Pulsation Phenomena Observed during a Magnetospheric Substorm at Sanae

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A brief analysis of magnetic micropulsations and riometer absorption pulsations during a substorm at Sanae is presented. The correlations between these pulsations, the magnetic horizontal intensity and the auroral electrojet indices are discussed.

'n Kort analise van magnetiese mikropulsasies en riometer-absorpsiepulsasies wat tydens 'n substorm te Sanae waargeneem is, word aangegee. Die korrelasies tussen hierdie pulsasies, die magnetiese horisontale intensiteit en die AE-indekse word bespreek.

Introduction

Many studies have been made of geomagnetic micropulsations and their interrelationship with other magnetospheric phenomena (see *Orr*, 1973, and references cited by him). Most of these studies were of the continuous sinusoidal Pc type pulsations and the impulsive irregular pulsation trains Pi1 and Pi2. Relatively fewer studies were of the non-impulsive irregular pulsations observed during magnetospheric substorms.

To serve as a basis for study of pulsations and associated phenomena as observed during substorms at a sub-auroral station, a preliminary study was made of the substorm of 14 December 1970 as recorded at Sanae (latitude 63,6°S, longitude 43,9°E geomagnetic). The results of this preliminary analysis are described below.

Method of Analysis

Data were analysed for the period 04h00–14h00 LT for 14 December 1970. Sanae's geographic coordinates are 70° 18′ S, 02° 22′ W and therefore universal time and local time are practically equivalent.

The 10-minute mean values of the magnetic horizontal component H were scaled from the standard magnetogram (from which hourly mean values for H were also determined). The level of cosmic radio noise absorption at the centre of each 10-minute interval was scaled from the 30 MHz riometer chart record, and the maximum micropulsation amplitude, irrespective of period, appearing in each 10-minute interval was scaled from the micropulsation chart record.

The analogue graph recordings of micropulsation and riometer data were digitized with suitable arbitrary spacing using a D-mac pencil follower. An interpolation programme was used to determine equispaced data samples (4-second spacing for micropulsation, 15-second spacing for riometer) from the digitized data. Hourly mean values of micropulsation and absorption pulsation amplitudes, and of absorption were determined. (The significance of the mean value of a number of spot values of cosmic radio noise absorption is discussed by *Basler & Owren*, 1964.) The spectra for the micro-pulsation and riometer data in one-hour periods were obtained by using the power spectral density method as described by *Stuart et al.* (1971). Each spectrum was computed three times using different parameters, and only peaks greater than the standard error in at least two of the computed spectra were regarded as significant.

Results

Correlation of micropulsation amplitude with absorption, H, and auroral electrojet indices

In Fig. 1 the 10-minute values of the horizontal magnetic intensity (H component), the amplitude of the micropulsations, and the absorption at Sanae are plotted as functions of local time. Also plotted in Fig. 1 are the hourly mean values of the amplitudes of the pulsations in cosmic radio noise absorption. The similarity of these phenomena during the course of the substorm is clearly demonstrated. Because long-period pulsations are likely to have far greater amplitudes than short-period pulsations, this similarity is only demonstrated for the low-frequency pulsations. The relationship between a negative H bay, micropulsation amplitude, and electron precipitation holds generally when a magnetospheric substorm is in progress somewhere on the night side (*Coroniti et al.*, 1968).

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The correlation coefficients of the hourly mean values of the micropulsation amplitude, the absorption, and the amplitudes of the absorption pulsations with H and the auroral electrojet indices AE, AL, AU, and AO respectively (as obtained from World Data Centre A), were calculated and are given in Table 1.

From Table 1, the good correlation with H of micropulsation amplitude, absorption, and absorption pulsation amplitude respectively is once again evident. The correlation of these three quantities with AE is mediocre, whereas their correlation with AO is excellent.

The correlation coefficients of the 10-minute values of micropulsation amplitude and absorption with H, AE, and AO respectively are given in Table 2.

Comparison of the values given in Table 2 with those in Table 1 shows a reduction in correlation, which indicates that although the general trend of the curves in Fig. 1 is similar, the finer details do not correlate to the same extent. In fact, determination of the correlation coefficients of the 10-minute data divided into two-hour intervals sometimes showed excellent correlation, and at other times showed no correlation whatsoever. Though somewhat erratic, the trend seemed to be for the correlation to be good at the start of the substorm and to deteriorate as the substorm progressed.

The index AE depends solely upon the maximum eastward and westward electrojet currents and is independent of zonal currents or of the axially symmetric component of the magnetic fields from any distant sources. The index AO, on the other hand, is an approximate measure of the equivalent zonal currents affecting the auroral zone (*Davis & Sugiura*, 1966). Thus the values in Table 1 seem to indicate that the general trend of the micropulsation amplitude, the absorption and the absorption pulsation amplitude observed during this substorm were strongly correlated with zonal currents.

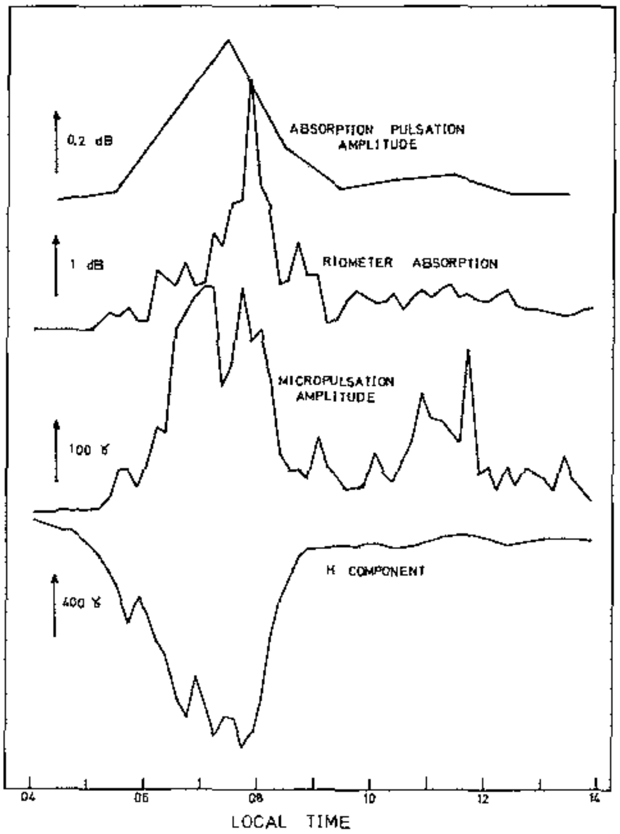

Fig. 1. Ten-minute values of horizontal magnetic intensity, amplitude of micropulsations, and absorption, and the hourly mean values of the amplitude of absorption pulsations at Sanae for 14 December 1970.

Correlation of micropulsation spectra with H and auroral electrojet indices

The micropulsation spectra showed significant peaks varying in period from 12 seconds to 400 seconds. The upper curve in Fig. 2 is an example of one of the micropulsation power spectra obtained.

The number of significant spectral peaks, and the shortest period in the micropulsation spectra, were noted for each hour. The correlation coefficients of these two quantities with the hourly mean values of H, and the indices AE, AL, AU, and AO respectively were determined and are given in Table 3. Table 3 shows some correlation between these two quantities and H. A similar correlation was observed by *Heacock* (1967) for his continuous

Table 1

Correlation coefficients

	H	AE	AL	AU	AO
Micropulsation amplitude	0,88	0,60	0,83	0,80	0,92
Absorption	0,81	0,64	0,84	0,75	0,92
Absorption pulsation amplitude	0,95	0,64	0,86	0,79	0,94

Table 2

Correlation coefficients

			H	AE	AO
Micropulsation amplitude			0,82	0,32	0,67
Absorption			0,70	0,54	0,80

Table 3

Correlation coefficients for micropulsation data

	H	AE	AL	AU	AO
Number of spectral peaks	0,56	0,84	0,82	0,21	0,74
Shortest period in spectra	0,69	0,84	0,79	0,13	0,69

non-impulsive type Pi(c) pulsations. However, the correlation with AL is seen to be far better. No correlation is observed with AU, thus it is likely that the correlation coefficients with AE and AO are high because AL has greater effect on these indices than AU.

As AL is a measure of the westward auroral electrojet intensity at the point where it is most intense, which will normally be at, or soon after, the meridian of local midnight (*Davis & Sugiura*, 1966), these results indicate that the spectrum of these pulsations was correlated with the westward auroral electrojet. *Heacock* (1967) suggests that at least a part of the pulsations observed during a substorm originates in the electrojet itself.

Comparison of micropulsation and absorption pulsation power spectra

As a result of noise in the riometer chart records, it was not possible to make reliable determinations of peaks in the absorption pulsation power spectra at periods of less than about 50 seconds. Thus only peaks with periods in the range 50 to 400 seconds could be studied. The micropulsation and absorption pulsation power spectra were compared to determine whether or not they exhibited similarities.

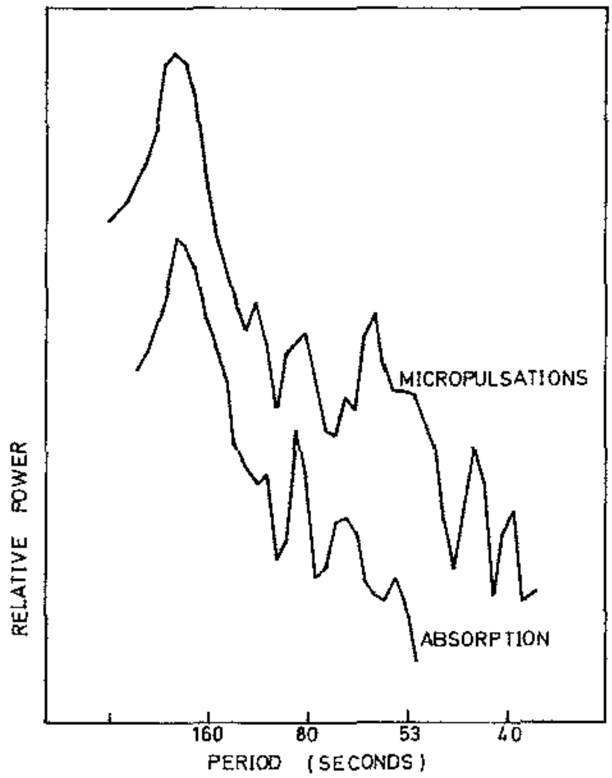

Fig. 2. The micropulsation (upper curve) and riometer absorption pulsation (lower curve) power spectra for the hour 12h00-13h00 L.T. on 14 December 1970.

Table 4 lists the results of this comparison. Peaks in the power spectra which were smaller than the standard error are shown in brackets in the fourth column.

From Fig. 1 and Table 4 it is apparent that absorption pulsations occurred only on a enhanced background of absorption. This agrees with observations by *Parks et al.* (1968) for 5-10 second period precipitation pulsations. Further, Fig. 1 shows that the amplitude of these pulsations increased as the level of absorption increased. In contrast, *Parks et al.* (1968) observed that modulation of the precipitation with periods of 20-35 seconds ceased at a very high level of precipitation, and ascribed it to some type of saturation effect. If this is the case, then it will be necessary to study a substorm with more intense absorption in order to determine whether this effect applies to modulation periods of 50-400 seconds.

A study of Table 4 indicates that as the substorm progressed, correlation between the micropulsation and absorption pulsations greatly improved. However, this could be an apparent effect, resulting from good correlation when the level of absorption remains relatively constant, which, in this specific case, was in the latter half of the period studied. Fig. 2 shows the correlation of the micropulsation and absorption power spectra for the period 12h00–13h00 UT.

Conclusion

A number of aspects of pulsation phenomena observed at Sanae during a substorm on 14 Desember 1970 have been discussed. Many more substorms will need to be studied in order to determine whether the observations made here apply to substorms in general or only to this particular substorm. This will in future become increasingly easy with the advent at Sanae of digital recording on paper tape of geophysical data. Only then will it be possible to discuss the pros and cons of various substorm theories in the light of observations.

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Table 4

Comparison of micropulsation and absorption pulsation power spectra

LT	Absorption (dB)	Remarks	Spectral peaks for Micropulsation (upper row) and Absorption pulsation (lower row) (seconds)	Correlation
04h00-05h00	0,0	No absorption pulsations		
05h00-06h00	0,232	Start of absorption pulsations	(400), 133, (73), 67, (55) 178 (133), 89	None except peak at 133
06h00-07h00	0,775	Not determinable because of very broad peak in micropulsation spectrum	320-89, 59 400, (200), (133), 107	?
07h00-08h00	2,199	Large absorption pulsations	(267), 178, (123), 533, (267), 133, 100, (67), (53), 47 80 (53)	Poor
08h00-09h00	1,402		267, (145), 123, 84, 400, (145), 114, (94), (67), 59, 50 61, (50)	Fair
09h00-10h00	0,345	Absorption pulsations only part of the time		
10h00-11h00	0,519		160, (123), 80, 67, 50 (160), (133), 84, (69), 57	Good
11h00-12h00	0,592		267, 145, (106), 84, 62 320, (133), 104, (84), 70	Fair
12h00-13h00	0,442		229, (107), 80, (67), 59 229, (100), 84, 67 (55)	Very good
13h00-14h00	0,282	No absorption pulsations		

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