OCCURRENCE OF VLF EMISSIONS AT SHOWA BASE

Masanori NISHINO and Yoshito TANAKA

Abstract

The observation of VLF emissions have been carried out at Showa Base (geomagnetic lat. 69.7°S) in the Antarctic from April 1967 to January 1968, using crossed loop antenna of triangle type and vertical antenna. In this paper, the occurrence of emissions and correlation with other geophysical phenomena are discussed.

VLF emissions at 12KHz occurred almost from 1800 to 0100 UT. in all seasons except for December and January, and the duration of the emissions was 10-20 minutes on average. VLF emissions at 12KHz showed a complicated dependence on geomagnetic disturbances, auroral displays and radio absorptions in the ionosphere.

On the other hand, VLF emissions at 750Hz were seldom to occurr in the daytime, and the duration of such emissions at 750Hz were longer than that at 12KHz. The upper frequency of such emissions was found to be about 4KHz utmost.

1. Introduction

Recently, the studies on the mechanism, and the observations of VLF emissions have been carried out, and the interesting results have been reported by many workers. Since 1963, our group have been observing VLF emissions at Moshiri in Hokkaido (geomagnetic lat. 34°N), and have succeed to obtain an outline of the character of VLF emissions at low latitude. But we did not yet have an oppotunity to know their character at high latitude until 1966. So, our group have desired to observe the emissions at high latitude. Fortunately, since 1966, geophysical observations at Showa Base in the Antarctic have been reopened, in which the observations of VLF emissions have come to be projected by us since 1967.

Observation of VLF emissions in the Antarctic had been made by Helliwell and Martin (1960), Helms (1963), Helliwell (1963) and Morozumi (1962, 63, 65, 66), where the correlation of VLF emissions to geomagnetic disturbances and to aurora were demonstrated and analyzed.

In this paper, we will report the results of VLF emission observation made from April 1967 to January 1968, and investigate its correlation with other geophsical phenomena recorded at Showa Base.

2. Location of Showa Base and observation technique

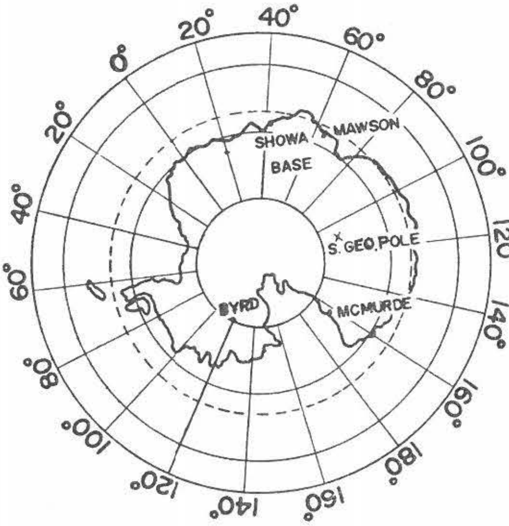

Fig. 1 Observation stations in the Antarctic.

As shown in Fig. 1, the location of Showa Base is as follows:

Geographic	Lat. 69.0°S
	Lon. 39.6°E
Geomagnetic	Lat. 69.7°S
	Lon. 77.4°E

Block diagram of the apparatus used at Showa Base are shown in Fig. 2. The apparatus used to observe the direction of arrival and polarization of VLF emission was described by A. Iwai and Y. Tanaka (1968). The antenna system was oriented along the geomagnetic cordinate. At Showa Base, the relation between the cordinates of geomagnetism and those of geography

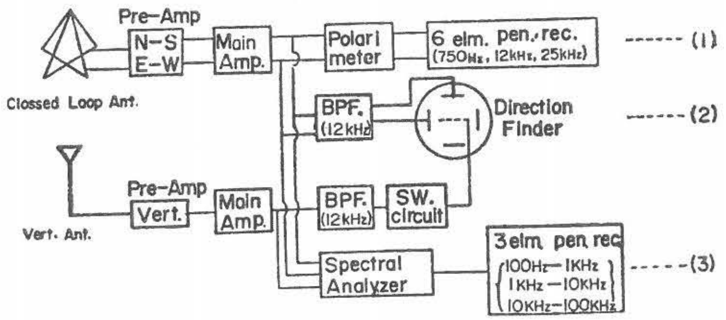

FIg. 2 Block diagram of the apparatus at Showa Base,
crossed loop antenna:
triangle type, 20m high, 40m long, 2 turns
vertical antenna: 10m high

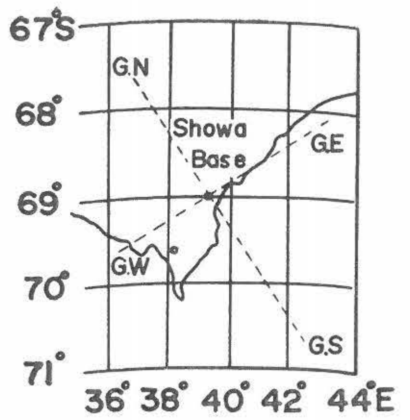

Fig. 3 Relation between the cordinates of geomagnetism and geography at Showa Base.

is shown in Fig. 3. The apparatus (3) in Fig. 2 is a spectral analyzer of the emission. This analyzer consists of 3 channel sweep receivers, whose receiving ranges are 100Hz-1KHz, 1KHz-10KHz and 10KHz-100KHz, respectively. The sweep period of sweep receivers is 1 minute or 10 minutes. Time constant of the detector is 0.5 sec or 5 sec. Usually, the observation was carried out with 1 minute period and 5 sec. time constant.

3. Diurnal variation of VLF emissions

Fig. 4 shows diurnal variation of occurrence hours of VLF emissions at 12KHz observed in the period from April 1967 to January 1968. 12KHz emissions occurred roughly from 1800 to 0100UT. (around magnetic midnight) in the season from April to October, and their maximum came between 2100 and 2200UT. Seasonal variation of the emissions at 12KHz is shown in Fig. 5. Fig. 5 shows that the emissions at 12KHz occurred at more than 24 nights a month through the winter (July, August), the occurrence rate then decreased towards the summer months (December, January). Fig. 6 shows a hystogram of duration of the emissions at 12KHz. The average duration of a series of VLF emission is found roughly to be 10-30 minutes, although it involves strong and sharp spikes of 1-2 minutes duration. In some few cases of geomagnetic disturbances the duration found roughly to be of 4-5 hours.

Fig. 7 shows the diurnal variation of occurrence hours of the emission at 750Hz. In this figure, straight lines with frame indicate the emissions of broad band width more than 10KHz. Another straight lines indicate the emissions of narrow band width less than 4KHz at the most. This figure shows that the emissions at 750Hz occurred almost in the hours of 0800-1500UT. from the September to January, and their maximum came between 1200-1300UT. In addition, the diurnal curves of 4-6KHz band emissions observed at Moshiri in 1963 and 1967 are shown in the same figure.

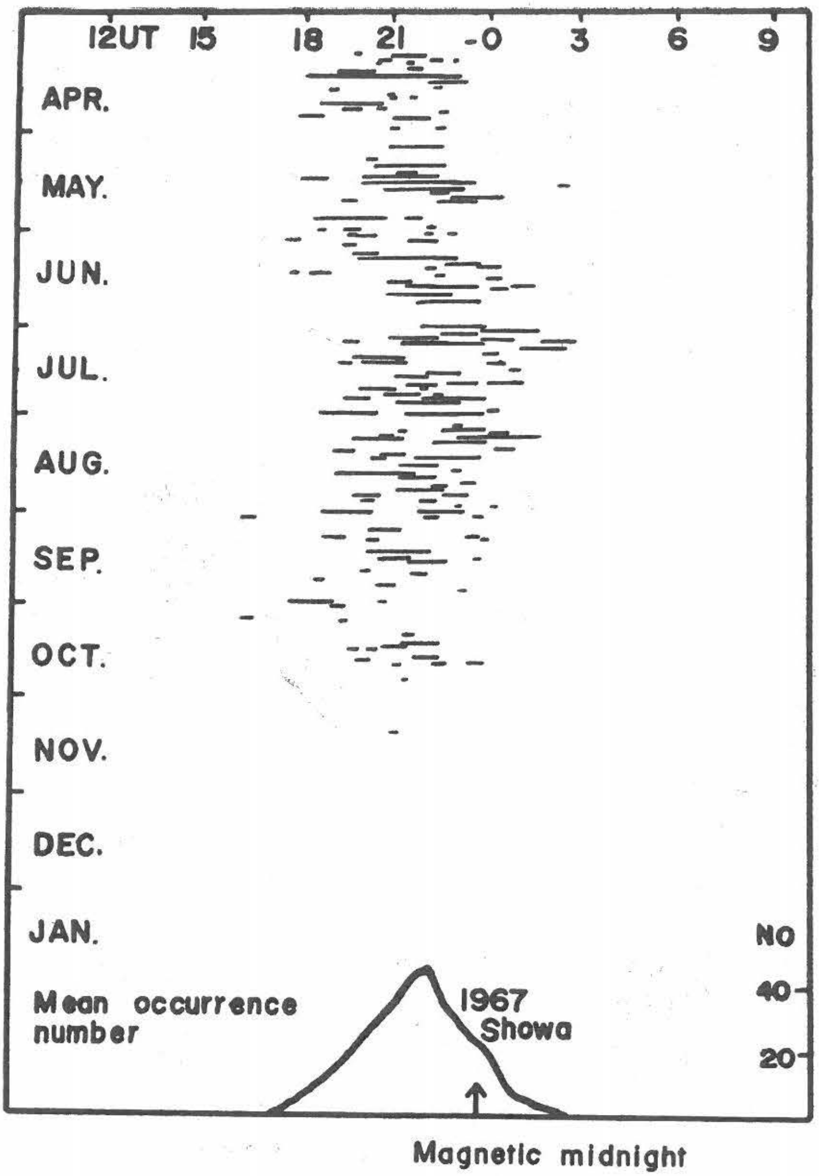

Fig. 4 Diurnal variation of the emissions at 12KHz at Showa Base from April 1967 to January 1968.

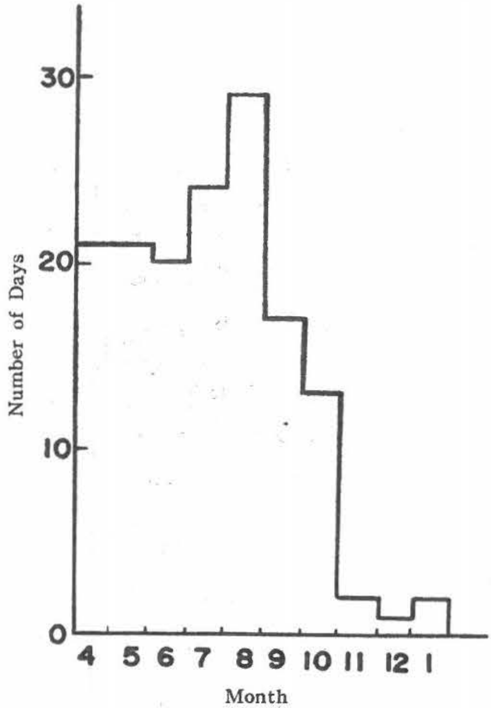

Fig. 5 Seasonal variation of the emission at 12KHz.

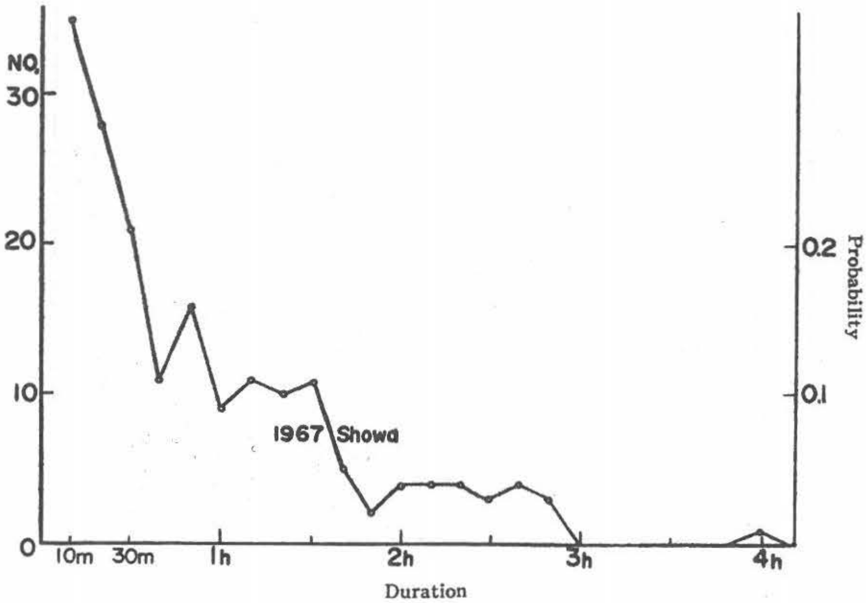

Fig. 6 Hystogram of duration of the emissions at 12KHz.

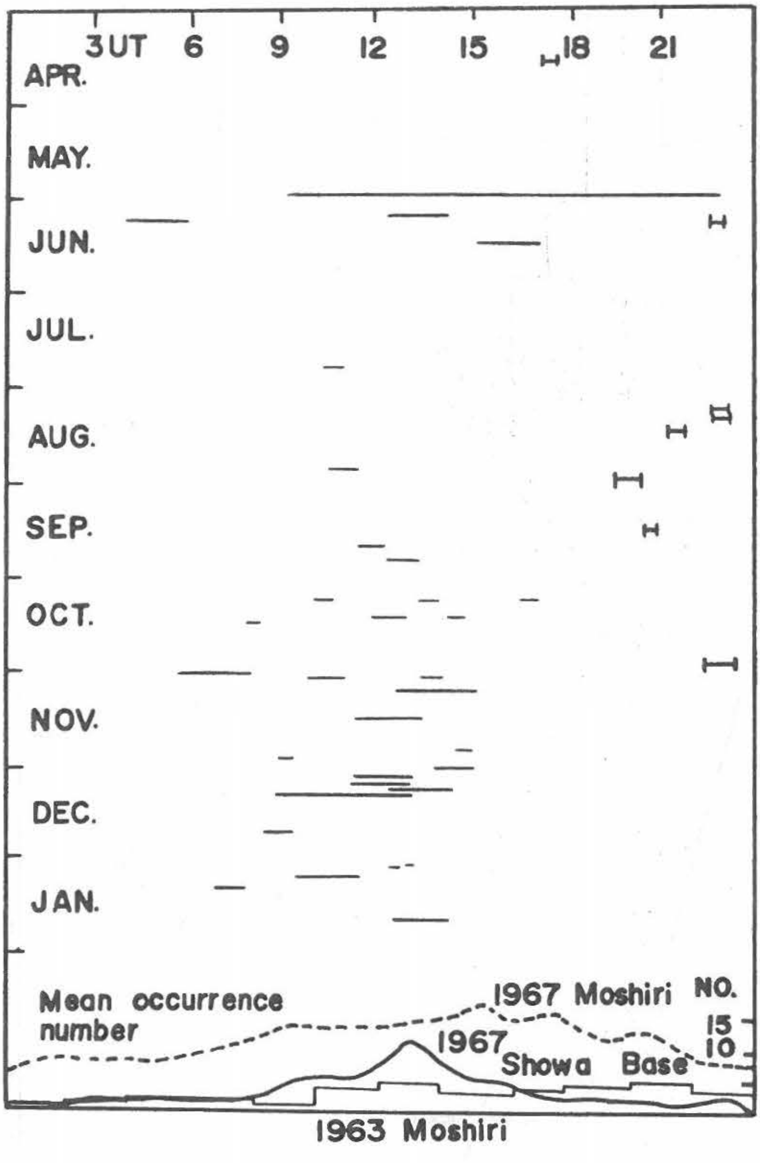

Fig. 7 Diurnal variation of duration of the emissions at 750Hz at Showa Base from April 1967 to January 1968.

Fig. 8 shows a hystogram of duration of the emissions at 750Hz. It is found that the duration of emissions at 750Hz were longer than that at 12KHz and its maximum duration reached 14 hours on hours on the occasion of greatest burst. In this figure to compare with hystograms of duration of the emissions observed at Moshiri in 1963 and 1967 are shown. The number of days, on which the emissions were observed at the both field sites, was 6 through the period from April to December in 1967. The number 6 is equivalent with 25 percent of the total occurrence number of the emissions at 750Hz. But the correlations between the occurrence hours at the two field sites can not be found in the present investigation. Therefore, it is doubtfull that the both stations received the same burst of VLF emissions.

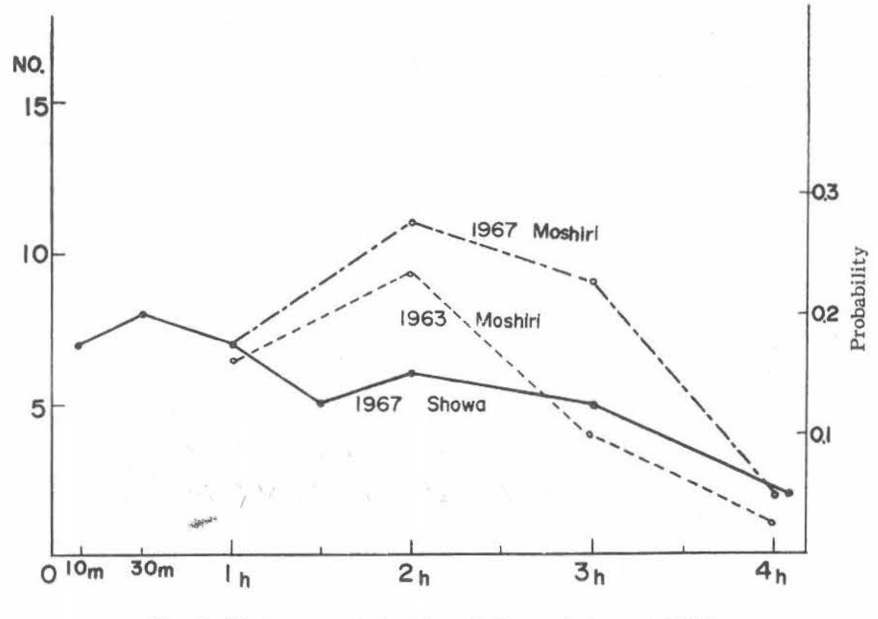

Fig. 8 Hystogram of duration of the emissions at 750Hz.

4. Correlation between VLF emissions and geomagnetic K-index*

Emissions at 12KHz almost occurred around the geomagnetic midnight in all seasons except for summer. Therefore, we have investigated the correlation between the emission at 12KHz and the values of K-index during the time interval 1800-0100UT. This result is shown in Fig. 9. Probability means the rate of number of K-index when emissions occurred to the total number of each range of K-index. So long as the K-index is investigated for K-index less than 3, occurrence number of the emissions at 12KHz is seen to increase as the increase of K-index, but the number begins to decrease beyond

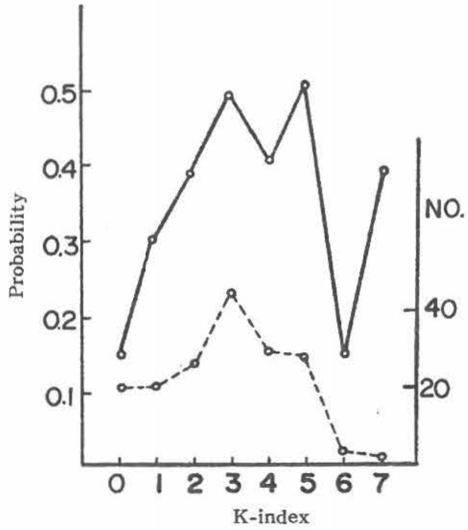

Fig. 9 Relation between occurrence of the emission at 12KHz and K-index
o——o : Occurrence probability versus K-index during 1800-0100UT.
o- - -o : Occurrence number versus K-index during 1800-0100UT.

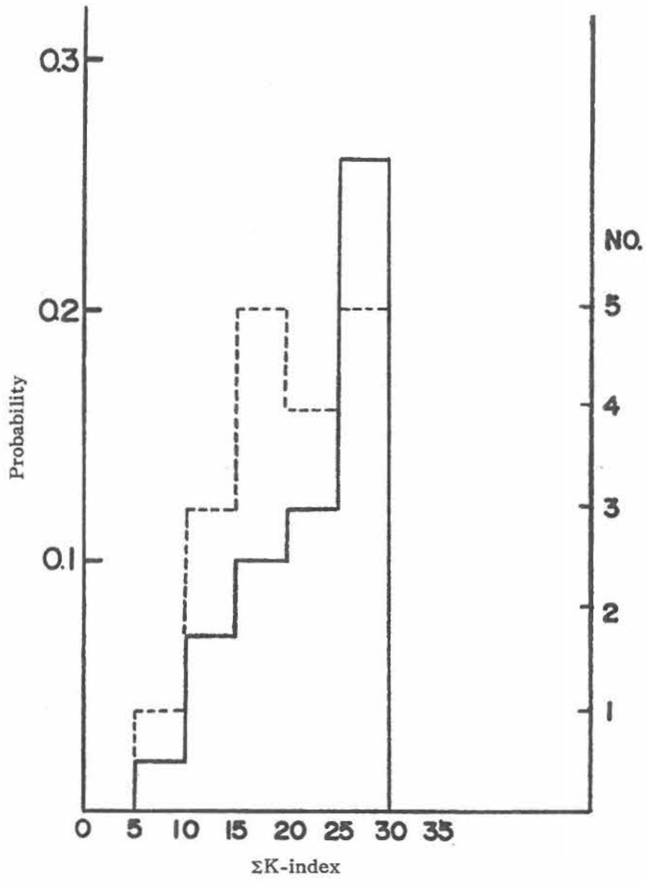

Fig. 10 Relation between occurrence of the emissions at 750Hz and daily sum of K-index expressed in steps K=5.
o——o : Occurrence probability versus ΣK-index.
o- - -o : Occurrence number versus ΣK-index.

the K-index 3. It is remarkable that occurrence probability of total number of days for K≦3 is 40 percent. That is, the emissions at 12KHz occurred considerably even on geomagnetic calm or on slightly disturbed days. But occurrence probability is found to be maximum on middle geomagnetic disturbance (K=3-5), and it decreases on great geomagnetic disturbance (K=6). As the great geomagnetic disturbance exceeding K=7 is seldom in our investigation, occurrence probability for K=7 seems to be doubtfull.

On the other hand, the emissions at 750Hz with longer duration occurrence mostly in the daytime. Therefore, we have investigated the correlation between emissions at 750Hz and daily sum of K-index (ΣK-index). This result is shown in Fig. 10. We see that occurrence number is maximum for ΣK-index around 15-20, that is, for middle geomagnetic disturbances, and it is zero for K-index exceeding 30 which stands for great geomagnetic disturbance. Occurrence probability seems to become maximum in the range 25 to 30 of ΣK-index.

It is not clear whether occurrence probality increases or not for ΣK-index 30 in our investigation.

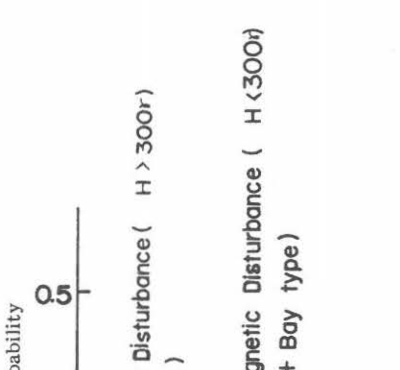

Fig. 11 Correlation between the emissions at 12KHz and disturbance types of geomagnetic horizontal component intensity H.
I : Initial phase of geomagnetic disturbances
M : Main phase of geomagnetic disturbances
L : Last phase of geomagnetic disturbances

5. Correlations among VLF emissions, geomagnetic disturbances, auroral displays and ionospheric absorptions

Fig. 11 shows the correlation between the emissions at 12KHz and types of time variation patterns of geomagnetic horizontal component H. About 30 percent out of the observed emission events correlated with geomagnetic pulsations, and about 20 percent with initial phase of relatively small bay type disturbances (H<300γ). Correlation probability of the emissions observed, with great magnetic disturbances H>300γ is found to be lower

* The classification of K-index at Showa Station is as follows.

K-index	0 (0γ -< 25γ)	5 (350γ -< 600γ)
	1 (25γ -< 50γ)	6 (600γ -<1000γ)
	2 (50γ -< 100γ)	7 (1000γ -<1660γ)
	3 (100γ -< 200γ)	8 (1660γ -<2500γ)
	4 (200γ -< 350γ)	9 (more than 2500γ)

than correlation probability with small magnetic disturbances $H<300\gamma$. But correlation probability with an initial phase is found high in either case of small, and great geomagnetic disturbances. About 25 percent of the occurrence dose not seem to correlate with any geomagnetic diturbances. In an other word, the emissions at 12KHz can occur in some cases even on geomagnetic calm days, as mentioned previously. Typical examples of the record indicating above results are given in.

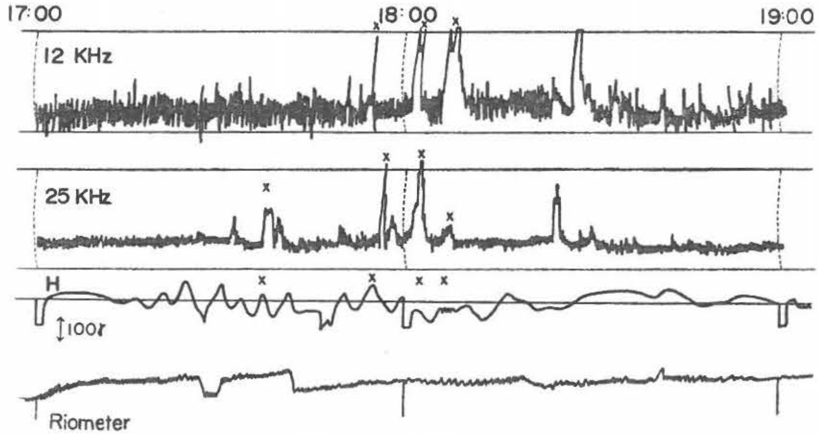

Fig. 12 The emissions at 12KHz and 25KHz during geomagnetic pulsation and radio absorption event in the ionosphere.

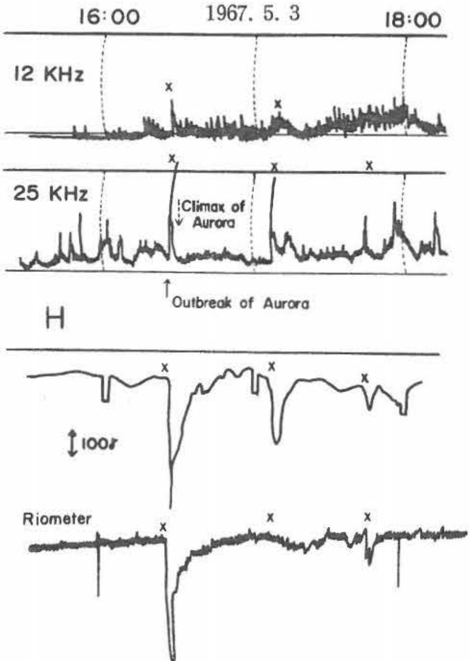

Fig. 13 The emissions at 12KHz and 25KHz at the phase of sharp negative decrease of H component and of sudden dip on the riometer curve.

Fig. 12 illustrates that the emissions occurred during geomagnetic pulsation. Occurrence of the emission roughly corresponded to positive swings in the variation of geomagnetic H component. During this emission radio absorption in the ionosphere could not be observed.

Fig. 13 shows the fact that emissions at 25KHz occurred at the phase of sharp decrease of H, and corresponded to sudden outbreak of active auroral luminosity with duration several minutes. A large radio absorption dip on the riometer record was observed at the same moment. So the duration of the emission was short.

Fig. 14 shows that the emission occurred during negative phase of relatively small geomagnetic bay type disturbance, and before the occurrence of absorption dip in the riometer record. At the moment of sudden radio absorption occurrence on the riometer record, the emission disappeared suddenly,

Fig. 15 shows that emissions occurred during gradual negative phase before a great geomagnetic disturbance. This emission disappeared in the initial great negative phase of H component variation. Similarly, riometer curve decreased suddenly at the commencement of the great negative phase of H component.

1967. 8. 7

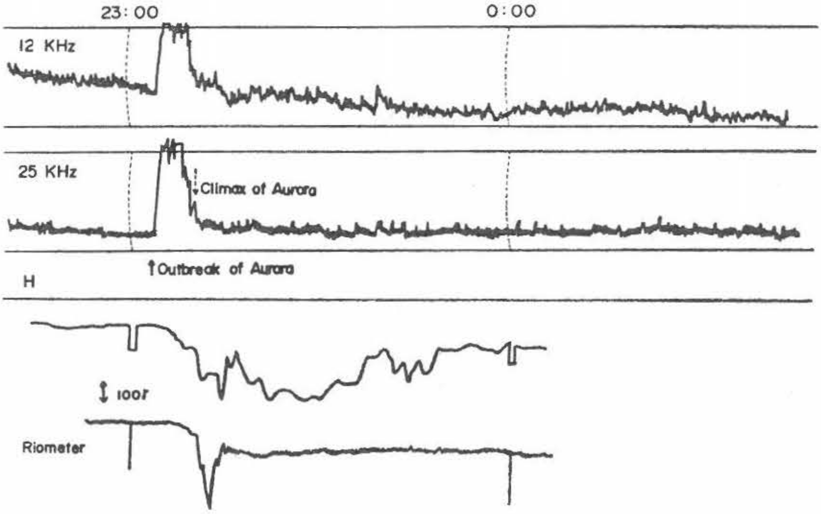

Fig. 14 The emissions at 12KHz and 25KHz during negative phase of geomagnetic disturbance and the dip on the riometer curve.

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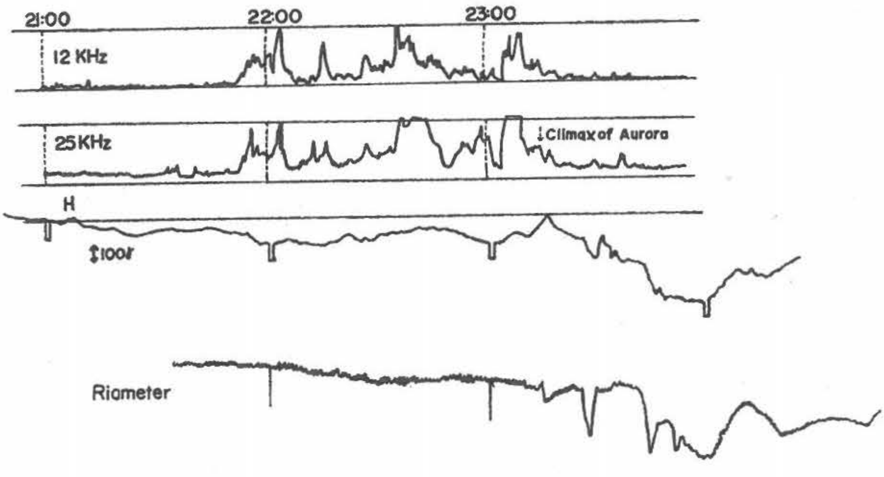
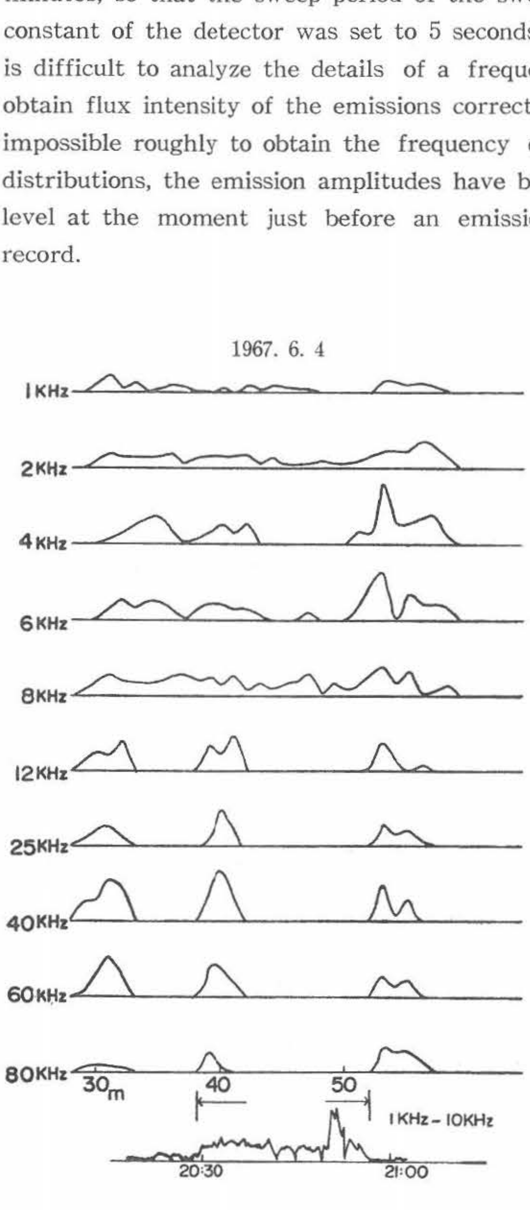


Fig. 15 The emissions at 12KHz and 25KHz during gradual negative phase before the great geomagnetic disturbance and absorption on the riometer curve.

6. Frequency distribution of emissions

Frequency distribution of emissions have been analyzed using the records obtained with apparatus (3) in Fig. 2. The duration of a spike of the emissions was within several minutes, so that the sweep period of the sweep receivers was set to one minute. Time constant of the detector was set to 5 seconds in order to avoid atmospherics noise. So it is difficult to analyze the details of a frequency distribution of the emissions and to obtain flux intensity of the emissions correctly by using these receivers. But it is not impossible roughly to obtain the frequency distribution of the emissions. To get the distributions, the emission amplitudes have been read out referring to background noise level at the moment just before an emission occurrence on each frequency analyzed record.



Fig, 16 Frequency distribution of the emission with single sharp spike.

Fig. 16, on which a sharp spike overlaps, shows the frequency distribution of the emission. At the beginning of the emission, the energy is found to be strong in the 40-60KHz band, and at the commencement of a spike, the energy is concentrated in the 4-6KHz band.

Fig. 17 shows the emission with gradual change. At the beginning of the emission, the energy is strong roughly in the 4-6KHz band, and at the end of the emission the energy is concentrated rather in the 8-12KHz band. From above two figures, the duration of lower frequency component is longer than that of higher frequency component. And two examples of broad emission strongly correlated with sharp negative phase of a geomagnetic disturbance and with an active auroral luminosity.

The emissions, which occurred regularly at night even in the geomagnetically calm days, had a band width of roughly less than 20KHz which was narrower than that of above examples.

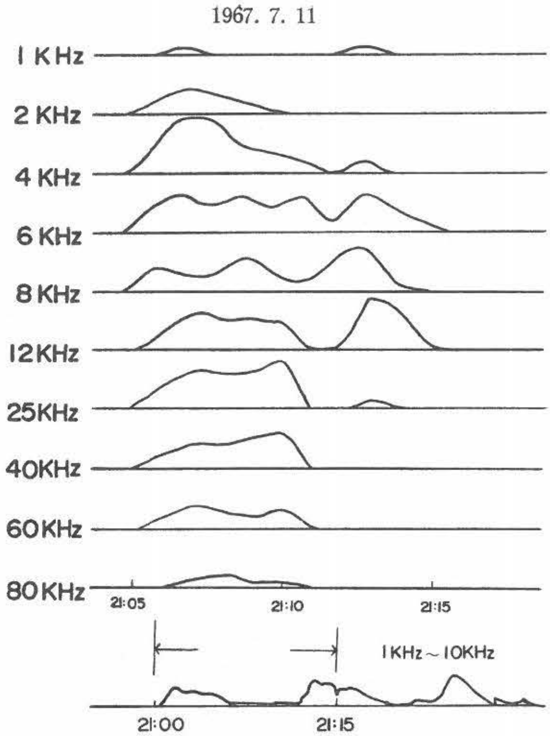


Fig. 17 Frequency distribution of the emission with gradual change.

Incidentally, the record of 1-10KHz band in the two figures were obtaind with a hiss recorder of Tokyo University.

Fig. 18 shows the emission in the daytime in November 1967. This emissions have lasted two hours and half. In the time interval 1245-1315 UT., audible periodic emission with the period of 30-60 seconds was recorded clearly.

The periodic emissions were recorded 5 times from April 1967 to January 1968. The result is listed in Table 1. The highest frequency of the periodic emissions, we observe, with the present analyzer was found to be about 4KHz. The record of Fig. 18 was obtained by hiss recorder of Tokyo University.

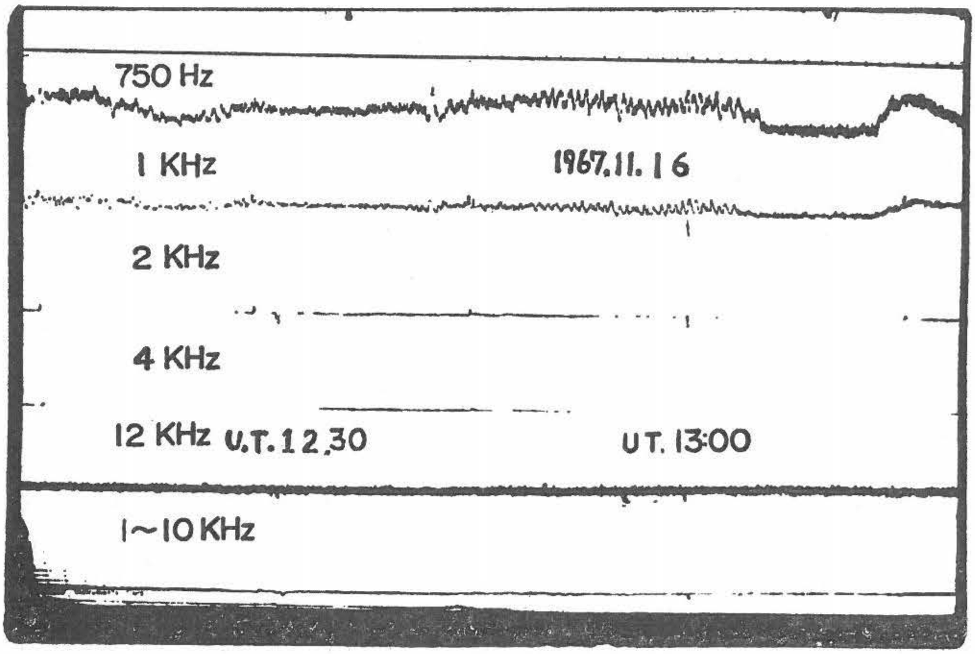


Fig. 18 The emission in the daytime in November.

Table 1. Periodic emissions

Date	Starting time UT.	Duration	Center frequency
1967.			
May. 31	19 h 00m	2 h 15m	2-4KHz
Jun. 15	15 45	0 45	1KHz
Jul. 24	10 15	0 35	2KHz
Nov. 16	12 45	0 30	750Hz
Dec. 7	11 15	0 15	750Hz

7. Concluding remarks

VLF emissions observed at Showa Base seem to be clssified in two types. The one is emissions which occurred around the geomagnetic midnight in all months except for December and January. A family of the midnight type of emissions strongly correlated with the geomagnetic disturbance, auroral displays and radio absorptions in the ionosphere, and the frequency band width of this family was extended to about 100KHz. The other family of the midnight type emissions did not correlate with any of the phenomena above mentioned. The upper most frequency of the emissions were found to be about 20KHz.

The other type is the emissions which occurred in the daytime in all seasons, though the occurrence number was the least in winter. The frequency band width of this type emissions is from several hundred Herz to 4KHz. This type includes a few families such as periodic emission and so on. Correlation between the emissions in the daytime and the other geophysical phenomena will be investigated further.

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