RAPID AURORAL PULSATIONS WITH FREQUENCIES OF 0.05–40 Hz

Takeo HIRASAWA

National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173

Abstract: An image intensifier-television system equipped with an auroral photometer has been installed at Syowa Station to observe the auroral rapid luminosity fluctuations. In addition to the large amplitude auroral fluctuations observed mainly at the time of onset of an auroral substorm, several different spectral types of pulsating auroras are found in the active auroras in the frequency range from 0.05 to 40 Hz, the principle dominant spectral frequencies being at about 0.08, 1, 10 and 25 Hz. Study of the association between auroral luminosity and magnetic pulsations shows that correlations are good in case of 0.08 Hz fluctuations, while poor in cases of the 1, 10 and 25 Hz rapid fluctuations.

1. Introduction

Records of auroral photometers often show a fine structure in the form of quasi-sinusoidal oscillations or trains of pulses, with frequencies ranging from 0.01 to 10 Hz. These are called auroral pulsations. They have been recorded at many observatories located in and near the auroral zone for several decades, but it is only lately that much attention has been paid to the study of auroral pulsations. Some investigators have examined the correlations between auroral and geomagnetic pulsations, and have found that the short period geomagnetic pulsations are frequently associated with auroral pulsations of the same period (CAMPBELL and REES, 1961; OGUTI, 1963; JOHANSEN and OMHOLT, 1966).

2. Outline of Instrumentation

A photometer was designed for investigating detailed characteristics of auroral pulsations in the frequency range between 0.05 and 50 Hz and their relationships with geomagnetic pulsations. The photometer consists of a single telescope equipped with a band-pass filter (4278 Å). The field of view is 5°. The amplified anode current of the RCA 1p21 photomultipliers is fed to two electrical band-pass filters (Fig. 1) and recorded on a slow running tape-recorder. The outputs of the band-pass filters are separately registered on multi-channel pen recorders together with the signals of the geomagnetic pulsations. The records of auroral pulsations

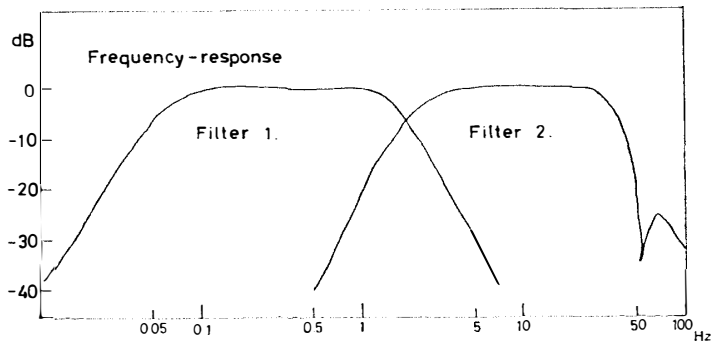

Fig. 1. Frequency response of electric band-pass filters for auroral pulsations.

obtained by the slow-running FM tape recorder are played back at a much higher speed (say, 1000 times or more) to permit dynamic spectrum analysis with the aid of the ordinary spectrum analyzer.

3. Continuous Auroral Pulsation

Observations of auroral pulsations by means of the equipments described in the preceding section were carried out in 1978 at Syowa Station (geomagnetic lat. 69.6°S, long. 77.1°E), Antarctica.

One of the major results of the observations is to show the continuous spectral bands of auroral pulsations in the frequency range of about 10 Hz and about 0.1 Hz. Fig. 2 shows examples of dynamic spectra of pulsations from 1 to 30 Hz in frequency.

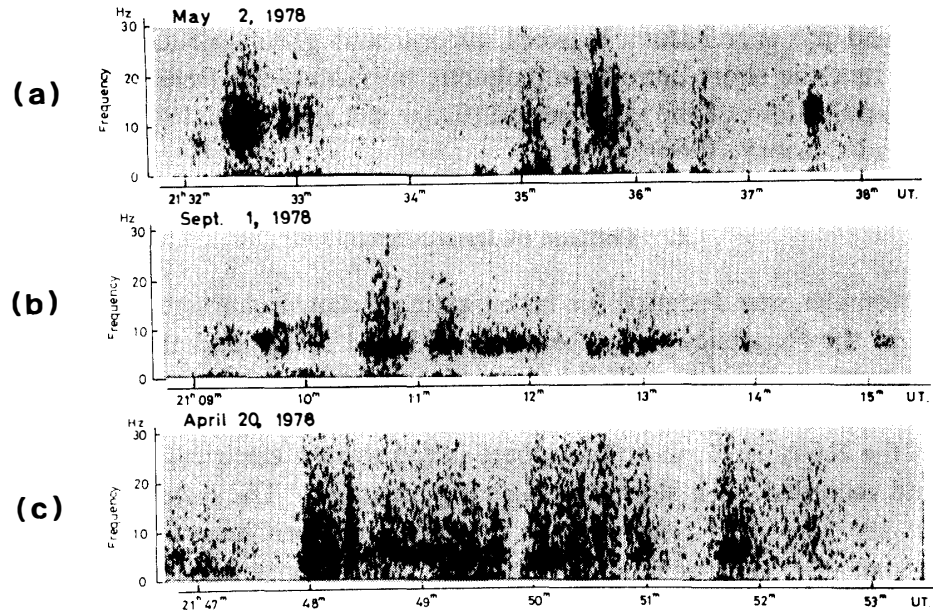

Fig. 2. Examples of f-t diagram of 10 Hz auroral pulsations.

In this figure (Fig. 2a, b, and c), there is a fairly sharp spectral band between 5 and 15 Hz lasting more than 5 min. This spectral band with an average frequency of 10 Hz may represent flickering aurora which is frequently observed in the bright auroral arcs occurring just before and during the auroral breakup. The flickering features consist mainly of interconnected spots of diameter roughly 1–5 km (BEACH *et al.*, 1968).

Since the time of its first description by STÖRMER (1955), it has been well known that auroral pulsations with a frequency of about 0.1 Hz occur most frequently in the latter part of the night and is typically observed during the recovery phase of an auroral substorm (CAMPBELL and REES, 1961; JOHANSEN and OMHOLT, 1966). Fig. 3 shows an *f-t* diagram of auroral pulsations of this type. On the left hand side of Fig. 3 (from 02h45m to 03h30m (UT) on the 22th of June, 1978), auroral pulsations with the burst-like spectral structure are observed successively over a wide frequency range from less than 0.1 Hz to more than 0.6 Hz. The bursts of auroral pulsations correspond to the irregular large amplitude ones which are associated with the activity of the aurora during the breakup phase of an auroral substorm. In the post breakup or recovery phase of the auroral substorm (from 03h30m to 04h30m), two stable spectral bands of auroral pulsations with central frequencies of 0.08 Hz and 0.20 Hz are noted in the *f-t* diagram of Fig. 3. The frequencies of these two bands decrease within the hour to 0.05 Hz for the lower frequency band and to 0.15 Hz for the higher frequency one. These spectral bands of auroral pulsations would be the same phenomena as described by some other investigators (CAMPBELL and REES, 1961; OGUTI, 1963; JOHANSEN and OMHOLT, 1966). There has been a question whether the auroral pulsations of this type are observable or not during the breakup phase of an auroral substorm (FUKUNISHI and HIRASAWA, 1970). The *f-t* diagram in Fig. 3 illustrates that two spectral bands of auroral pulsations begin to appear simultaneously at the onset of the auroral substorm (02h45m UT) and last through the course of the substorm, although it is somewhat difficult to find out the spectral bands on the *f-t* diagram during the breakup phase because the intense auroral bursts are superimposed upon the spectral bands.

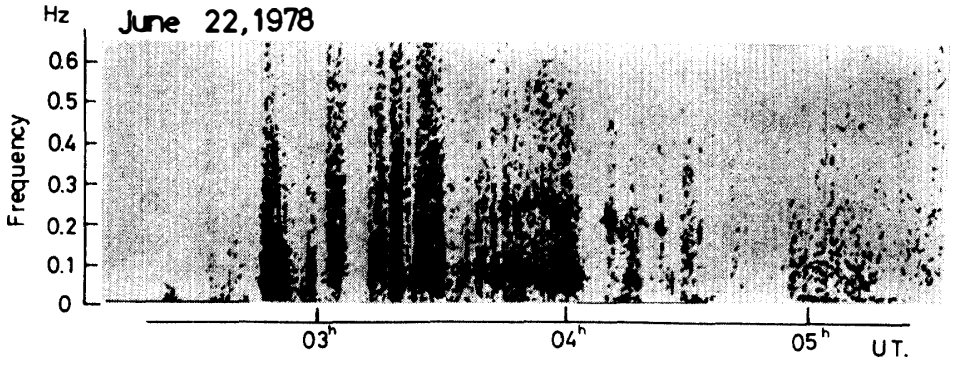

Fig. 3. Example of f-t diagram of 0.1 Hz auroral pulsations.

4. Burst-Like Auroral Pulsation

In addition to the intense burst-type auroral pulsations during the breakup phase of an auroral substorm, a burst-like auroral fluctuation with an average frequency of about 1 Hz is found in the quiet bright auroral arcs. The *f-t* diagram in Fig. 4 shows successive occurrences of this type of pulsation with each duration of about 5 min. The frequency ranges from 0.5 to 1.5 Hz. Auroral pulsations of this type are observed mainly in the evening hours and occasionally in the early morning.

In Fig. 5, a momentary burst-like auroral fluctuation is illustrated. The duration of this event is less than 1 minute and its frequency ranges up to more than 40 Hz. In the *f-t* diagram, it is seen that its spectrum is intensified around 20~30 Hz. This auroral burst is associated with an intense bright auroral arc, especially with the breakup type aurora which shows a poleward motion around the midnight

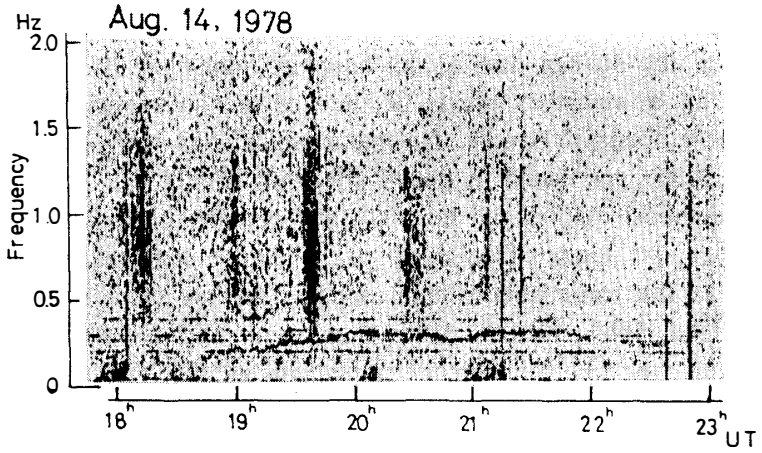

Fig. 4. Example of f-t diagram of 1 Hz auroral pulsations.

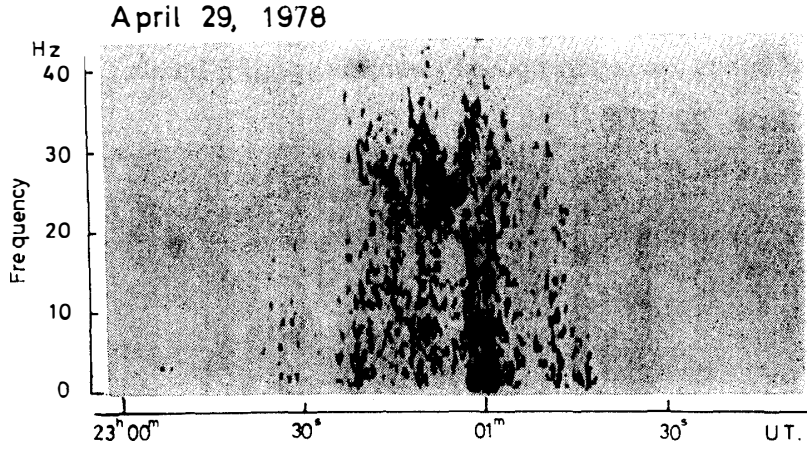

Fig. 5. Example of f-t diagram of 25 Hz auroral pulsations.

hours (HIRASAWA and NAGATA, 1972).

5. Correlation between Auroral and Geomagnetic Pulsations

Correlation between auroral and geomagnetic pulsations depends distinctly on their frequency (HIRASAWA and KAMINUMA, 1970). Most of auroral rapid fluctuations of frequency larger than 0.2 Hz are not accompanied by geomagnetic fluctuations. Auroral and geomagnetic pulsations with frequencies lower than 0.1 Hz have waveforms similar to each other. So that, the correlations in the 0.08 and 0.20 Hz auroral bands are good while but not poor in cases of 1, 10 and 25 Hz rapid fluctuations.

6. Diurnal Variation of Occurrence of Auroral Pulsations

After the study of auroral *f-t* diagrams of more than 200 clear night hours obtained at Syowa Station, we have reached a conclusion that auroral pulsation in the frequency range 0.05 to 40 Hz can be classified into the following five types.

Type A: Irregular fluctuations with large amplitudes observed mostly at the time of onset of an auroral substorm (Fig. 3).

Type B: Long-lived auroral pulsations with a pulse-like waveform. In the *f-t* diagram, the pulsations show stable spectral bands with frequency and amplitude about 0.1 Hz and a few k*R* (at 5577 Å), respectively. This type is dominant in the morning hours (Fig. 3).

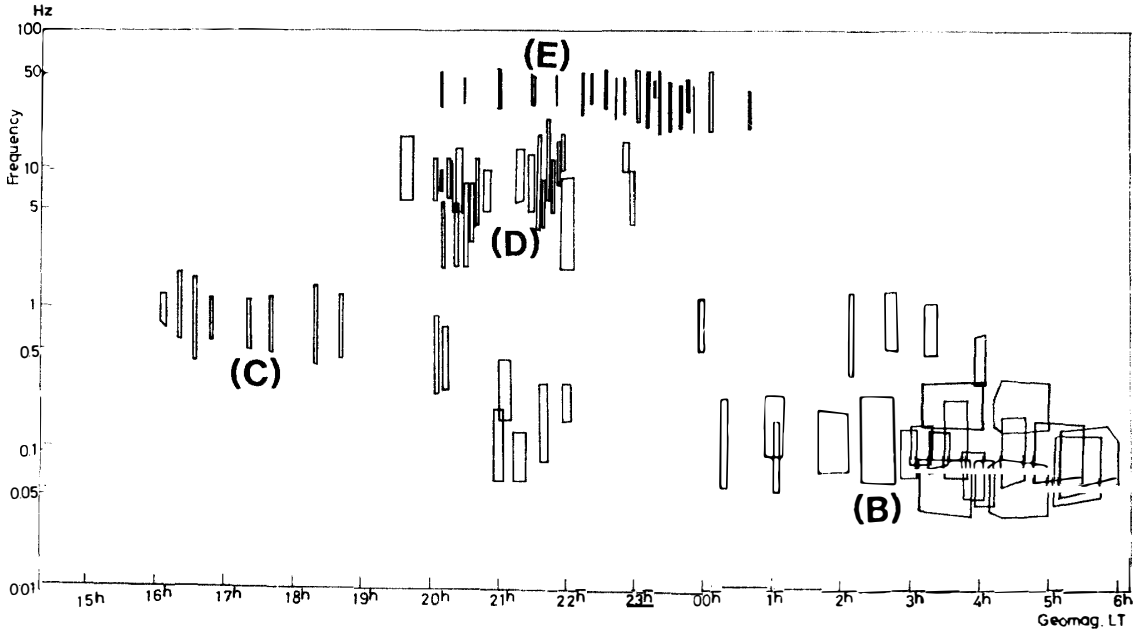

Fig. 6. Diurnal variations in occurrences of auroral pulsations.

Table 1. Characteristics of auroral pulsations observed at Syowa Station.

Type	Frequency (Hz)	Waveform	Duration	Diurnal variation in		Correlation with geomagnetic pulsation	Other remarks
				Activity	Frequency		
A	0.01～1.0	Irregular	2～5 min	Most active around midnight (20 h～03 h LT)			Usually observed at the onset time of auroral substorms
B	～0.1	Pulse-like	More than an hour	Active in the early morning hours (00 h～06 h LT)	Decreases towards morning	Very good	Observed at the post breakup or recovery phase of auroral substorms
C	～1	Pulse-like	A few minutes	Active in the evening hours (16 h～20 h LT)		None	Observed in bright auroral arcs
D	～10	Quasi-sinusoidal	2～20 min	Active in the evening hours (20 h～22 h LT)		None	Observed just before or during the breakup phase of the auroral substorm
E	～25	Quasi-sinusoidal	1 min	Active in the evening hours (20 h～24 h LT)		None	Observed most frequently in the breakup aurora

Type C: Short-lived auroral pulsations with a pulse-like waveform. In the *f-t* diagram, the pulsations show burst-like spectral structures, with frequency and amplitude about 1 Hz and several hundreds *R* in 5577 Å, respectively (Fig. 4).

Type D: Rapid fluctuations of auroral luminosity at a frequency of about 10 Hz. So-called "flickering auroras" (Fig. 2).

Type E: Extremely rapid fluctuations with a frequency of about 20–30 Hz. The auroral pulsations of this type occur most frequently at the time of the equatorial movement of auroral arcs before auroral breakup and also at the time of the poleward movement of breakup type auroras.

As illustrated above, several kinds of distinct auroral pulsations are noted in the *f-t* diagrams. The diurnal occurrences of the types of auroral pulsations based on the above classification are shown in Fig. 6 as a statistical *f-t* diagram.

In Fig. 6, we notice the following tendencies.

(1) Though type A pulsations are not included in Fig. 6, the pulsations are mainly observed around 23h LT associated with the auroral breakups.

(2) Type B pulsations are most frequently observed in the early morning hours (around 3h) with the average frequency of 0.1 Hz.

(3) Type C pulsations occur mainly in the evening hours and occasionally in the early morning.

(4) Type D pulsations appear at 19–22h LT and usually before the auroral breakup (23h LT).

(5) Type E pulsations are observed just before or during the breakup phase of auroral substorms.

7. Summary

The results of the investigation of auroral and geomagnetic pulsations observed simultaneously at Syowa Station, Antarctica, have shown that the auroral pulsations can be classified into five kinds whose typical characteristics are summarized in Table 1.

References

BEACH, R., CRESWELL, G. R., DAVIS, T. N., HALLINAN, T. I. and SWEET, L. R. (1968): Flickering, a 10-cps fluctuation within bright auroras. Space Sci., **16**, 1525–1529.

CAMPBELL, W. W. and REES, M. H. (1961): A study of auroral coruscation. J. Geophys. Res., **66**, 41–55.

FUKUNISHI, H. and HIRASAWA, T. (1970): Progressive change in pi 2 power spectra with the development of magnetospheric substorm. Rep. Ionos. Space Res. Jpn, **24**, 45–64.

HIRASAWA, T. and KAMINUMA, K. (1970): Space-time variation of aurora and geomagnetic disturbances–Auroral observations at Syowa Station in Antarctica 1967–1968. JARE Sci. Rep., Ser. A, **8**, 29 p. with Appendix 139 p.

HIRASAWA, T. and NAGATA, T. (1972): Constitution of polar substorm and associated phenomena

in the southern polar region. JARE Sci. Rep., Ser. A, **10**, 76 p.
JOHANSEN, O. E. and OMHOLT, A. (1966): A study of pulsating aurora. Planet. Space Sci., **14**, 207–215.
OGUTI, T. (1963): Inter-relations among the upper atmosphere disturbance phenomena in the auroral zone. JARE Sci. Rep., Ser. A, **1**, 82 p.
STÖRMER, C. (1955): The Polar Aurora. Oxford, Clarendon Press.

(*Received May 1, 1980*)