Frequency of Pulsation and Geomagnetic Activity

By KAZUO YANAGIHARA

摘　要

脈動の頻度と地磁気活動度との関係については前論文[6]にても多少論及したが，こゝでは頻度日変化の経度効果を地磁気活動度の日変化のそれに基いて説明を試みた．脈動の出現頻度の日変化は主として地方時に従つて経過するが，経度によつて極大の現れる時刻が系統的に異つている．これは地磁気活動度の変化と統計的に平行関係にある脈動の一次原因の活動度が世界時に従つて変化すること，即ち地球のどの経度が太陽の方を向いているかによつて変化すること，によつて説明される．

§ 1. Introduction

It is fairly well known that pulsations of geomagnetic field or earth-currents can be classified into two groups. The one is called as "night pulsation" (by Scholte and Veldkamp, 1955[1]), or "burst oscillation" (by Troyickaya, 1955[2]) and so on. Recently Dr. Romana, Chairman of the Committee of Rapid Magnetic Variation and Earth Current, I. U. G. G., proposed to assign the symbol pt to this group of pulsations.

In the present stage of available data of pt-pulsations, the discussions of their world-wide distribution of field components are impossible, because the most reliable and widely collectable data are of the diurnal variations of frequency. The frequency of pt-pulsations generally reaches its maximum at about local midnight, but the time of maximum frequency slightly changes according to the longitude. In Europe this time is found in somewhat earlier hour than midnight, while in East Asia or West America the frequency reaches its maximum after midnight. This longitude effect may be due to the universal time variation of the original intensity of pulsation.

§ 2. Diurnal variation of frequency

Fig. 1 shows the diurnal variation of frequency of pt-pulsation for eight stations. In early stage of investigation the classification of pulsation was not so well defined as at present, but the pulsation of longer period may almost belong to the pt-group. In the figure the curves of Samoa, Batavia and Zikawei are based on the early data by Lubiger[3]. The curves for Göttingen and Central Asia are due to the recent results of Angenheister[4] and Troyickaya[2], respectively. Though

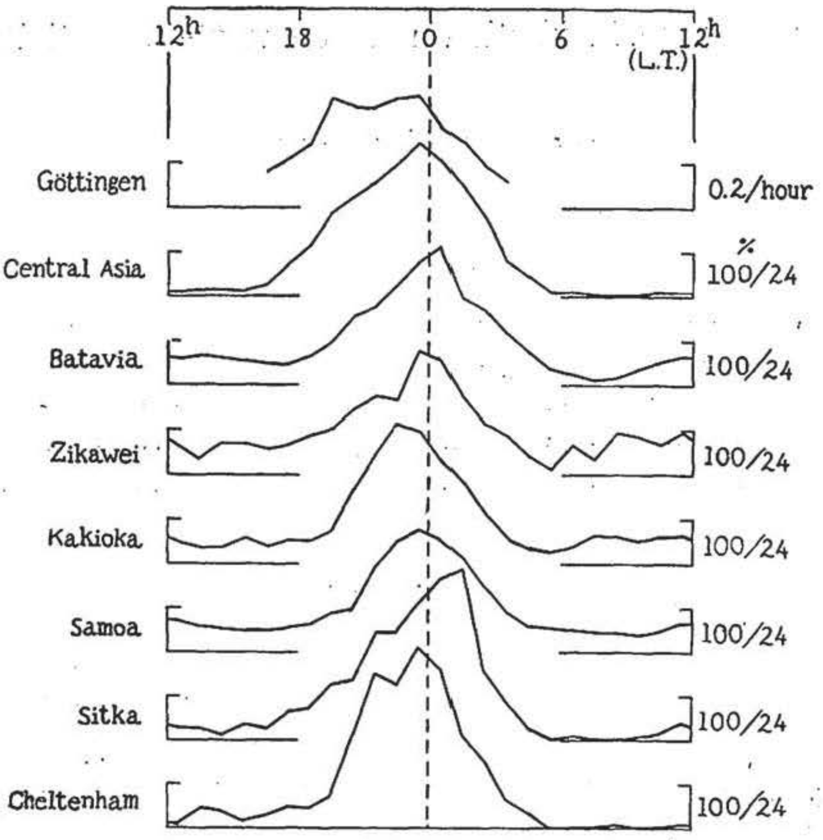

Fig. 1. Diurnal variations of frequency

Troyickaya has stressed that the diurnal variation of frequency proceeds according to universal time, in this paper her diurnal curve is reproduced by using corresponding local time of Central Asia instead of universal time. The frequencies of pt-pulsation at Sitka and Cheltenham were given by Ohchi(5) for 1951 and 1952, using the reproductions of megnetogram. At these higher stations, amplitudes of pulsations are fairly great so that their appearance on the reproduction of magnetogram can be easily recognized, while it is hardly done on the similar reproduction at rather low latitude, e. g. San Juan or Honolulu. The diurnal variation at Kakioka was given and discussed in the previous paper(6).

At Göttingen and Kakioka, the maximum frequencies appear in rather earlier hours than midnight, while at Batavia and Sitka they are found in later hours. The curves for Central Asia, Zikawei, Samoa and Cheltenham are the intermediates. From these curves it may be pointed out that the time of maximum frequency changes rather systematically according to longitude.

§ 3. Kp-index and frequency of pt-pulsation

In the previous paper, the author studied some relations between Kp-index and pt-pulsation observed at Kakioka. This result is briefly reproduced in Fig, 2. The curve in the figure shows the rate of occurrence of pt-pulsation for each Kp-index. At a glance, it is easily noticed that the rate of occurrence of pt-pulsation increases linearly from zero at Kp=0 to some greater value at Kp=4 or 5. For a higher Kp-index than 5 the rate seems to be saturated, though it is not so clear because of few data. At any rate the rate of occurrence increases with increasing geomagnetic activity. This is concluded being based on the average status for solar 11-year cycle, therefore the fact that the frequency of pulsation is inversely proportional to the solar activity in annual means is not contradictory to the curve in Fig. 2.

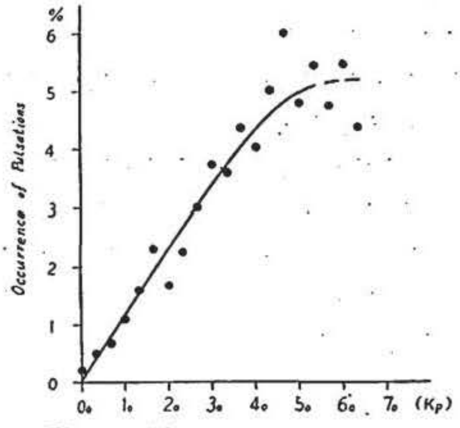

Fig. 2. The rate of occurrence of pt-pulsation for each Kp-index

The diurnal variation of frequency of pt-pulsation is somewhat affected by the geomagnetic activity level. This was also reported in the previous paper based on the Kakioka's data, and is shown in Fig. 3 briefly. Three curves of the figure show the diurnal variations of frequency for Kp=0_0-2_+, $3_- - 4_+$ and $5_- - 6_+$, respectively. The curves for higher Kp have their maximum in earlier hours, whereas the curve for Kp=0_0-2_+ is symmetrical with respect to the time of maximum, 23.5 h. This is a remarkable fact to be mentioned. For Kp=$5_- - 6_+$, the maximum of frequency shifts considerably to earlier hour and the secondary maximum appears after midnight. This curve is similar to the diurnal curve for the European station shown in Fig. 1. In the case of Kp=$3_- - 4_+$, the curve is the intermediate.

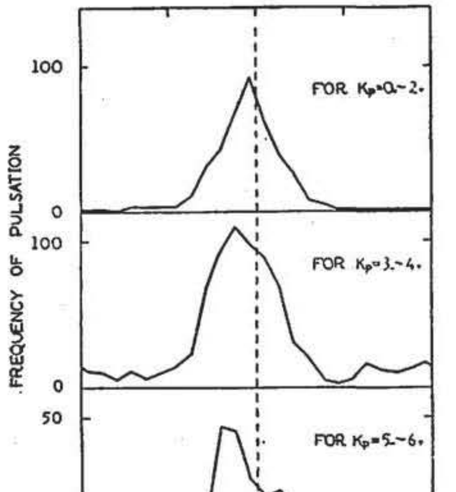

Fig. 3. Diurnal variations of frequency at Kakioka for the three geomagnetic activity levels, Kp=0_0-2_+, $3_- - 4_+$ and $5_- - 6_+$.

The symmetrical character of frequency for low geomagnetic activity suggests us to imagine an intrinsic diurnal variation. If the diurnal variation of frequency is mainly due to the local time control on the amplitude, it is not unnatural to suppose that the curve mentioned above may show the fundamental mode of local time control in view of the simplicity of symmetrical form and low activity, though we have no evidence yet to show that the original intensity of pulsation for low geomagnetic activity does not depend on the universal time in the course of a day.

If the manner of the local time control on the amplitude is the same for the case of higher Kp as well as for low activity, shifting of maximum frequency to earlier hour is naturally understood by taking into consideration that the primary intensity of pulsation is much more controled by the universal time for higher geomagnetic activity, or in other words, primary intensity depends on what meridian is faced to the sun.

§ 4. Diurnal variations of K-index and frequency of pt-pulsation

The diurnal variation of frequency of pt-pulsation is mainly controled by local time, which is due to the depression of amplitude in daytime but its longitude effect is also noticeble (Fig. 1). This effect is a self-manifestation of character of primary origin, and the primary intensity of pulsation depends on what meridian is faced to the sun.

As the rate of occurrence of pulsation increases linearly with increasing geomagnetic activity, the primary intensity or frequency of pulsation may statistically be proportional to geomagnetic activity except the case of very high activity.

On the other hand, Nickolson and Wulf[7] reported recently the universal time diurnal variation of K-index. Though they noticed the seasonal change, the annual mean diurnal variation is calculated from their twelve monthly curves and shown in Fig. 4. It is to be considered, therefore, that this variation shows the universal time diurnal variation of primary activity of pulsation.

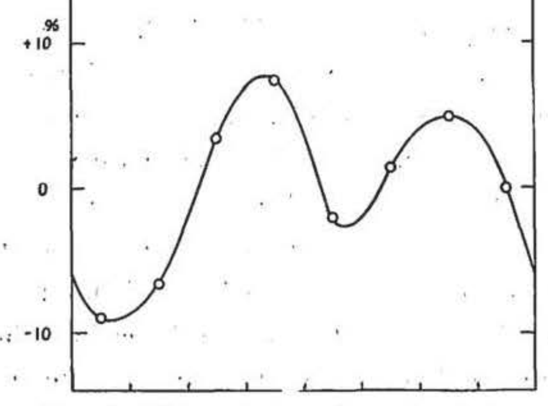

Fig. 4. Universal time diurnal variation of K-index

As to the observed local time diurnal variation of pulsation at the individual longitude, the said universal time control must be taken into consideration as well as the local time control. Thus, say, at the European station, where the primary activity of pulsation falls on the decreasing stage at the local midnight, the flat or double maximum frequency curve near midnight is easily recognizable.

We assume that the rate of occurrence of observable pulsation at a meridian $\varphi, P(\varphi, t)$, can be expressed by

$$P(\varphi, t) = P_1(T) \cdot P_2(t)$$

where t is local time and T is the corresponding universal time at the meridian. For the station in the meridian specified by hour angle φ measured from the Greenwich meridian, T is given by $t-\varphi$.

As the rate P is proportional to geomagntic activity A for the data averaged over all local times, $P_1(T)$ is also proportional to the A which varies according to the universal time; $P_1(T) = \alpha \cdot A(T)$. The universal time diurnal variation of the geomagnetic activity represented by K-indices is shown in Fig. 4, and for a little change of T from T_0, $A(T)$ can be expressed by the formula,

$$A(T) = A_0\{1+\beta(T-T_0)\},$$

where A_0 is the value of $A(T)$ at the time T_0. And hence $P_1(T)$ is given by,

$$P_1(T) = P_{10}\{1+\beta(T-T_0)\}.$$

As to $P_2(t)$ the following expression is assumed so as to conform to the symmetrical local time diurnal variation of frequency at Kakioka,

$$P_2(t) = P_{20}\{1-\alpha|t-t_0|\},$$

where t_0 is 23.5 h and α is equal to 1/6. Thus, the following expression is given, provided that T_0 is taken as the universal time corresponding to t_0 at the meridian φ;

$$P(\varphi, t) = P_0(1+\beta \cdot \Delta t)(1-\alpha|\Delta t|),$$

where $P_0 = P_{10} \cdot P_{20}$ and $\Delta t = t - t_0 = T - T_0$.

Hence, if $\beta > 1/6$ maximum frequency is found after 23.5 h, and if $\beta < -1/6$ it appears before 23.5 h. For the case, $-1/6 < \beta < 1/6$, the time of maximum frequency remains the same as 23.5 h, but the symmetrical form of frequency curve is not kept. At the European station β is estimated as about -0.04 in Fig. 4, and hence the condition does not seem to be satisfied for the shift of the maximum frequency, but the following argumentation is to be considered.

It is not convincible that all of geomagnetic disturbances increasing K-index participate the occurrence of pulsation. There are found some facts showing the increased amplitude of the universal time diurnal variation of some sorts of disturbances which may be principally related to the origin of pulsation. Considering that pulsations relate deeply to the commencement of disturbances as they are frequently found in psc, the frequency of the occurrence of abruptly increased K-index is examined statistically. Fig. 5 shows the universal time diurnal variation of such occurrence deduced from the local time diurnal variation for the seven stations, San Fernando, Ksara, Alibag, Kakioka, Honolulu, Teoloyucan and San Juan, by the same method as described in the Nickolson and Wulf's paper. The curve has the same general tendency as that shown in Fig. 4, but its amplitude is

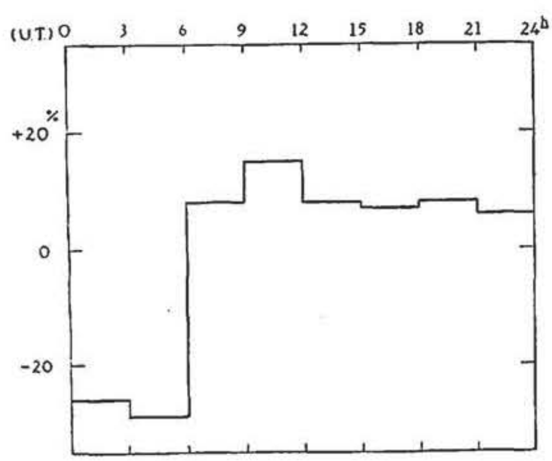

Fig. 5. Universal time diurnal variation of frequency of occurrence of abruptly increased K-index

much greater. Therefore, the coefficient $|\beta|$ participating the activity of pulsation can be greater than the value estimated in Fig. 2, and may satisfy the condition for the earlier occurrence of the maximum frequency.

Thus, the earlier occurrence of the maximum frequency is explained for the European station, and the similar explanation of the frequency curve is possible for the stations in the other longitudes. For example, at Sitka the time of maximum frequency is to be found after t_0 ($\equiv 23.5$ h) for $\beta>0$, and the observed time of shifting is 1.5 h.

More plausible agreement will be obtained if the variation of K lags one or half an hour behind that shown in Fig. 4. At Kakioka the effect that the variation of K is in decreasing stage is most effectively realized at 14.5 h (U. T.). Such an uncertainty may be derived from using K-index, which is assigned for each three hour interval, and reduced to a certain extent by the process to deduce the universal time diurnal variation. In spite of this uncertainty, it is explained fairly that the maximum frequency of pulsation is found in earlier hours than midnight in Europe in later hours in America or East Asia, and at about midnight in Central Asia or Central Pacific Ocean.

The diurnal variations of frequency for rather higher geomagnetic activity are also explained by similar argumentations. Their curves become unsymmetric by the effect of the universal time diurnal variation of geomagnetic activity in contrast with the symmetry for low activity.

§ 5. Short final remarks

The longitude effect of the local time diurnal variation of frequency of pulsations has been discussed and it is shown that the universal time diurnal variation of K-index affects critically the (L. T.) diurnal curve of frequency for each longitude.

In the present stage of investigation, we know very little how the solar corpuscles impinging upon the terrestrial atmosphere participate in the origin of pulsation, if they concern, but the inclined geomagnetic axis to the rotational one and the irregularity of the magnetic field may affect the distribution of impinging corpuscules and cause the universal time diurnal variation of terrestrial phenomena concerned.

References

(1) Scholte, J. G. and J. Veldkamp (1955) : Journ. Atmos. Terr. Phys. **6**, 33
(2) Troyickaya, V. A. (1955) : T 174 R, Defence Research Board, Canada, Mar. 1955 (translated in English by E. R. Hope)
(3) Lubiger. F. (1935) : Zeits. Geophys., **11**, 116
(4) Angenheister, G. (1954) : Gerl. Belit. Geophys., **64**, 108
(5) Ohchi, K. (1957) : Memo. Kakioka Mag. Obs. 8, 87-92
(6) Yanagihara, K. (1957) : Memo. Kakioka Mag. Obs. **8**, No. 1, 49
(7) Nickolson, S. B. and O. R. Wulf (1955) : Journ. Geophys. Res. **60**, 389