz is enhanced at Syowa Station. It is worth noting from the f–t spectra at Husafell that the intensity of the higher frequency band was stronger than that of the lower band. Fig. 9 indicates another example of discrete emissions

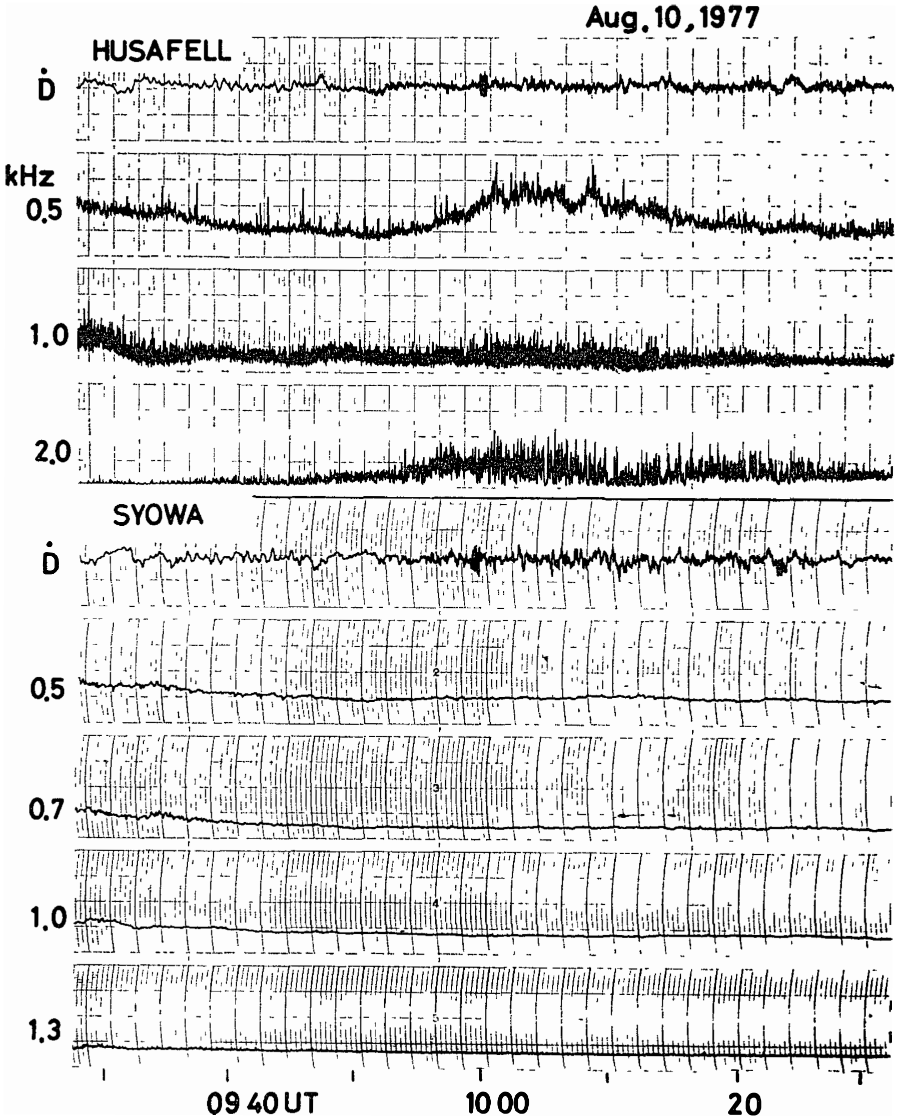

Fig 7. The D component of magnetic pulsations and the VLF emissions observed at the conjugate-pair stations on August 10, 1977.

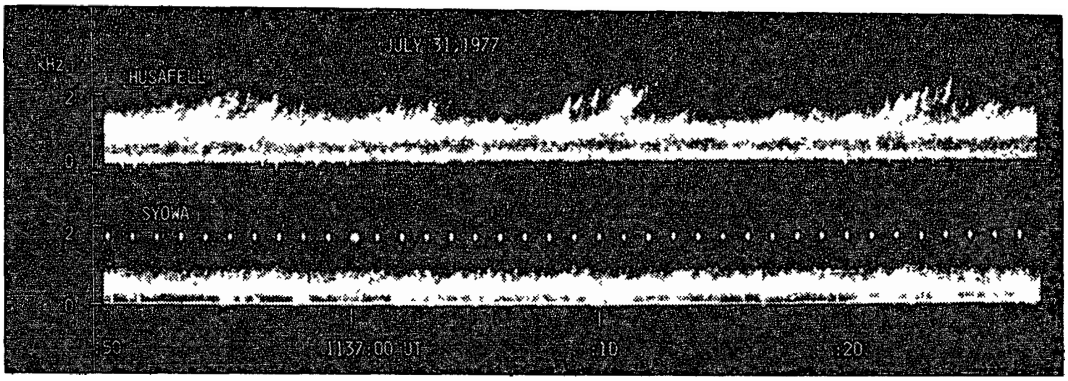

Fig. 8. Frequency-time spectra of bursts of discrete emissions observed at the conjugate-pair stations on July 31, 1977.

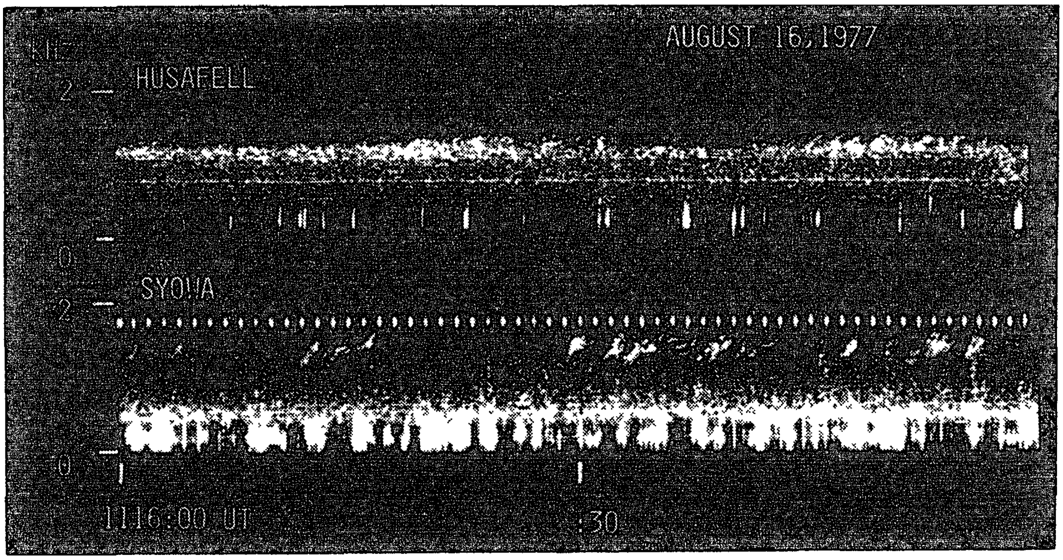

Fig 9 Frequency-time spectra of discrete emissions observed at the conjugate-pair stations on August 16, 1977

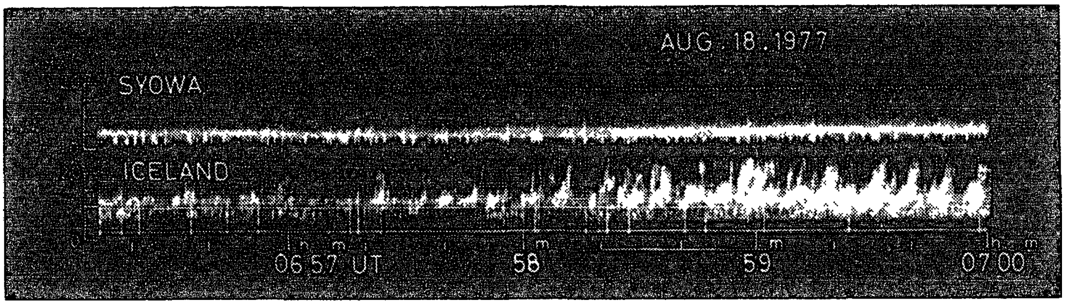

Fig 10. Frequency-time spectra of auroral chorus observed at the conjugate-pair stations on August 18, 1977

observed at Syowa Station and Husafell on August 16, 1977. On the *f–t* spectra at Husafell, diffuse and discrete emissions occurred at the frequency around 1.3 kHz, and the emission intensity is modulated quasi-periodically with a period ~30 sec. However, at Syowa Station only discrete clusters are observed.

Fig. 10 shows examples of *f–t* spectra of auroral chorus observed at the conjugate-pair stations at 0656: 10–0700: 00 UT on August 18, 1977. The frequency-time spectra at Syowa Station indicate the diffuse noise emissions with a constant frequency of 0.4–0.8 kHz which was also seen at Husafell, Iceland, and a group of strong discrete risers was dominant in the frequency range of 0.5–2.5 kHz. Discrete elements at Syowa Station were so weak that we could not notice them.

Most of the conjugate VLF data in 1977 showed the same tendency as mentioned above. Therefore, it is concluded that burst type of VLF emissions shows rare conjugacy, and the emission intensity is mostly stronger at Husafell than at Syowa Station.

4. Auroral Hiss

Auroral hiss is well known to be associated with appearance of auroral arc (OGUTI, 1975; MAKITA, 1978). Pronounced diurnal and seasonal variations of auroral hiss are found at ground stations. Hiss is primarily observed between 18 and 03 magnetic local time (HARANG and LARSEN, 1965; MAKITA, 1978) and its intensity enhances during the winter (WATTS *et al.*, 1963; MAKITA, 1978). HUDSON (1971) reported that the conjugacy of auroral hiss is poorer than the polar chorus, and suggested that the pronounced seasonal variation in hiss activity is probably caused by absorption in the lower ionosphere. It is interesting to examine the conjugacy of auroral hiss in connection with the seasonal variation of hiss emissions.

Fig. 11a shows the amplitude records of magnetic pulsations and emission intensity in the frequency bands of 0.75, 1.0, 2.0 kHz at Husafell, Syowa and Mizuho Stations in the interval of 2222–2328 UT on August 5, 1977. It is clear that auroral hiss emissions in these frequency bands enhanced at Syowa and Mizuho Stations, associated with the enhancement of magnetic disturbance in the time intervals of 2230–2306 and 2319–2322 UT. However, no emissions appeared at Husafell in the northern hemisphere. Fig. 11b shows another example of auroral hiss and auroral chorus observed at conjugate-pair stations on August 6, 1977. Before 2306 UT, the auroral hiss in 8.0 kHz band was enhanced at Syowa and Mizuho Stations in the southern hemisphere, and no emission was observed at Husafell in the northern hemisphere. Impulsive auroral hiss with a wide frequency band from 0.4 kHz to more than 20 kHz occurred associated with auroral breakup at Syowa and Mizuho Stations. However, at Husafell in the northern hemisphere hiss emissions were observed in the frequency band higher than 2 kHz, and emissions did not appear at 1.0 kHz. It is noticiable that the auroral chorus became active only in the northern hemisphere after the auroral breakup in the time interval of 2214–2225 UT. Fig. 11c shows the *f–t* spectra of auroral hiss and auroral chorus observed at the conjugate-pair stations. It is interesting that an impulsive auroral hiss was observed at Syowa Station in the interval of 0104: 10–0104: 35 UT. However, at Husafell no auroral hiss appeared and only strong auroral chorus was observed.

We can conclude from these evidences that the conjugacy of auroral hiss emissions is generally low, and its intensity is much higher at Syowa Station (winter hemisphere) than at Husafell (summer hemisphere). This may be due to the seasonal variation of the ionospheric absorption. However, the emission intensity of auroral chorus which occurred simultaneously or successively with auroral hiss is larger at Husafell than at Syowa Station.

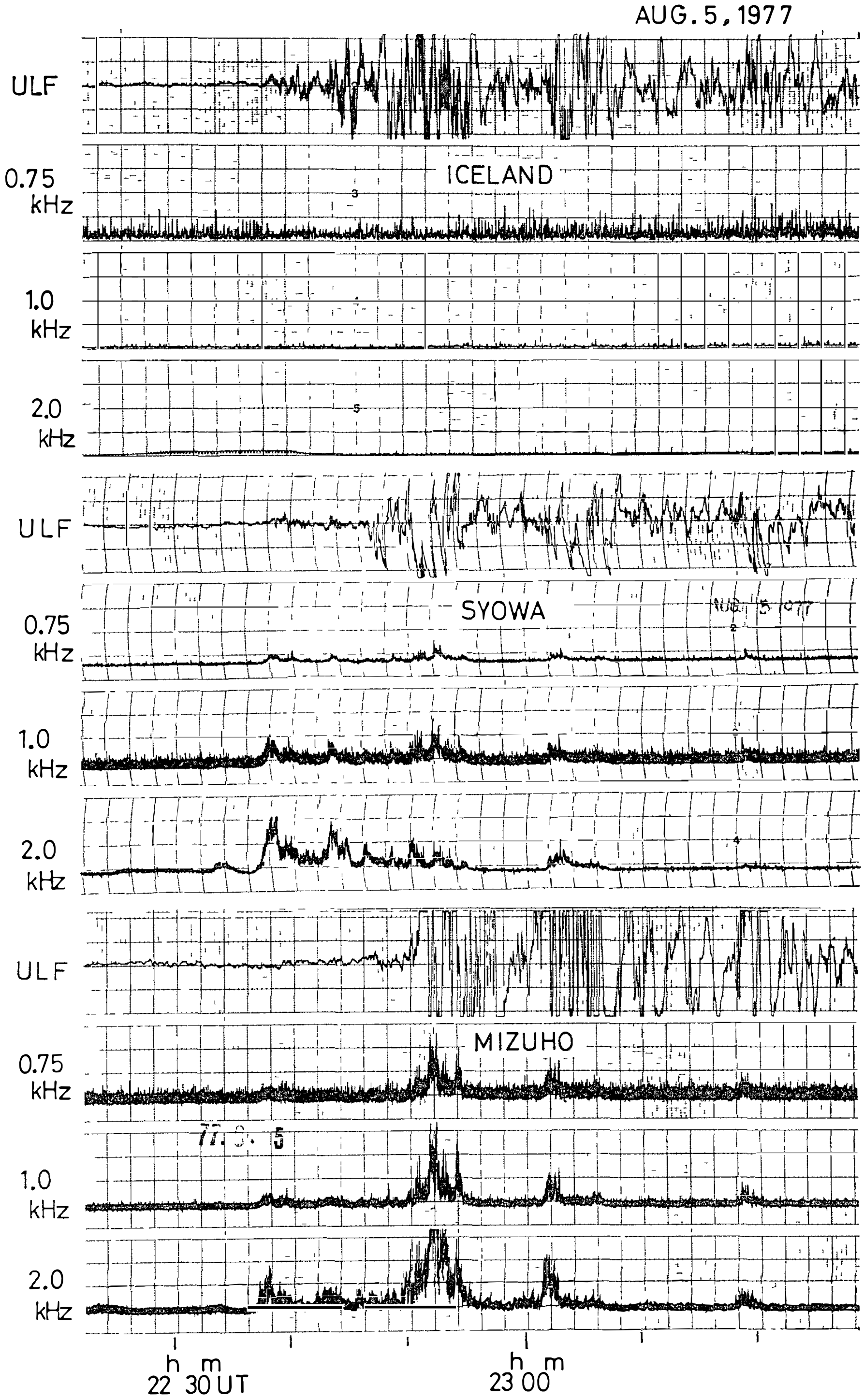

Fig. 11a Amplitude records of magnetic pulsations and auroral hiss emission intensity in the frequency bands of 0.75, 1.0 and 2.0 kHz observed at Husafell, Syowa and Mizuho Stations on August 5, 1977.

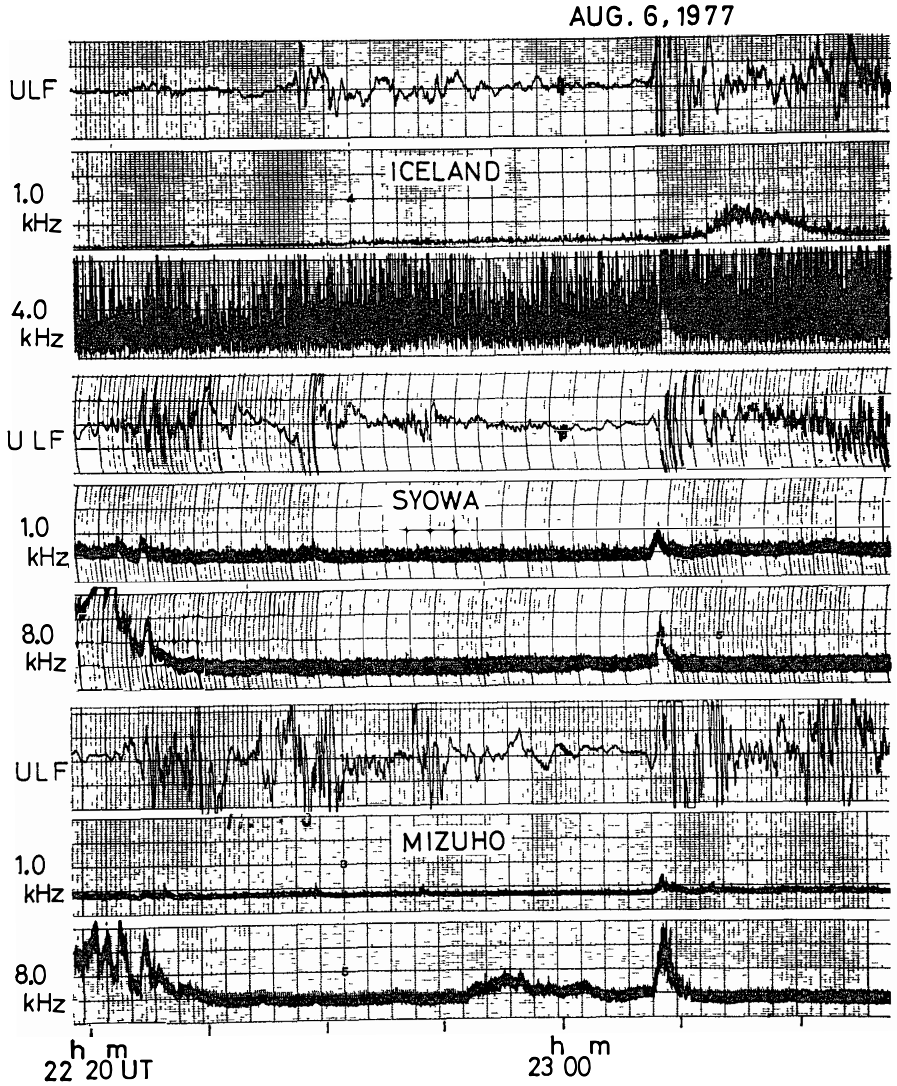

Fig. 11b. Intensity records of auroral hiss and auroral chorus emissions with magnetic pulsations observed at conjugate-pair stations on August 6, 1977.

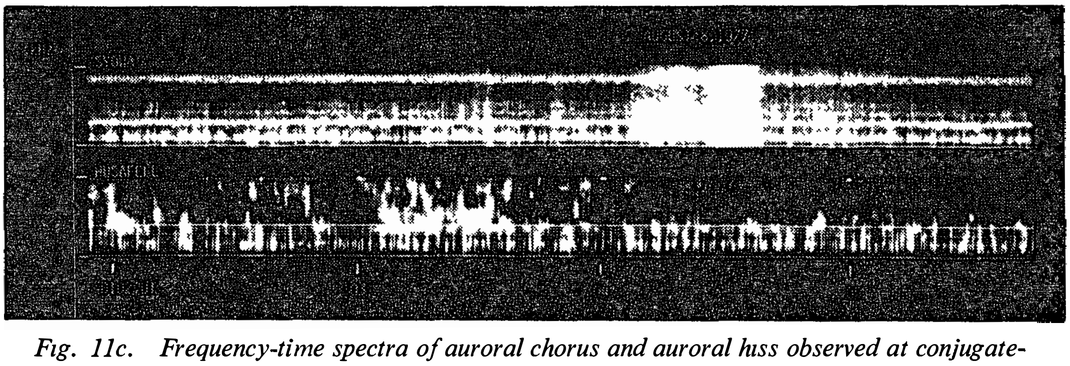

Fig. 11c. Frequency-time spectra of auroral chorus and auroral hiss observed at conjugate-pair stations with no correlation

5. Occurrence Distribution of ELF-VLF Emissions at Syowa Station and Husafell

In this section, statistical properties of conjugate activity of ELF-VLF emissions are examined on the basis of total occurrences of emissions observed at conjugate-pair stations for 16 days from August 5 to August 20, 1977. Fig. 12a shows the diurnal variation of the emission occurrence in 1.0 kHz band observed at Husafell and Syowa Station. The magnetic local time is almost equal to universal time at these stations. It is evident that emission occurrence peaked around daytime at the conjugate-pair stations. The occurrence of emissions at 1.0 kHz in this period showed the same characteristics as the results of HAYASHI *et al.* (1968) observed at Syowa Station. Fig. 12b shows a difference in the duration of emission occurrence in 1.0 kHz band

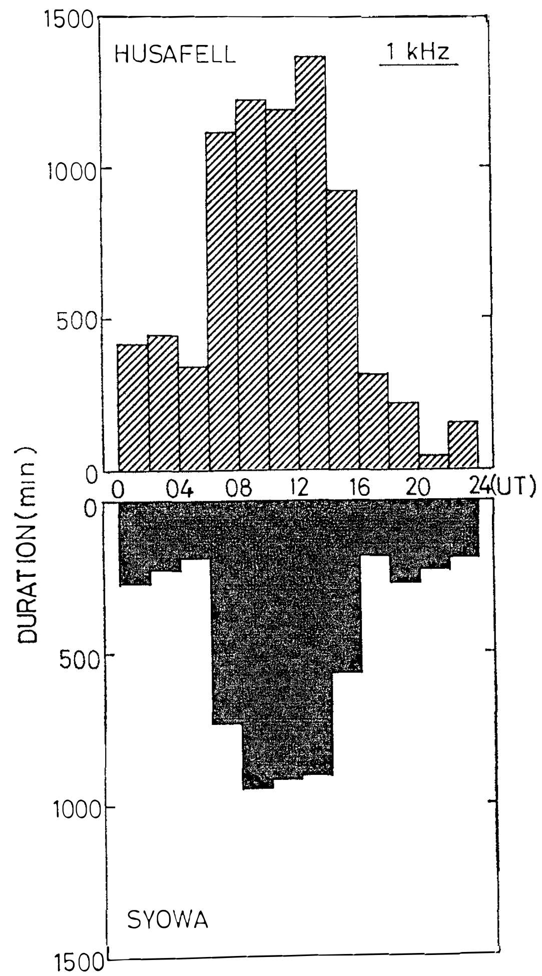

Fig. 12a Diurnal variation of the emission occurrence in 1.0 kHz band observed at Husafell and Syowa Station for 16 days from August 5 to August 20, 1977.

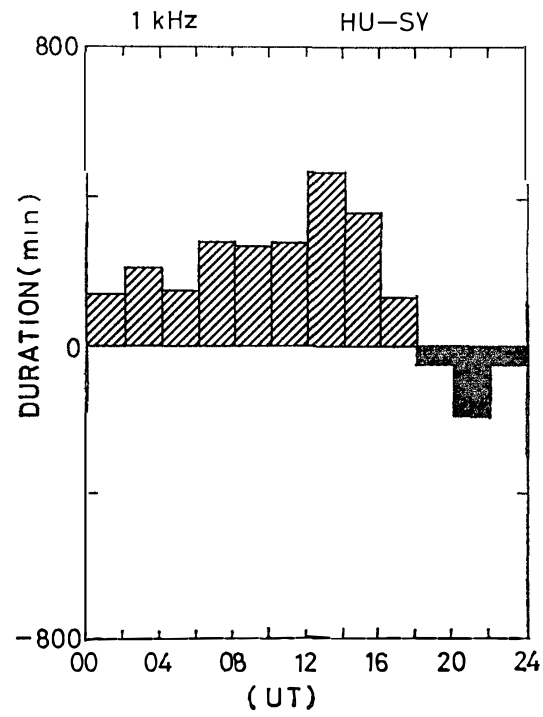

Fig 12b. Difference in the duration of the emission occurrence in 1.0 kHz band observed at the conjugate-pair stations.

between the conjugate-pair stations. It is evident that 1 kHz-emissions were often received at Husafell (northern station) in the interval of 00–18 UT, while *vice versa* in the interval of 18–24 UT. The 1 kHz-emissions in the interval of 00–18 UT consist of auroral chorus (post midnight), burst of discrete emissions (early morning), and polar chorus (daytime). On the other hand, the emissions in the interval of 18–24 UT consist of impulsive type auroral hiss emissions. Fig. 13a shows the diurnal variation of the emission occurrence in 4.0 kHz band observed at the conjugate-pair stations. In the southern hemisphere, an occurrence peak appeared in the nighttime, while occurrences of 4 kHz-emissions were quite low in the northern hemisphere throughout the day. Fig. 13b shows a difference in the duration of emission occurrence in 4.0 kHz band between Husafell and Syowa Station. Emissions in the interval of 18–02 UT are found to be auroral hiss. In the daytime from 04 to 06 UT, most emissions at

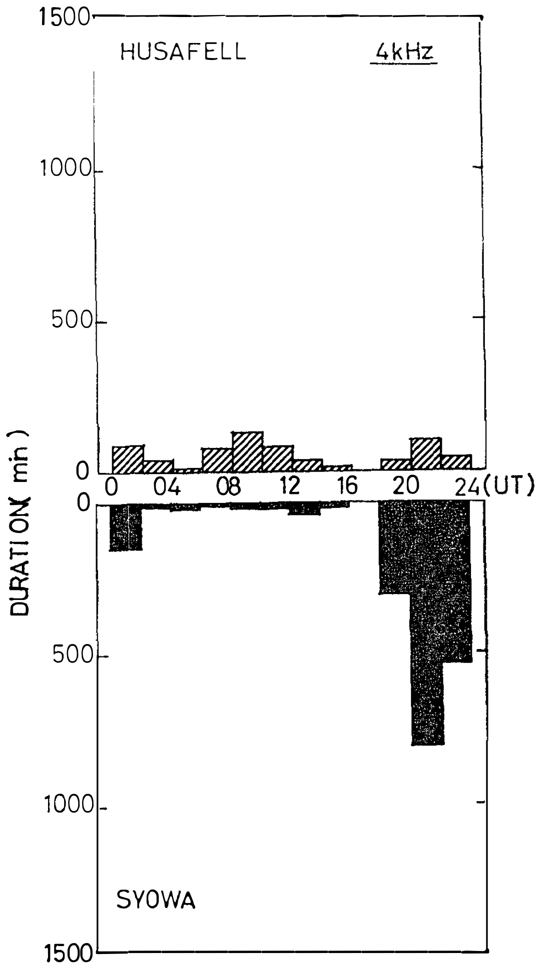

Fig. 13a. Diurnal variation of the emission occurrence in 4.0 kHz band observed at the conjugate-pair stations for 16 days from August 5, 1977.

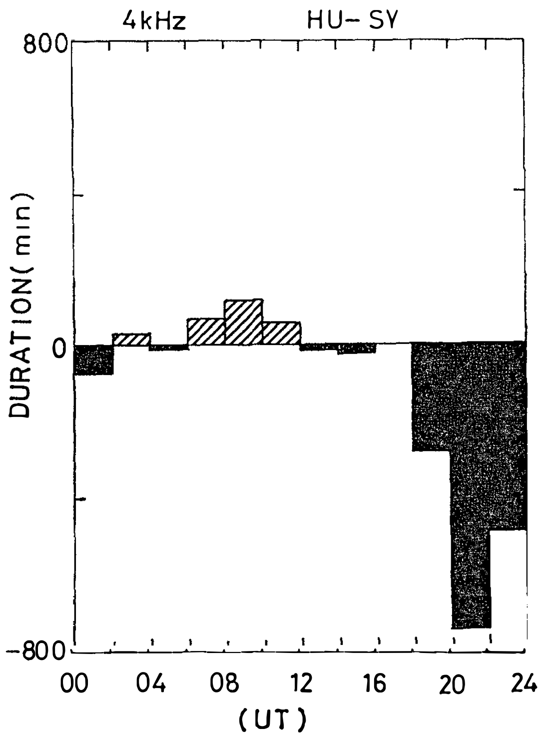

Fig. 13b. Difference in the duration of the emission occurrence in 4.0 kHz observed at the conjugate-pair stations.

4.0 kHz are bursts of discrete emissions.

Statistical properties of the emission occurrence at the conjugate points during the period from August 5 to August 20, 1977 show that the auroral chorus, burst of discrete emissions and polar chorus are much more frequently observed in the northern hemisphere than in the southern hemisphere, while the emission activity of auroral hiss is greater in the southern hemisphere than in the northern hemisphere. These characteristics coincide with a fact that the occurrence of chorus emissions become larger during the summer, and those of auroral hiss are enhanced during the winter.

6. Discussion

From the ELF-VLF data recorded at the Syowa Station-Husafell conjugate pair in the northern summer season from July 29, 1977 to September 17, 1977, it is found that polar chorus and QP emissions during the daytime are well correlated with each other in the conjugate regions near $L=6$. The highly correlated activity may be explained by a model that emissions are generated near the equatorial plane in the outer magnetosphere, and propagate through wave ducts along the field lines of force from the generation region to the ground (HAYASHI *et al*., 1968; HUDSON, 1971; SATO and KOKUBUN, 1979). Seasonal variation in occurrence of polar chorus may be related with formation of wave duct and with absorption in the lower ionosphere.

Burst of discrete emissions was observed more often at Husafell in the northern hemisphere than at Syowa Station in the southern hemisphere. The emission activity of auroral hiss on the ground is significantly different at the conjugate stations, *i.e.*, the emission activity is quite low in the northern hemisphere. The conjugacy of discrete emissions observed at Syowa Station-Husafell was different from that observed at Byrd-Great Whale. HUDSON (1971) explained the predominance of discrete emissions at Byrd by assuming that the discrete emissions are triggered by spherics in the opposite hemisphere and these occurrences may be influenced by conditions in the magnetosphere. He also suggested that low auroral hiss activity in the summer hemisphere is probably caused by absorption in the lower ionosphere.

In order to examine the physical process of conjugate phenomena, we must take into account the difference of the geophysical conditions at the conjugate-pair stations. STENBAEK-NIELSEN *et al*. (1973) explained the intensity difference of auroral arc at the conjugate-pair stations by simplified theoretical calculations that particle precipitations at conjugate point are different from a magnetic potential difference between both hemispheres. The differences in geophysical conditions at Husafell and Syowa Station are as follows; 1) the total intensity of magnetic field is about 45000 γ at Syowa Station and 52000 γ at Husafell, 2) the dip angle of magnetic line of force is 65° at Syowa

Station and 75° at Husafell, 3) geographic local time is delayed one hour at Husafell and advanced three hours at Syowa Station in comparison with geomagnetic local time. Furthermore, sunlit time in the ionosphere is very different at the both stations in the summer and winter seasons, 4) geomagnetic field lines are asymmetrically distored with respect to the solar wind direction.

As is shown in Figs. 11b and 11c, the auroral hiss was observed at Syowa Station, but no auroral hiss appeared and only strong auroral chorus was observed at Husafell. Of course, the auroral hiss and auroral chorus propagating in the whistler mode suffer from the absorption in the lower ionosphere. Thus, the seasonal variation in occurrence of auroral hiss can not be explained only by the absorption effect in the ionosphere.

Many trials have been carried out to explain auroral hiss interms of incoherent Cerenkov radiation from the precipitating electrons (ELLIS, 1957; LIEHMON, 1965; JØRGENSEN, 1968; LIM and LAASPERE, 1972; JAMES, 1973; TAYLOR and SHAWHAN, 1974; SWIFT and KAN, 1975; NODA and TAMAO, 1976). However, the incoherent mechanism hardly explains the observed power fluxed as high as $10^{-11} \sim 10^{-12}$ W/m²Hz at satellite altitudes (BARRINGTON *et al.*, 1971; GURNETT and FRANK, 1972; MOSIER and GURNETT, 1972). Recently, MAGGS (1976) has shown that the wave amplification of incoherent whistler mode radiation by the convective instability caused by the beam of precipitating auroral electrons accounts for the observed power fluxed of VLF hiss. Growth rate of auroral hiss generated by the convective instability is written as follows (MAGGS, 1978; YAMAMOTO, 1979; MAKITA, 1978).

$$\gamma \propto \frac{n_b}{n_0}$$

where γ, n_b, and n_o shows growth rate, density of the electron beam and the ambient plasma density, respectively. In the summer season, ambient plasma density in the summer hemisphere is much higher than that in the winter hemisphere. Furthermore, beam density of precipitating electrons is higher at Syowa Station than that at Husafell, because mirror height at Syowa Station is much lower than at Husafell as suggested by STENBAEK-NIELSEN *et al.* (1973). So, it is suggested that the auroral hiss grows mostly in the southern hemisphere in the period of July-September. This result can well explain the seasonal variation of auroral hiss without considering absorption in the lower ionosphere in the summer hemisphere.

Auroral chorus and burst of discrete emission may be generated by electron-cyclotron resonance associated with electron beam in the outer magnetosphere (BRICE, 1964; HELLIWELL, 1965; KIMURA, 1967). The intensity of electron beam toward Syowa Station is higher than that of electron beam toward Husafell because of the difference of mirror height at Syowa Station and Husafell as mentioned above. In the electron-

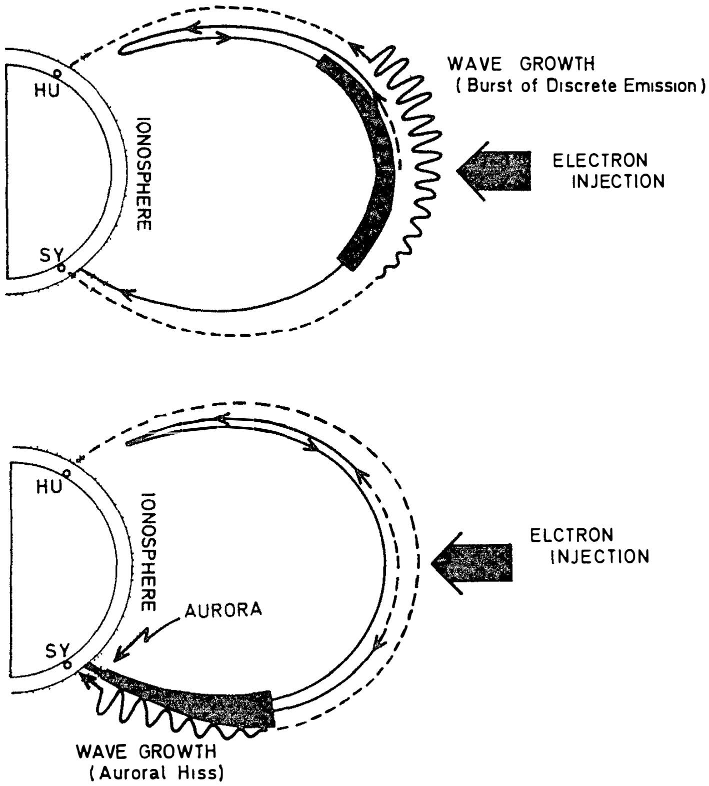

Fig. 14. Schematic illustration to explain the poor conjugacy of auroral hiss and burst of discrete emissions

cyclotron instability radiations are emitted in opposite direction to the electron beam Therefore, it is likely that the emission intensity at Husafell is considerably high. Fig. 14 shows the schematic illustration to explain the poor conjugacy of auroral hiss and burst of discrete emissions at the conjugate-pair stations, Syowa Station and Husafell.

We have proposed a phenomenological model different from HUDSON (1971)'s idea to explain the poor conjugacy of burst of discrete emissions and auroral hiss. In order to confirm this model, additional data recorded simultaneously on the ground and satellites are needed.

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