POLARIZATION AND ARRIVING DIRECTION OF VLF EMISSIONS AT SHOWA BASE

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Abstract

Polarization and direction of arrival of VLF emissions have been observed at Showa Base in the Antarctic by using a combination of a vertical antenna and corossed loop antenna with their planes lying in geomagnetic E-W and N-S directions. The results obtained with a polarimeter show that the emissions at 750Hz, 12KHz and 25KHz were left-handed polarization wave in all seasons, if one looks towards the observation site on earth's magnetic field. But there seemed to be seasonal variation in the ratio of right-handed polarization wave to left-handed polarization wave. A pronounced evidence is that the emission at 25KHz was linearly polarized in winter (July and August).

The oscillographic patterns obtained here with a direction finder seem to indicate that the emission at 12KHz simultaneously arrived from various directions, and that the emission was elliptically polarized. But some few cases, the emission seemed to come down roughly from vertical direction along a geomagnetic field line, and to be circularly polarized.

1. Introduction

In the previous report in this volume, we discussed the occurrence of VLF emissions at Showa Base and its correlation with geomagnetic disturbances, auroral displays and radio absorptions in the ionosphere. Then we could to know the character of occurrence of VLF emissions at high latitude. In the following, we will discuss geophysical aspects of the emissions, such as polarization and direction of arrival.

We have made the observation of polarization and arriving direction of VLF emission (4-6KHz) at Moshiri too. The result obtained at Moshiri shows that the emissions at low latitude were almost linealy polarized and arrived from north (auroral zone). Namely, VLF emissions can be thought to propargate from auroral zone to low latitude in a wave-guide mode between the ionosphere and the ground. As shown in the previous report, the character of VLF emissions at high latitude is very different from that at low latitude. Therefore, observations of polarization and arriving direction at Showa Base (in an auroral zone) are very important and necessary to the study of propagation mode and occurrence mechanism of VLF emissions.

Harang (1965) observed polarization and direction of arrival of 8KHz band emissions at Tromsö, Auroral observatory, using two crossed loops with their planes lying in E-W and N-S directions. Analyzing the emission date he came to a conclusion as follows. Ordinary broad and irregular VLF emissions come from all directions and change its aspect, the polarization reversing the sense of rotation. Isolating sharp burst comes down vertically along geomagnetic field line, and is circulary polarized keeping the sense of rotation unaltered. Ellis (1960) have observed the direction of arrival and the source size at 5KHz emission at three stations in sountheastern Australia, and estimated the source area of the emissions at low latitude.

2. Polarization and Direction of Arrival of VLF emissions

It is usually assumed that VLF emissions propagate through the ionosphere in a whistler mode, and are circulary polarized as an extraordinary component. The energy propagates from a source to various directions with a wave-guide mode between the ionosphere and the ground. Showa Base, as an Auroral Observatory, is located within a area of precipitation of the emissions, hence they will come from vertical direction and will show the state of a nearly circular polarization with only one possible sense of rotation against the magnetic vector. However, the observations to confirm above assumption have not been carried out yet successfully. Therefore, the polarization records to be obtained at Showa Base are very interesting and important to the study in future of physical aspects of the emissions.

Observing techniques were reported once by A. Iwai and Y. Tanaka (1968). And the block diagram of the apparatus has been described in the previous report in this volume. Apparatus (1), refer to Fig. 2 in the previous report, is for the observation of sense of rotation of the polarization plane. Observation frequencies are 750Hz, 12KHz and 25KHz, and their band widths are 10Hz, 150Hz and 250Hz, respectively. Detectors used are of minumum detecting method, and their time constant is about 10 sec. Recordings are made continuously on a chart of 6 elements pen recorder. Apparatus (2) is for to observe the direction of arrival and the polarization pattern of emissions at 12KHz. The band width of the direction finder is 20Hz. Lissajou's figure on an oscillograph are modurated by an output of vertical antenna in order to avoid 180° ambiguity. Exposure time is about 33μsec (four cycles of 12KHz). The Lissajou's figure on the oscillograph are photographed continuously during the emission event. The results obtained by apparatus (1) and (2) will be given in the next section.

3. Observation Results

Fig. 1 shows seasonal variations of the polarization at 750Hz, 12KHz and 25KHz. These values of C were picked up from many records, where C represents the ratio of amplitude of right-handed polarization wave to left-handed polarization wave. So, if C>1, the emission have right-handed elliptic polarization, and if C<1, left-handed elliptic polarization, and if C=1, linear polarization. From this figure the emissions at three frequencies are found roughly to have left-handed elliptic polarization. But there seems to be seasonal variations of the C value at 12KHz and 25KHz. Namely, dispersing of C value at 12KHz in winter (July, August) is smaller than that in other seasons. Moreover, it is remarkable that the emissions at 25KHz are linearly polarized in winter.

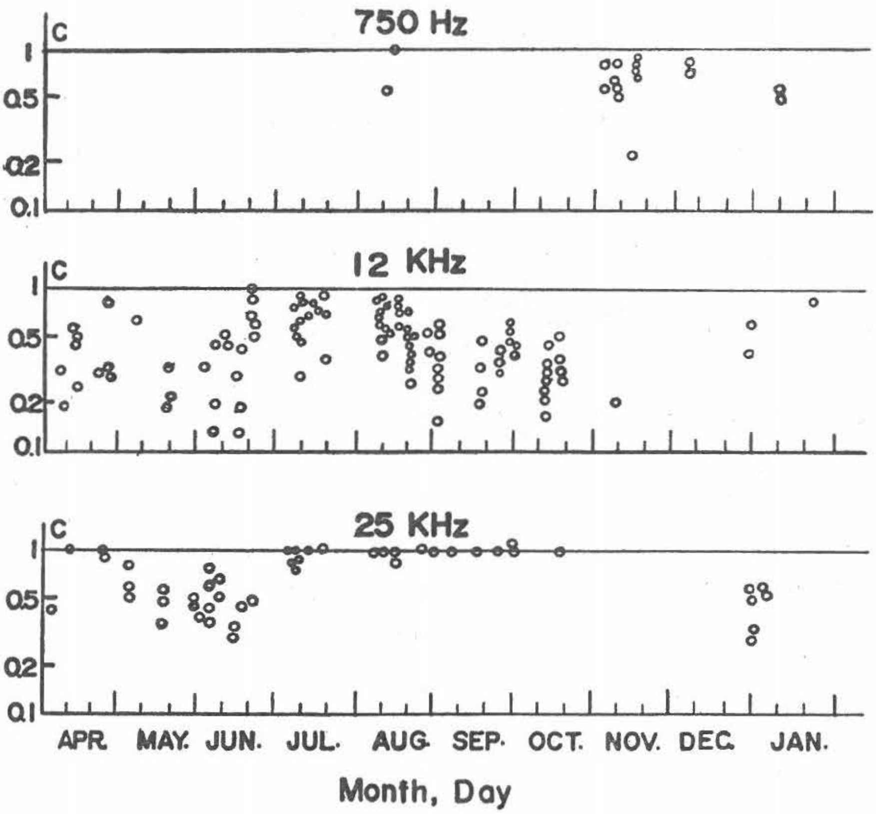

Fig. 1 Seasonal variation of the polarization.

C : the ratio of right-handed polarization wave to left-handed polarization wave.

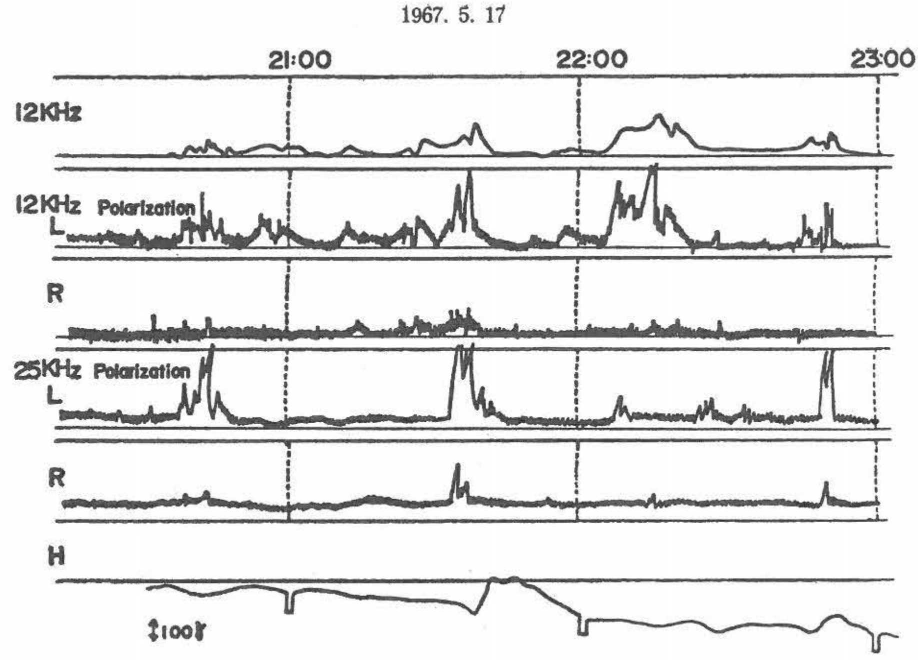

Fig. 2 A sample record of polarization in May, 1967

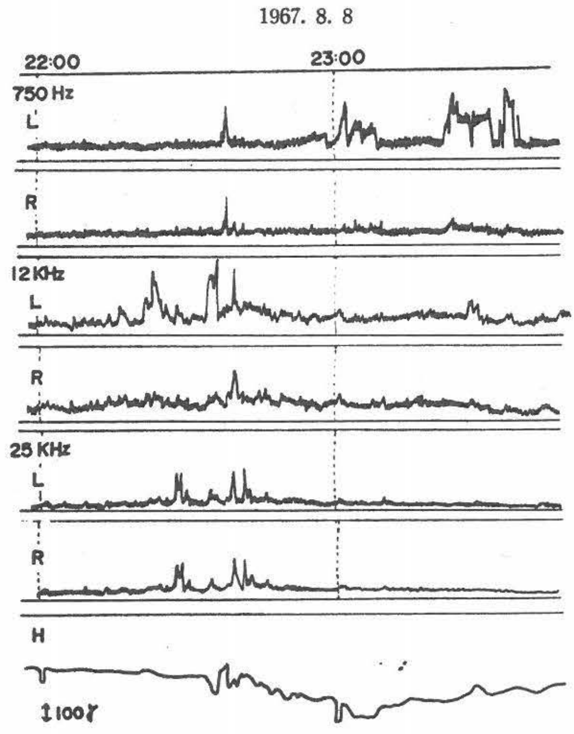

Fig. 3 A sample record of polarization in August, 1967

Fig. 2 shows that the emissions occurred during a gradual decrease of geomagnetism, on May 17, 1967, and were almost left-handed polarized at both 12KHz and 25KHz. Each spikes of the emission at 12KHz showed stronger left-handed polarization than that at 25KHz.

Fig. 3 shows that the emissions at three frequencies occurred in a initial pulsive phase of a small geomagnetic disturbance, on August 8, 1967. The emission at 750Hz occurred very rarely in the hours from 1800 to 0100UT. in August, and it was strongly left-handed polarized clearly, while the emission at 25KHz was quite linealy polarized.

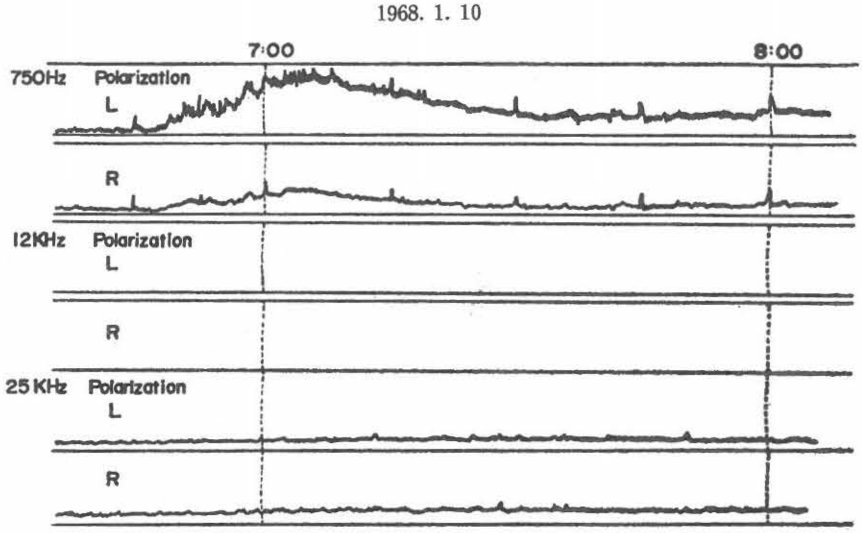

Fig. 4 A sample record of polarization in January, 1968

Fig. 4 shows the emissions which occurred in the morning on January 10, 1968. The emission at 750Hz was left-handed polarized clearly. Emissions at 12KHz and 25KHz could not be found on the record on this occasion.

Fig. 5 shows the time variation of C value for a emission event in winter on August 18, 1967. The spikes indicated with the broken line arrow ⇡ were more strongly left-handed polarization, while the spikes indicated the real line arrow ↑ weakly left-handed polarization.

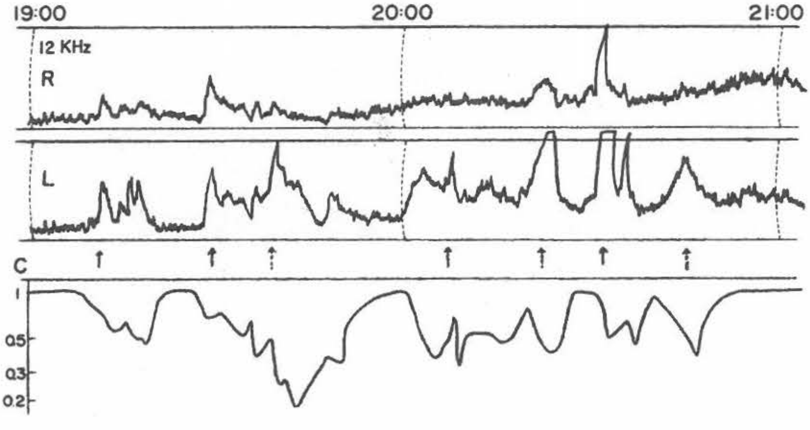

Fig. 5 Time variation of the value C for a sample record in August, 1967

Fig. 6 illustrates irregular oscilligraphic patterns of the emission at 12KHz on June 4, 1967. These two patterns were not modurated by an output of vertical antenna, however, the patterns seem to suggest that this emission arrived simultaneously from about two directions with various amplitude, and was elliptically polarized. Intensity of this emission was stronger in the E-W geomagnetic direction than in the N-S direction.

Fig. 7 shows the oscillographic patterns obtained continuously on August 18, 1967. Pattern (A) shows the start of single spike of the emission. This spike arrived from the direction between geomagnetic N and W. Pattern (B) shows a different arrival direction from Pattern (A). Pattern (C) shows a expanding spike of Pattern (A), and it came down at oblique incidence, and was circularly polarized. Pattern (D) and (E) show a peak of the emission, and this emission arrived from vertical direction, and was circularly polarized.

The intensity of atmosphrics at Showa Base was considerable strong at 12KHz. So it seemed to be difficult to catch the exact patterns of the start of emissions, and therefore the patterns obtained might be the emissions, whose sources expanded to a wide area near to the ground. In an other word, it seems to be difficult at 12KHz to know the propagation mode and the arrival direction from beginning to end of a VLF emission event. To cover this, it is desiable to observe them at higher frequency than 12KHz (for example, 25KHz), because 25KHz is not so much interfered with atmospherics, and the emission at 25KHz strongly correlate with luminous auroral activity.

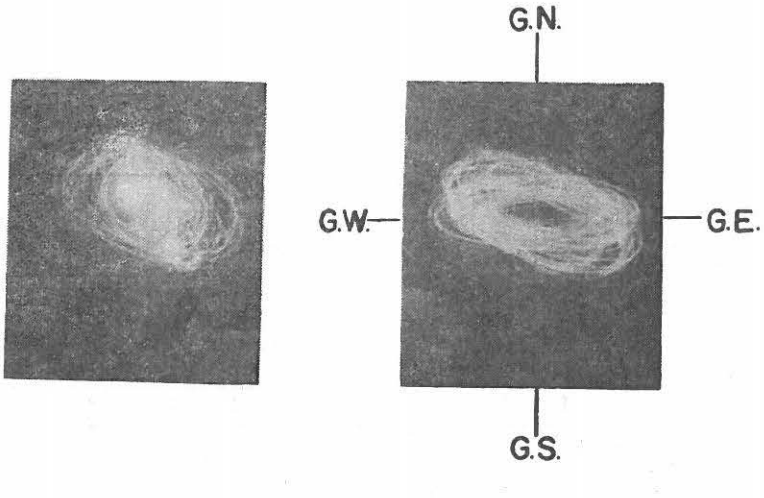

Fig. 6 Oscillographic patterns of the emission at 12KHz on June 4, 1967

4. Discussion

We will discuss the physical aspects of the emissions, taking into consideration the occurrence of the emissions and their correlation with other phenomena as given in the previous report in this volume.

We showed that VLF emissions at 12KHz in the auroral zone occurred during a limited time hours of a day 1800-0100UT. It is not clear at present whether the limited hours of the occurrence may be due to a diurnal variation of radio absorptions in the ionosphere or to mechanism of generating VLF emissions. But the constant radio absorption occurrence rate in the late nighttime 0100-0600UT. is independent of any geomagnetic disturbances. So the mechanism of generating VLF emission (Cerenkov-radiation and gyro-radiation) seem to be predominant factors which determine the diurnal variation of VLF emissions.

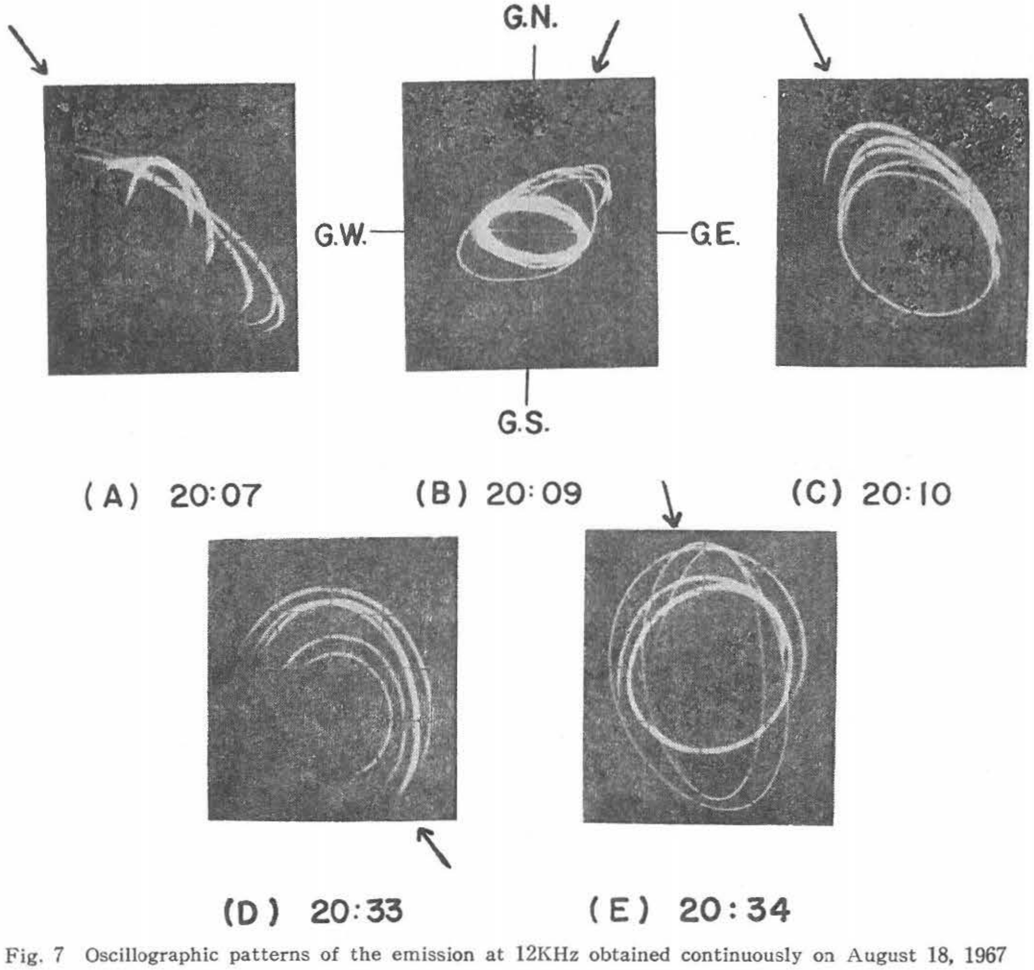

Fig. 7 Oscillographic patterns of the emission at 12KHz obtained continuously on August 18, 1967

Reber and Ellis (1965) observed 520KHz continuous radio noise with flux intensities up to $10^{-22}W/m^2(Hz)^{-1}$.

Omholt (1957) supposed that Cerenkov-radiation may be emitted by electrons in the velosity range of 0.06-0.03c (c: velocity of light) which is the same order of magnitude assumed for electrons produing auroral displays. In facts, we observed at Showa Base the 25KHz band emissions which strongly correlated with active auroral displays. This event seems to be best explanation, if we assume the Cerenkov-radiation.

Helliwell (1965) reported that if the emissions propagated along the geomagnetic field lines in whistler mode, the sense of rotation of polarization would be left-handed in the Southern Hemisphere. This hypothesis seems to have been substantiated by investigating the results obtained at Showa Base. However, as shown in Fig. 1, the emission at 25KHz was quite linealy polarized in winter (July, August and September), and the emission at 12KHz was less polarized in winter than in other seasons. From this facts two propagation modes would be expected. The one is that the precipitation area of the emissions is slighty apart from auroral zone, and the energy propagates from the precipitation area towards the low latitudinal area in wave-guide mode formed between the ionosphere and the ground. The other is that the condition for polarization is variable with frequency in the process of propagation within the ionosphere. It seems to be difficult to clarify either propagagation modes would be predominant at the present observation. Thus, several simultaneous observations will be desired along the latitudinal meridian. Moreover the observations of intensity, polarization and arriving direction at their stations have to be carried out correctly.

Aarons (1960) reported that gyro-frequency of protons of 100km high in the Kiruna area (geomagnetic lat. 65.3°N) is nearby 750Hz. Our observation results showed that the emission at 750Hz in the daytime is clearly left-handed polarized. If the effects of protons are considered, the emissions at 750Hz will show the different state of polarization with that at 12KHz and 25KHz. Above these problems will be discussed by successive observation and several simultaneous observations near auroral zone in future.

Acknowledgement

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