# Occurrence of VLF Emissions at Syowa Station

Masanori NISHINO* and Yoshito TANAKA*

# 昭和基地における VLF エミッションの発生

西野正徳*・田中義人*


## 要　旨

1967年4月から1968年1月まで，昭和基地（地磁気緯度69 7°S）において，VLF 帯電磁放射の観測を行なった 受信アンテナは，直交枠形アンテナと垂直アンテナを用いた ここでは VLF 放射の発生の性格と，他の超高層物理現象との相関について報告する

12kHz 帯の VLF の放射は，12月，1月の夏を除いたすべての季節において，夜18 00から01 00UT に発生した

放射の継続時間は平均して10分から20分が多く，概して地磁気嵐，オーロラ出現，電離層における電波吸収現象と複雑な相関を持っている

一方750Hz 帯の VLF 放射は，その発生頻度は少ないが，主に昼間に生じた

放射の継続時間は，12kHz帯の放射のそれより長く，大きな地磁気嵐時には，数時間に及ぶものもあった 750kHz 帯放射の占有帯域幅の上限はせいぜい 4kHz 程度であった

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

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

On the other hand, VLF emissions at 750Hz seldom occurred in the daytime, and their duration was longer than that at 12kHz. The occupied highest frequency of such emissions was found to be about 4kHz at most.


*名古屋大学空電研究所　The Research Institute of Atmospherics, Nagoya University, Toyokawa.

## 1. Introduction

In recent years, VLF emissions and the mechanism have been studied and interesting results have been reported by many workers. Since 1963, our group has been observing VLF emissions at Moshiri in Hokkaido (geomagnetic lat 34°N), and has succeeded to obtain an outline of the character of VLF emissions at low latitudes. But until 1966 we had no opportunity to know their character at high latitudes. Fortunately, the geophysical observations at Syowa Station in the Antarctic were resumed in 1966, and our project of VLF emission observation made a start in 1967

Observation of VLF emissions in the Antarctic had been made by HELLIWELL and MARTIN (1960), HELMS (1963), HELLIWELL (1963) and MOROZUMI (1962, 1963, 1965, 1966), and the correlation of VLF emissions to geomagnetic disturbances and to aurora was demonstrated and analyzed.

In this paper, the results of VLF emission observation made from April 1967 to January 1968 are reported, and the correlation between VLF emissions and other geophysical phenomena recorded at Syowa Station is discussed.

## 2 Location of Syowa Station and Observation Technique

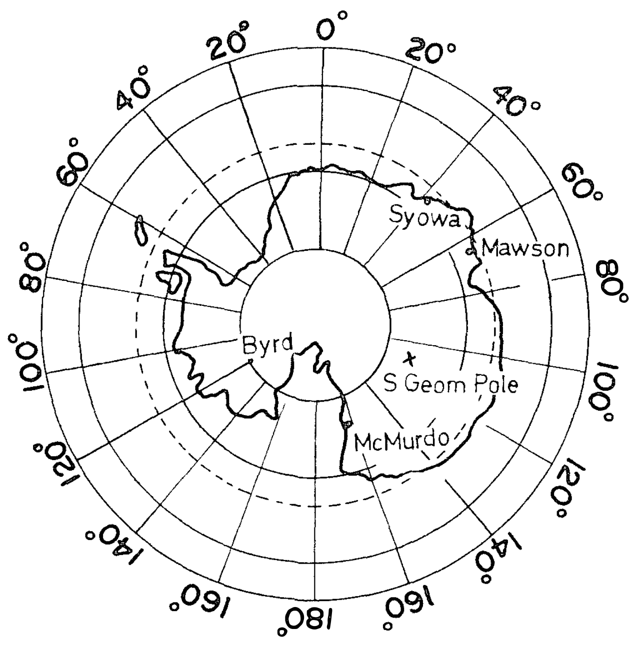


*Fig 1 Observation stations in the Antarctic*

As shown in Fig. 1, the location of Syowa Station is as follows:

Geographic Lat. 69.0°S<br>
Long. 39.6°E<br>
Geomagnetie Lat. 69.7°S<br>
Long. 77.4°E

Fig. 2. is a block diagram of the apparatus used at Syowa Station. The apparatus used in observation of the direction of arrival and polarization of VLF emissions was described by IWAI and TANAKA (1968). The antenna system was oriented along the geomagnetic coordinate. The relation between the coordinates

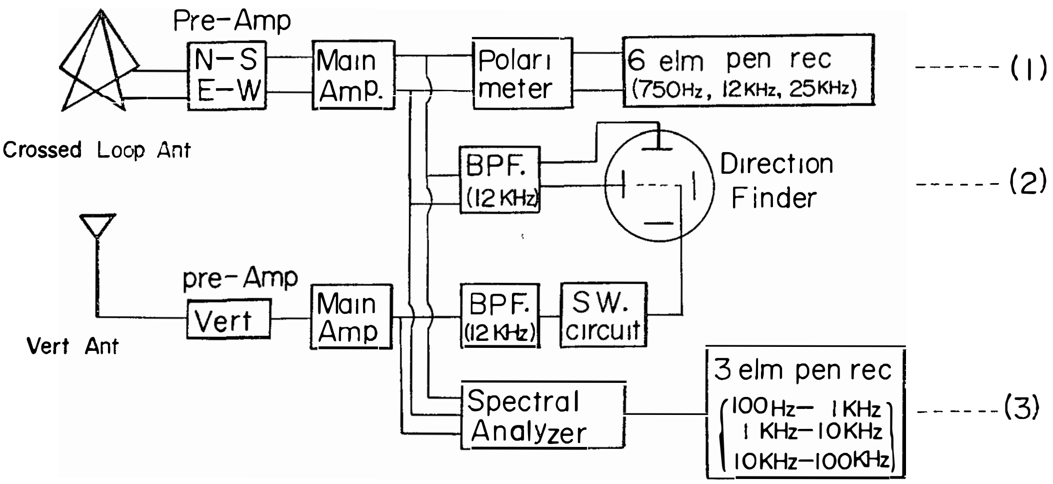


*Fig 2 Block diagram of the apparatus at Syowa Station*
*Crossed loop antenna· triangle type, 20m high, 40m long, 2 turns*
*Vertical antenna: 10m high*

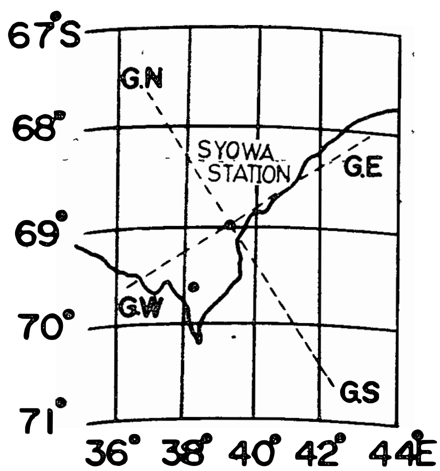


*Fig 3 Relations of the coordinates of geomagnetism and geography at Syowa Station*

of geomagnetism and those of geography at Syowa Station is shown in Fig 3. The apparatus (3) in Fig. 2 is a spectral analyzer, consisting of 3 channel sweep receivers, with receiving ranges 100Hz-1kHz, 1kHz-10kHz and 10kHz-100kHz, respectively. The sweep period of the receivers is 1 minute or 10 minutes Time constant of the detector is 0 5s or 5s Usually, the observation was carried out with 1 minute period and 5s time constant.

## 3. Diurnal Variation of VLF Emissions

Fig. 4 shows the diurnal variation of occurrence hours of VLF emissions at 12kHz during the period from April 1967 to January 1968. From April to October, the 12kHz emissions occurred mostly between 1800 and 0100 U.T. (around magnetic midnight), and culminated between 2100 and 2200U.T. Seasonal variation of the emissions at 12kHz is shown in Fig 5. It shows that these emissions occurred more

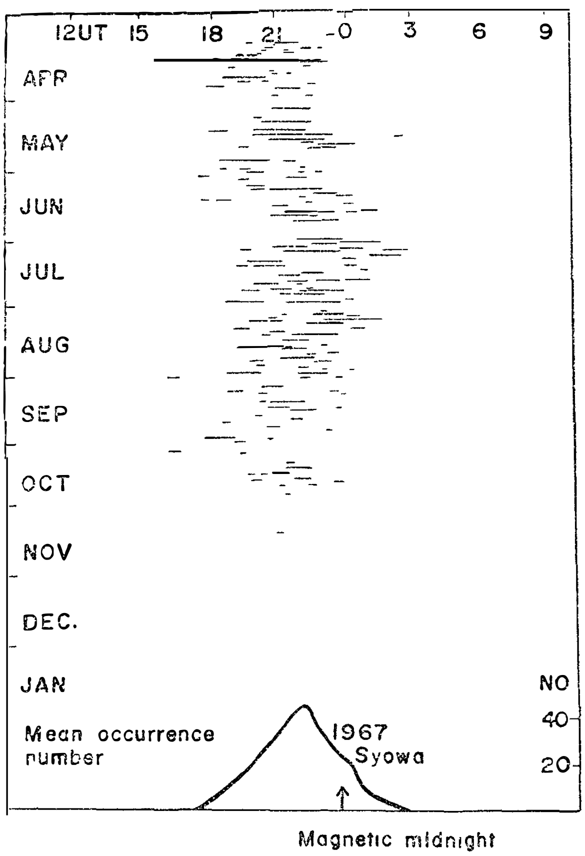


*Fig 4 Diurnal variation of the emissions at 12kHz at Syowa Station from April 1967 to January 1968*

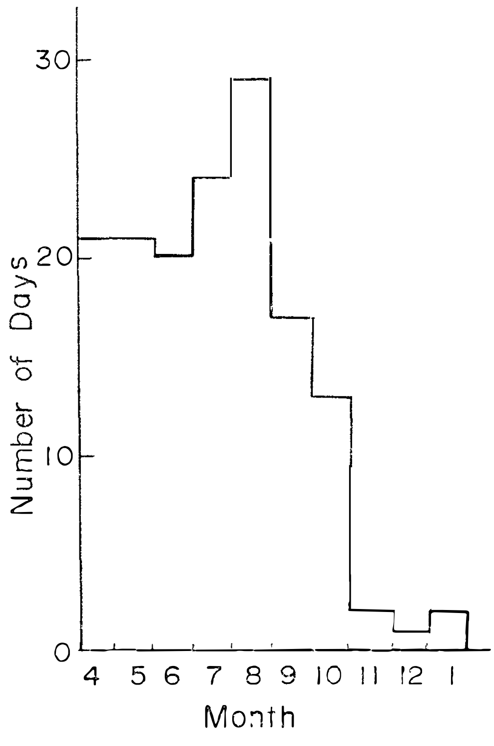


*Fig 5 Seasonal variation of the emission at 12kHz*

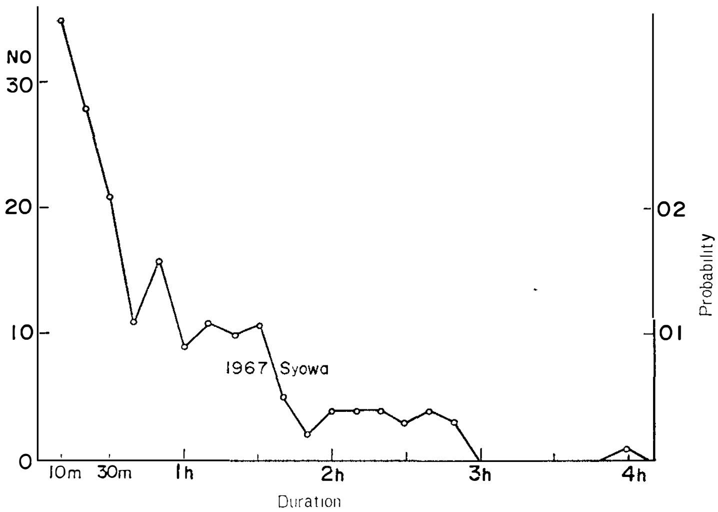


*Fig 6 Hystogram of duration of the emission at 12kHz*

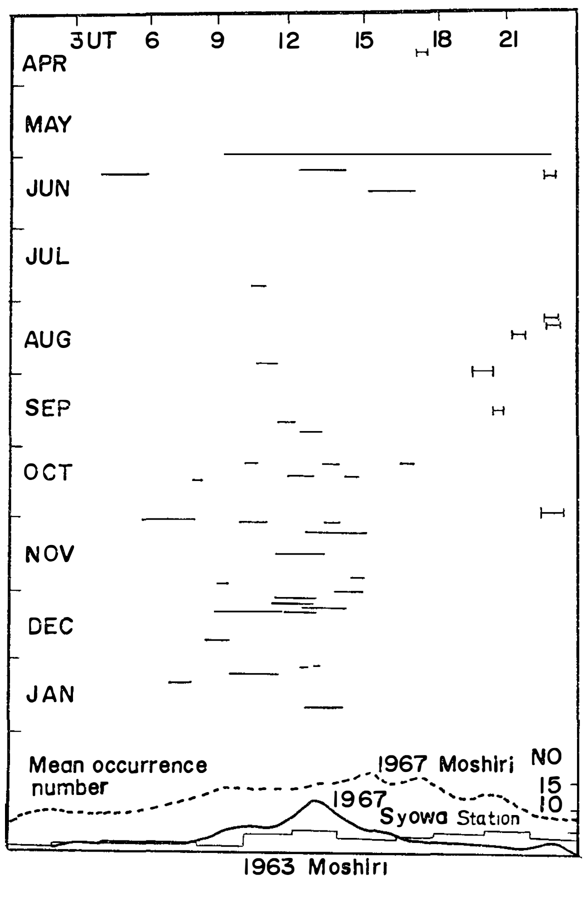


*Fig 7 Diurnal variation of duration of the emissions at 750Hz at Syowa Station from April 1967 to January 1968*

than 24 nights a month through the winter (July, August), and the occurrence frequency decreased towards the summer months (December, January) Fig 6 is a hystogram of duration of the emissions at 12kHz. The average duration of VLF emissions is found to be 10–30 minutes, although it involves strong and sharp spikes of 1–2 minutes duration. In a few cases of geomagnetic disturbance the duration was roughly 4–5 hours.

Fig 7 shows the diurnal variation of occurrence hours of VLF emissions at 750Hz. In this figure, straight lines with frame(|—|) indicate the emissions of broad band width more than 10kHz. Other straight lines indicate the emissions of narrow band width less than 4kHz at the most. It is known from the figure that from September to January the emissions at 750Hz occurred almost always in the hours of 0800–1500U.T. with the maximum between 1200–1300U.T For comparison, the diurnal curves of 4–6kHz band emissions observed at Moshiri in 1963 and 1967 are shown in the same figure.

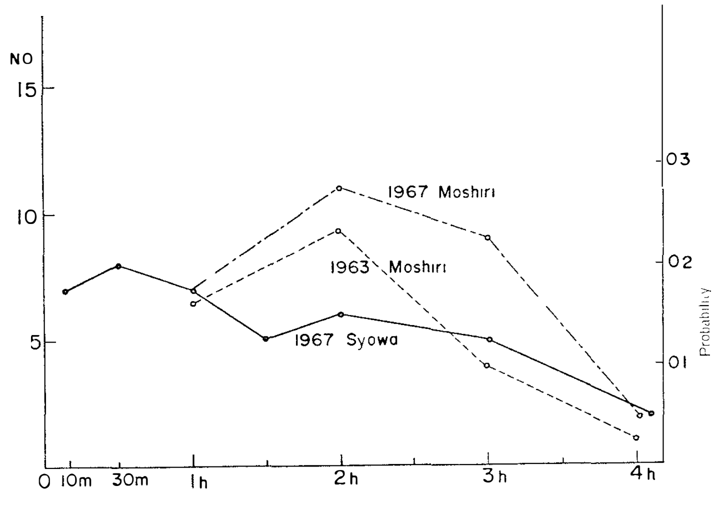


*Fig 8 Hystogram of duration of the emissions at 750Hz*

Fig. 8 is a hystogram of duration of the emissions at 750Hz. It is found that the duration of these emissions was longer than that at 12kHz and the maximum duration amounted to 14 hours on the occasion of the greatest burst. For comparison, the hystograms of duration of the emissions observed at Moshiri in 1963 and 1967 are shown in the same figure. The number of days when during the emissions were observed at the both field sites was 6 during the period from April to December in 1967. The number 6 is equivalent to 25 percent of the total occurrence of the emissions at 750Hz. But the occurrence hours showed no correlation between the two field sites in the present investigation. Therefore, it is doubtful that the both stations received the same burst of VLF emissions.

## 4. Correlation between VLF Emissions and Geomagnetic K-index*

Emissions at 12kHz occurred almost around the geomagnetic midnight in all seasons except for summer. Therefore, we have investigated the correlation between the emissions at 12kHz and the values of K-index during the time from 1800 to 0100U.T. The obtained result is shown in Fig. 9. The probability is the

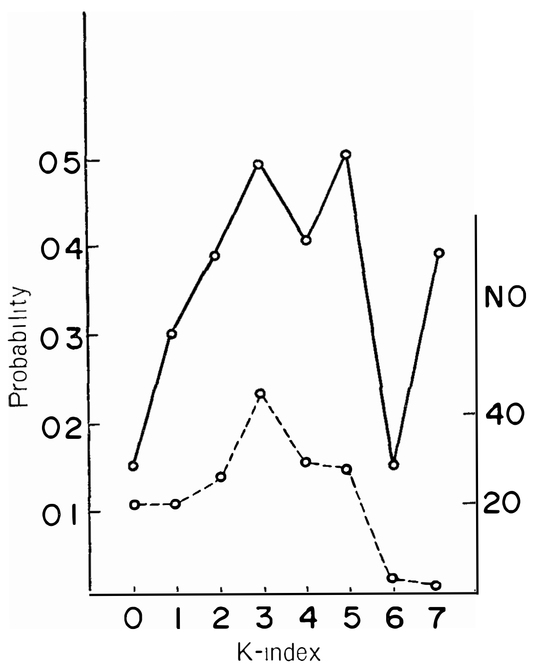


*Fig 9 Relation between occurrence of the emission at 12kHz and K-index.*

○——○ *Occurrence probability versus K-index during 1800–0100U T*

o---o *Occurrence number versus K-index during 1800–0100U T*

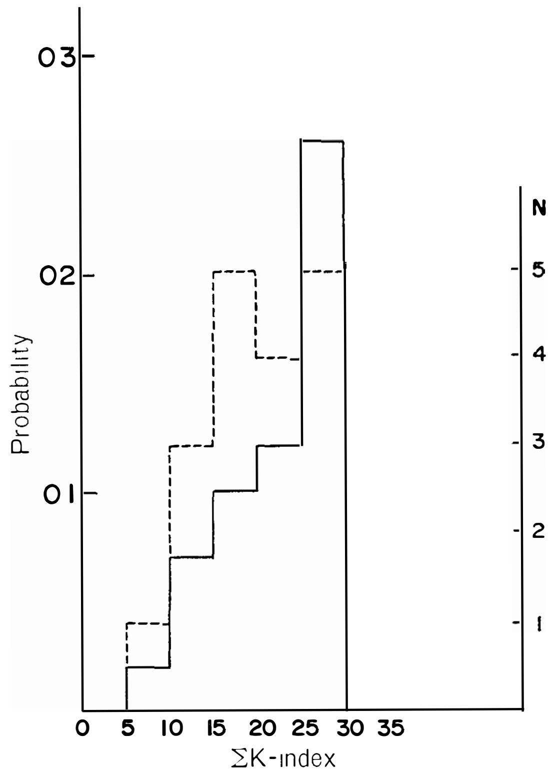


*Fig 10 Relation between occurrence of the emissions at 750Hz and daily sum of K-index.*

—— · *Occurrence probability versus ΣK-index*

---- · *Occurrence number versus ΣK-index*

---

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

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

ratio of number of K-index when emissions occurred to the total number in each range of K-index. So far as the K-index is less than 3, the number of occurrence of the emissions at 12kHz is seen to increase with the increase of K-index, but the number begins to decrease beyond the K-index 3 It is remarkable that the occurrence probability of the total number of days for K≦3 is 40 percent That is, emissions occurred at 12kHz considerably even on geomagnetically calm or slightly disturbed days. But the occurrence probability attains its maximum in moderate geomagnetic disturbances (K=3–5), and decreases in great geomagnetic disturbances (K=6). At strong geomagnetic disturbances exceeding K=7 were seldom recorded in our investigation, the occurrence probability of K=7 seems to be doubtful.

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

Whether the occurrence probability increases or not for ΣK-index 30 is not clear in our investigation.

## 5 Correlations among VLF Emissions, Geomagnetic Disturbances, Auroral Displays and Ionospheric Absorption

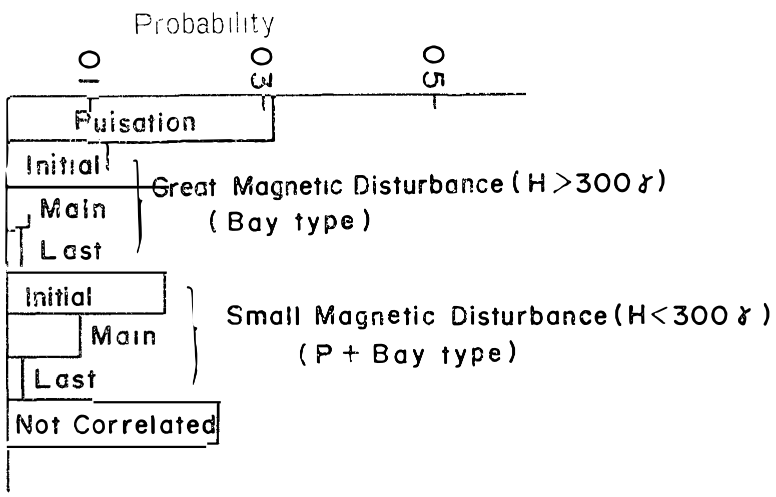


*Fig 11 Correlation between the emissions at 12kHz and disturbance types of geomagnetic horizontal component intensity H*
*Initial Initial phase of geomagnetic disturbances*
*Main Main phase of geomagnetic disturbances*
*Last Last phase of geomagnetic disturbances*

Fig. 11 shows the correlation between the emissions at 12kHz and the 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 the initial phase of relatively small bay type disturbances ($H<300\gamma$). The correlation probability of the observed emissions with great magnetic disturbances $H>300\gamma$ is found to be lower than the one with small magnetic disturbances $H<300\gamma$. But the 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 disturbances. In other words, emissions at 12kHz can occur even on geomagnetic calm days, as mentioned previously. Typical examples of the record indicating the above results are given as follows.

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

Fig. 13 shows that emission at 25kHz occurred at the phase of sharp decrease of H, and corresponded to a sudden outbreak of active auroral luminosity which lasted several minutes. A large radio absorption dip on the riometer record was

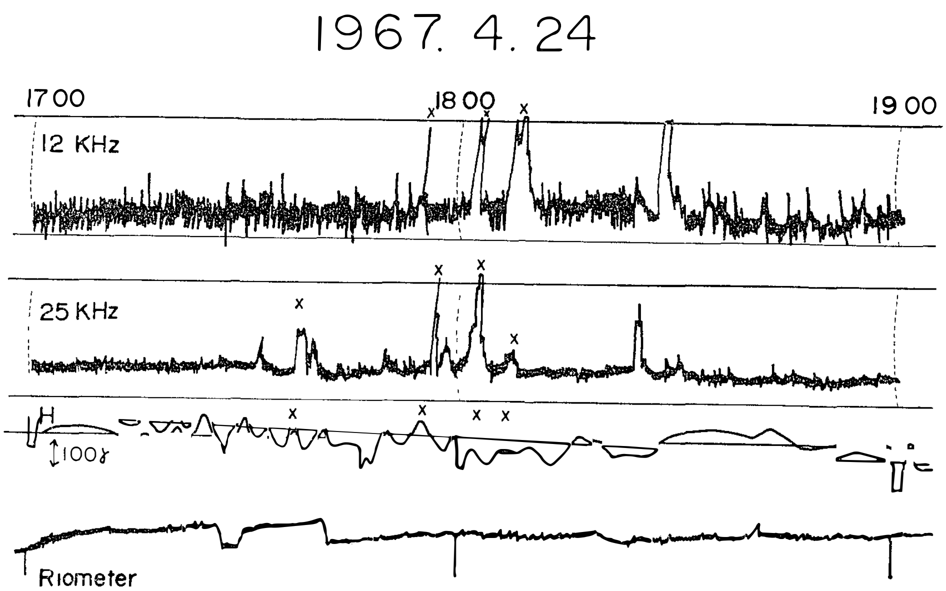


*Fig 12 The emissions at 12kHz and 25kHz during geomagnetic pulsation and radio absorption event in the ionosphere*

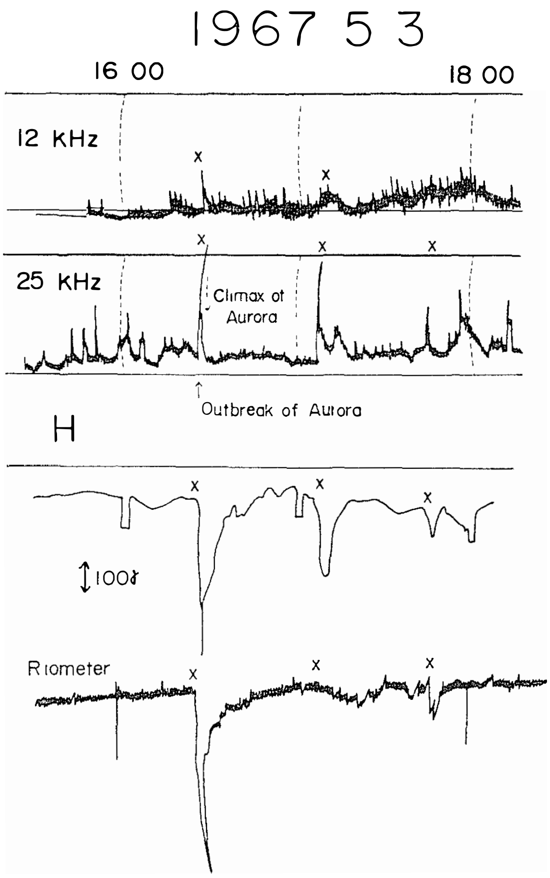


*Fig 13 The emissions at 12kHz and 25kHz at the phase of sharp negative decrease of H component and of a sudden dip on the riometer curve*

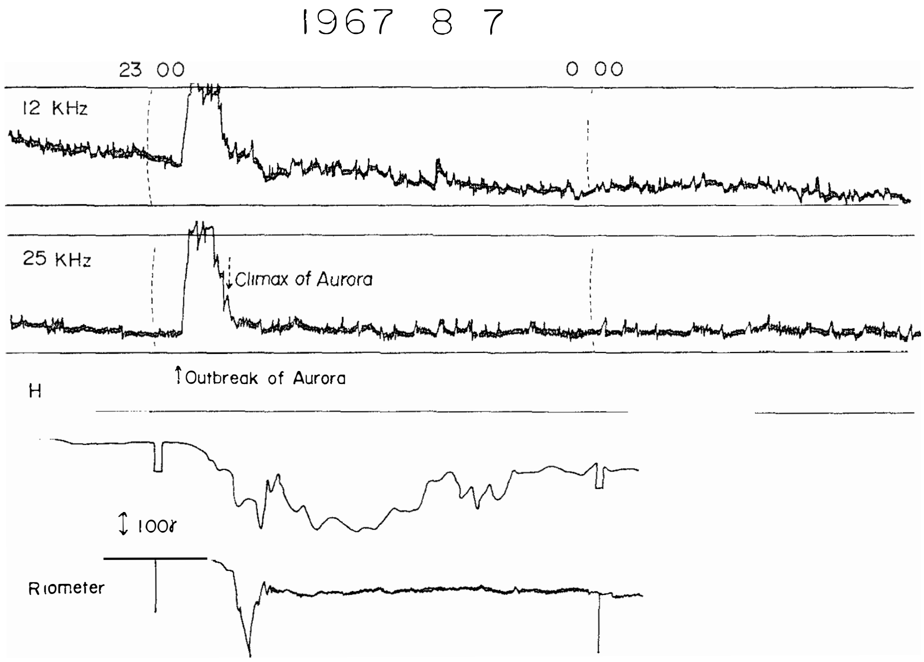


*Fig 14 The emissions at 12kHz and 25kHz during the negative phase of geomagnetic disturbance and the dip on the riometer curve*

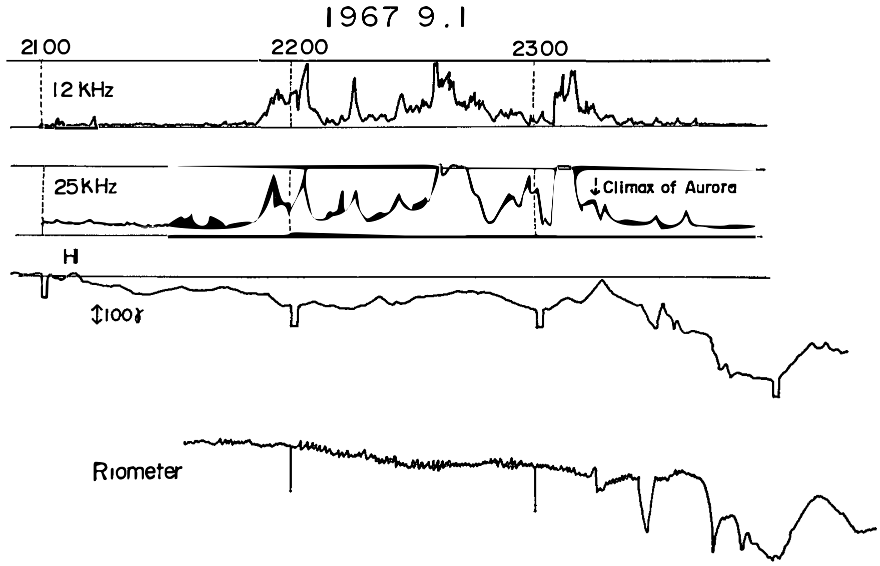


*Fig 15 The emissions at 12kHz and 25kHz during the gradual negative phase before the great geomagnetic disturbance and absorption on the riometer curve*

observed at the same moment. So, the duration of each spikes of the emission at 25kHz was short.

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

Fig. 15 shows that emission occurred during a gradual negative phase before a great geomagnetic disturbance. And this emission disappeared at the commencement of the great negative phase of H component variation. Similary, the riometer curve decreased suddenly at the commencement of the great negative phase of H component.

## 6. Frequency Distribution of Emissions

Frequency distribution of emissions has 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 at one minute. Time constant of the detecter was set at 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 with these receivers. But it is not impossible to obtain a rough frequency distri-

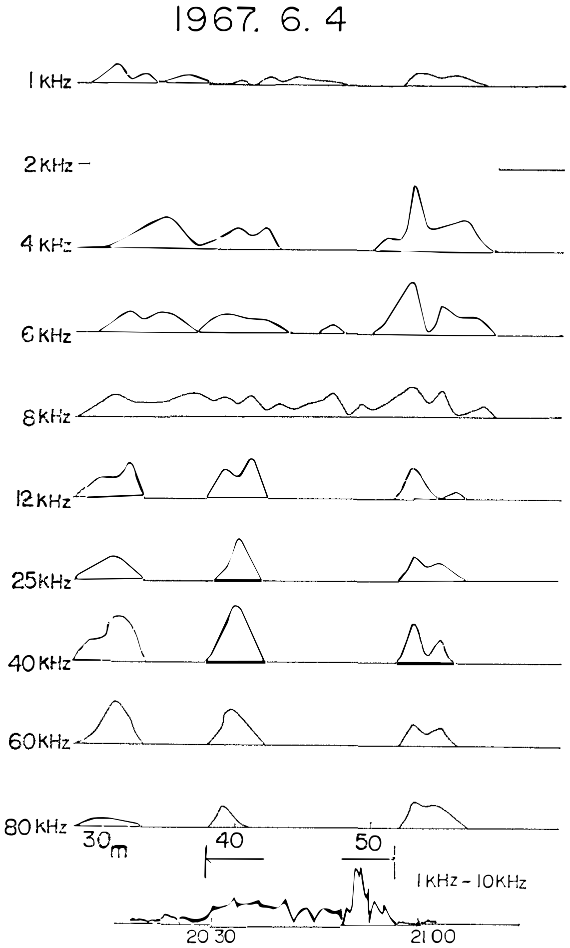


*Fig. 16 Frequency distribution of a emission with a single sharp spike*

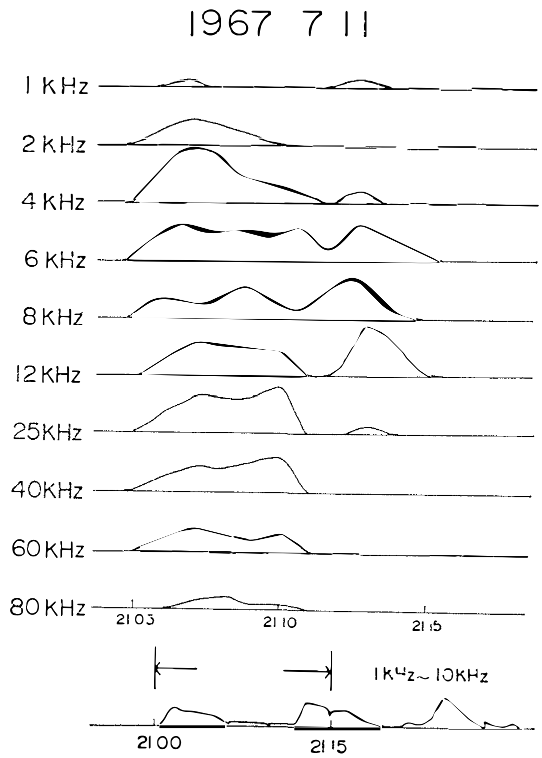


*Fig. 17 Frequency distribution of a emission with gradual change*

bution of the emissions. To obtain the distribution, the emission amplitudes have been read out referring to the background noise level at the moment just before an emission occurs in each frequency analyzed record.

Fig. 16 shows the frequency distribution with single sharp spike. 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 frequency distribution of the emission with a 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 the above two figures, the duration of lower frequency component is longer than that of higher frequency component. And two examples of broad band emissions are distinctly correlated with a sharp negative phase of a

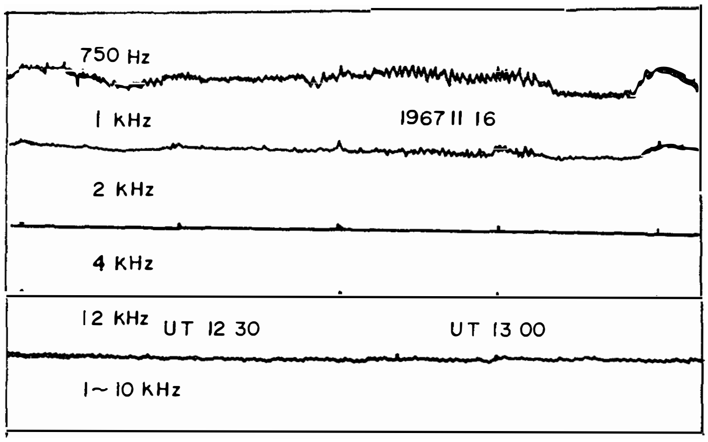


*Fig 18 A emission in the daytime in November*

geomagnetic disturbance and with an active auroral luminosity.

Emissions which occurred regularly at night of even on the geomagnetically calm days had a band width of roughly less than 20kHz, which was narrower than that of the above examples. Incidentally, the record of the 1–10kHz band in the figures was obtaind with a hiss recorder of the University of Tokyo.

Fig. 18 shows emissions in the daytime in November 1967. The emissions have lasted two hours and half. In the time interval 1245–1315U.T. an audible periodic emission with the period of 30–60 seconds was recorded clearly. 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 observed with the present analyzer was found to be about 4kHz. The record of Fig. 18 was obtained with the hiss recorder of the University of Tokyo.

*Table 1 Periodic emissions*

| Date | Starting time (U.T.) | Duration | Center frequency |
|---|---|---|---|
| 1967 | | | |
| May 31 | $19^{h}00^{m}$ | $2^{h}15^{m}$ | 2–4kHz |
| June 15 | 15 45 | 0 45 | 1kHz |
| July 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 Syowa Station may be classified in two types. The one is those which occurred around the magnetic midnight in all months except for December and January. A group of emissions of the midnight type is distinctly correlated with geomagnetic disturbances, auroral displays and radio absorptions in the ionosphere, and the frequency band width of this group was extended to about 100kHz. Another group of the midnight type emissions was not correlated with any of the phenomena above mentioned. The occupied highest 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 emissions of this type is from several hundred Herz to 4kHz This type includes continuous emissions and discrete emissions. Correlation between the emissions in the daytime and the other geophysical phenomena will be investigated further.

**Acknowledgements**

We wish to express our sincere thanks to Prof. A. IWAI, Associate Prof. J OHTSU and Associate Prof. T. KAMADA of the Research Institute of Atmospherics of Nagoya University for their kind guidance and advise. Our sincere thanks are also due to Dr. T. HIRASAWA, Dr. K. KAMINUMA, Mr M. OSE and Mr. I. NISHIMUTA of the group of the 8th Japanese Antarctic Research Expedition for kindly offering us the data at Syowa Station.

**References**

HARANG, L and K N HAUGE (1965) Radio wave emissions in the v l f band observed near the auroral zone 1 Occurrence of emissions during disturbances J Atmos Terr Phys, **27**, 481-497

HARANG, L (1968) VLF emissions observed at stations close to the auroral zone and at stations on lower latitudes J Atmos Terr Phys, **30**, 1143-1160

HELLIWELL, R A (1965) Whistlers and Related Ionospheric Phenomena, Stanford Univ Press

HELMS, W. J and J P TURTLE (1964) A Cooperative Report on the Correlation between Auroral, Magnetic and ELF Phenomena at Byrd Station, Antarctica, Stanford Univerity Radioscience Laboratory

IWAI, A , J. OUTSU and Y TANAKA(1964). The observatıon of VLF emıssıons at Moshırı Proc Res. Inst. Atmos Nagoya Unıv , **11**, 29-40,

IWAI, A. and Y. TANAKA(1968) Measurement of polarızatıon, ıncıdent angle and dırectıon of VLE Fmıssıons (1) Proc. Res. Inst. Atmos Nagoya Unıv , **15**, 1-16.

TANAKA, and M KASIWAGI(1968) Correlatıon between VLF hıss and geomagnetıc actıvıty ın Hokkaıdo Proc. Res Inst. Atmos Nagoya Unıv , **15**, 67-73

(*Receıved Aprıl 17, 1969*)