GENERAL CHARACTERISTICS OF pc-TYPE PULSATIONS

By R. W. E. McNicol*† and J. S. Mainstone*

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Summary

An analysis of geomagnetic micropulsations of the pc type, i.e. continuous pulsations detectable for several hours at a time, recorded at Brisbane (35°S. geomagnetic latitude) from May to October 1962 has shown that the frequency spectrum was usually spread over several octaves even when the waveform shown on the chart records was quasi-sinusoidal. The greatest spread was around midday, being from about 0·02 to 0·08 c/s on days of mild magnetic activity ($K_p = 3$). Generally pc occurred most strongly between about 0600 and 2000 L.M.T., but on occasions were recorded throughout the whole 24 hours. A striking feature was the sudden change in activity which frequently took place within an interval of a few minutes. Good correlation was obtained between both the amplitude and the highest frequency in the pc spectrum, and K_p.

I. Introduction

Using the apparatus described by Mainstone and McNicol (1962), continuous records of geomagnetic micropulsations with frequencies in the range 0·01 c/s to about 1 c/s have been made on both paper charts and magnetic tape, since May 1962. The chart records include all three magnetic components (north-south, east-west, and vertical), but the tape records are confined largely to the north-south horizontal component. The recording site is near Esk, about 30 miles north-west of Brisbane and its geomagnetic coordinates are latitude 35°S., longitude 231°.

The equipment noise level is sufficiently low that micropulsation signals (in the absence of site noise) down to 0·0004 γ/s ($1\ \gamma = 10^{-9}$ webers m^{-2}) are detectable; for micropulsations of frequency 0·03 c/s (i.e. of period 33 s) this value corresponds to a peak-to-peak amplitude of approximately 0·005 γ. Unfortunately, the site noise is negligible only for the north-south component; in the east-west and vertical components, interference from the Brisbane d.c. tramway system (although originating 30 miles away) is, except between 0100 and 0500 L.M.T. each day, strong enough to mask out on the charts signals of strength less than 0·002 γ/s.

II. Frequency Spectrum Analysis

Frequency spectrum analysis of the magnetic tape records has been carried out with a Kay Electric Sonagraph. The signals are recorded at a tape speed of about $2\frac{1}{2}$ in/hr (at which speed the frequency response extends up to about 1 c/s), and played back at 30 in/s, i.e. with a speed-up factor of 44 000, into the Sonagraph. Each "Sonagram", displaying frequency components against time, covers frequencies from 0 to 8 kc/s and deals with 2·4 s of record (on playback); this corresponds to a frequency range of 0–0·18 c/s and a time interval of about 26 hr, in the original

* Physics Department, University of Queensland.

† Present address: Boeing Scientific Research Laboratories, Seattle, U.S.A.

record. Thus one complete day's record can be made to appear on a single Sonagram. Short bursts of timing tone are automatically recorded on the magnetic tape for about 40 min commencing at midnight, and these give distinctive marks on the Sonagrams, marking the beginning and end of each day.

The design of the Sonagraph is such that a spectrum may be obtained under narrow- or wide-band conditions, corresponding to effective bandwidths of the analysing filters of 45 and 330 c/s respectively. The selection of the narrow-band filter when producing a Sonagram increases frequency resolution at the expense of time resolution (due to the ringing of the filter network), whereas the wide-band filter provides good time resolution with less frequency discrimination. Allowing for the tape speed-up factor of 44 000, the frequency resolution is something like 1 mc/s for narrow-band and 7 mc/s for wide-band conditions (writing "mc/s" for "millicycles per second").

As will be shown below, the frequency spectrum of pc-type micropulsations can change significantly in intervals of the order of a few minutes. The time taken by the Sonagraph analyser to respond to these changes is limited only by the bandwidth of the filter in use; for the wide-band filter (effective bandwidth 330 c/s) this response time is no more than 3 ms, which corresponds to about 2 min of real time, after allowing for the speed-up on tape replay. Thus use of the Sonagraph does not involve the assumption made in some methods of frequency spectrum analysis, that the time series which is being analysed is statistically stationary over the whole of the interval under examination. This is a very valuable feature, since, as is shown below, in the case of certain types of micropulsations, this assumption is not necessarily true.

III. Observed Frequency Spectra

Only "continuous" pulsations, pc, i.e. pulsations of quasi-sinusoidal waveform displaying, in general, relatively little damping, and detectable on the charts for periods of up to several hours at a time, are considered in this paper. During the period May to October the pc activity was found to contain frequency components in the range 0·01–0·12 c/s (more conveniently expressed as 10–120 mc/s). The frequency spectra were usually spread over such a wide range that the pulsations at any given time could not justifiably be assigned a specific "frequency"; consequently they could not be assigned a specific "period". It was only on rare occasions—say 1 or 2 days out of the 150 days dealt with in the present paper—that the frequency was well enough defined for it to be possible to say that the "period" of the micropulsations was some specific value. Usually all that could be said was that the frequency spectrum extended from a certain lower to a certain upper limit, since the normal form of Sonagram gives only a qualitative measure of the amplitude of any given spectral component. It was only on rare occasions that it was possible to discern any resolvable structure in the frequency spectra.

Figure 1 is an example of an occasion when the frequency spectrum was fairly well defined; on this occasion the spectrum spread only from 20 to 40 mc/s for much of the day. As would be expected the chart record for this day showed pulsations of substantially sinusoidal waveform.

On days when the magnetic K index remained more or less constant at a value greater than zero, systematic variations in the appearance of the frequency spectrum

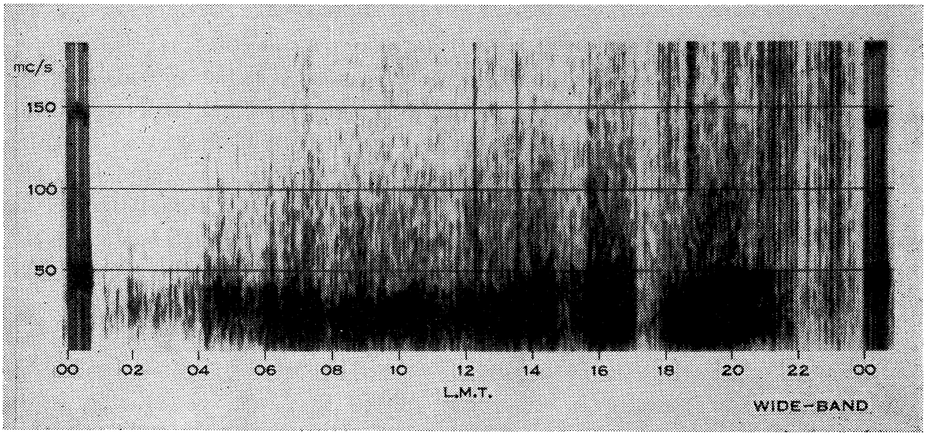

Fig. 1.—June 8, 1962. Sonagram of day when frequency spectrum of pc-type pulsations was fairly well defined (between 20 mc/s and 40 mc/s around midday); 1 mc/s $\equiv$ 1 millicycles per second.

sometimes occurred. Thus it was common for a low frequency component, in the range 15–30 mc/s, to be present for most of the time the pulsations were observable,

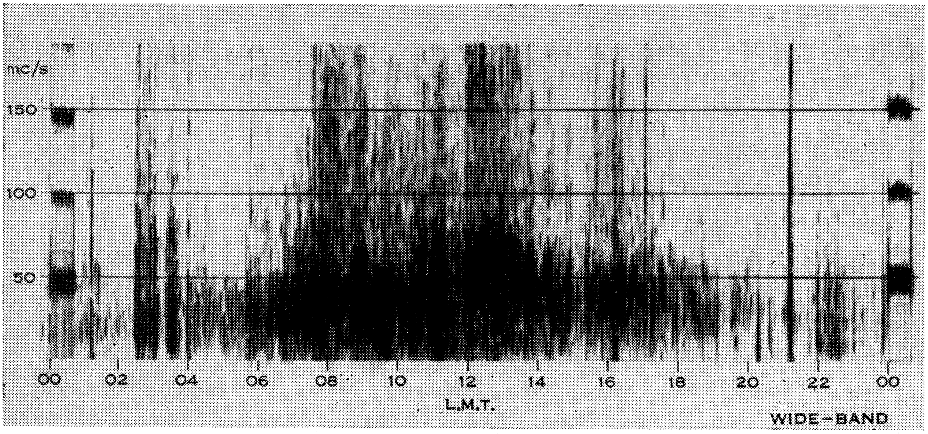

Fig. 2.—May 7, 1962. Sonagram of day when frequency spectrum of pc-type pulsations showed its greatest spread around midday.

and in addition extra components of progressively higher frequency appeared as midday approached, and dropped out again during the afternoon. Figure 2 illustrates this kind of behaviour.

IV. Occurrence of pc-Type Pulsations

For many years various workers have reported that pc-type pulsations (period 10–60 s) are essentially confined to daylight hours in middle latitudes at all seasons of the year. The local time dependence has been confirmed in recent years by Maple (1959), Kato and Saito (1962), and others.

The present Brisbane results show clearly that pc activity extends in general from 6 ± 1 hr before midday to 8 ± 1 hr after midday; a slight asymmetry about midday is often evident, the pulsations tending to start about dawn and continuing until a few hours after sunset. However, in the five months under examination, pc with amplitude greater than about 25% of the average day-time value occurred before 0500 or after 2100 L.M.T. on roughly 20% of the days, with a preference for the pre-dawn period. Occasionally pc were observed virtually continuously throughout the whole of a 24-hr period, with the amplitude during the night for the most part not less than about one-quarter of the average day-time amplitude.

It would appear that the probability of occurrence of night-time pc at Brisbane (35°S. geomagnetic latitude) is somewhat higher than the world-wide average calculated by Romañá and Cardús (1962) for the data collected during the IGY and IGC. However, observatories in the equatorial zone report a relatively small diurnal variation of pc (i.e. a high probability of night-time pc), so that the results for the subtropical Brisbane station seem to be consistent with the picture of increasing diurnal variation of occurrence with increasing latitude which is implicit in the (rather limited) IGY and IGC data.

V. Irregular Variations of Amplitude of pc

Although, as has been stated in Section IV above, the strength of the pc-type pulsations was usually high during the hours of daylight, certain well-marked exceptions to this rule frequently occurred. These took the form of

(i) sudden commencement of pulsation activity

(ii) sudden cessations of pulsation activity

(iii) sharp interruptions in pulsation activity at times of otherwise continuous occurrence.

Figure 1 shows an example of a sharp, deep interruption in the pc activity which occurred between 1710 and 1740 h, and a less complete interruption between 1445 and 1540 h on June 8, 1962. The pc activity was otherwise more or less continuous from about 0200 to 2200 h.

Examination of the corresponding chart record at times of such sudden changes of pc intensity showed that a real change in the amplitude of the pc did in fact occur, usually within an interval of a few minutes.

VI. Correlation between Magnetic K index, and Characteristics of pc.

(a) *During Quiet Conditions* (K_p = *0 to 4*).

A good correlation was found to exist between magnetic K index, and both the amplitude and the highest frequency in the frequency spectrum, of the pulsations.

When K_p was zero, no pc-type pulsations were detectable on the chart records, but they could be seen weakly on the Sonagrams, in the range 20–40 mc/s, during daylight hours only. As the K_p index increased above zero, the strength of the pulsations increased more or less linearly, the amplitude going to approximately $0 \cdot 3\ \gamma$ peak-to-peak for a K_p index of 3. A similar relationship has been found by Maple (1959). At the same time the upper limit of the frequency spectrum also increased as the K_p index increased, rising from about 30 mc/s when $K_p = 0$ to about 100 mc/s as K_p approached the value 4. This latter effect was sometimes observed to occur almost discontinuously, i.e. on a number of occasions, even near midday, the frequency spectrum displayed very little high frequency content until a certain time, after which strong high frequencies appeared quite suddenly. An example of this behaviour can be seen at 1540 h on Figure 1. Conversely, at other times the high frequencies have been observed to drop out suddenly.

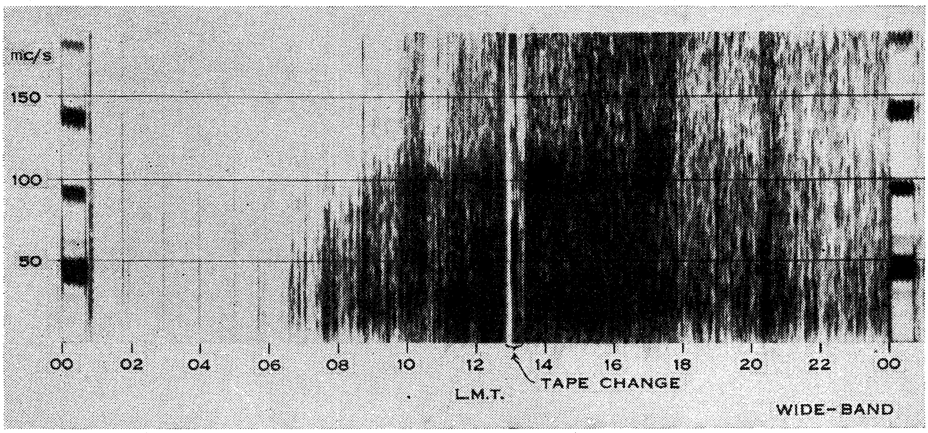

Fig. 3.—July 26, 1962. Sonagram showing behaviour of frequency spectrum of pc-type pulsations on day of a weak magnetic storm, with $f_{\text{min.}}$ down to 10 mc/s and $f_{\text{max.}}$ up to 125 mc/s. Note sharp cut-off at 1800 h.

(*b*) *During Weak Geomagnetic Storms* (K_p = *5 to 7*).

Although the period, May to early October 1962, was fairly quiet magnetically, a small number of weak magnetic storms did occur. On each of these occasions it was found that the highest frequency present in the pc spectra rose above 100 mc/s, whereas it normally did not exceed this value. It may be significant that, despite minor variations in the apparent strength of the storms, the highest frequency ($f_{\text{max.}}$) never seemed to exceed about 120 mc/s, whereas the lowest frequency ($f_{\text{min.}}$) varied greatly from one storm to another, e.g. during the storm of July 26, 1962, as shown in Figure 3, $f_{\text{min.}}$ fell from its normal day-time value of 20 mc/s to as low as 10 mc/s, whereas during the storm of October 8, 1962, shown in Figure 4, $f_{\text{min.}}$ of the dominant activity was as high as 75 mc/s. The remarkable feature of the high value of $f_{\text{min.}}$ on the latter occasion was that on the storm day the lower frequency components in the spectrum dropped out almost completely leaving the micropulsation activity to occur, quite vigorously, at the high frequencies.

Another interesting point is that during a storm the value of $f_{max.}$ exceeded 100 mc/s only during the hours of daylight. Even for storms lasting for several days, the value of $f_{max.}$ fell below this value at or about sunset and did not rise to above it again until within a few hours of dawn on the next day. The fall of $f_{max.}$ was indeed quite sharp—almost discontinuous—at 1800 h on July 26, as shown in Figure 3.

VII. Discussion

The fact that both the amplitude and the frequency spectrum of pc-type micropulsations vary greatly from day to day, and indeed exhibit sharp changes even during the course of individual days, suggests that the mechanism exciting the pulsations changes considerably in effectiveness from time to time. Since the variations in magnetic *K* figure show good correlation with the variations in pc characteristics both at quiet times and during weak magnetic storms, it appears that the micropulsations might have the same origin as the general magnetic activity.

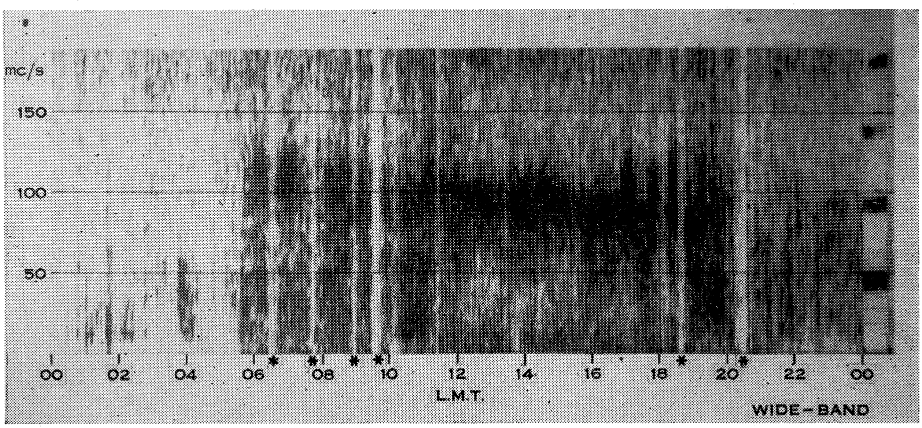

Fig. 4.—October 8, 1962. Sonagram showing behaviour of frequency spectrum of pc-type pulsations on day of a weak magnetic storm, with $f_{min.}$ at about 70 mc/s and $f_{max.}$ at 120 mc/s. *: Interruption to recording.

If this were so, observation of the characteristics of the micropulsations at any given time would provide a sensitive and continuous measure of the strength of the originating mechanism, changes in times as short as a few minutes being readily detectable. A check on this theory would be to see whether the sharp changes (in amplitude and frequency spectrum) of the pulsations observed at a given place also occur simultaneously, and in the same form, at other stations spread over a range of geomagnetic latitude and longitude. Some initial observations to check this point are being made at the present time.

VIII. Acknowledgments

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