

Power Spectra of Geomagnetic Pulsations during November 1960 storms

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ABSTRACT. A spectral study has been made of geomagnetic noise observed in the horizontal force of the geomagnetic field during the main phase of great storms of 12 and 13 November 1960 at the equatorial station of Trivandrum. The power spectra indicate that geomagnetic fluctuations are confined to frequency range of approximately 0.0004 to 0.008 cycles per second and that the periodicities in minute-range, obtained from selected periods of two storms, are almost same. The frequency range in which the noise is observed is in agreement with the range proposed by Cole (1966) in his theory for the energization of the ring current responsible for the main phase of a storm.

1. Introduction

The fine structure of the magnetic storms has been investigated by many authors in the last decade. Recent theoretical investigations have proved the significant importance of storm-time pulsation activity or geomagnetic 'noise' in the earth's magnetic field. Geomagnetically disturbed periods are characterised by irregular micropulsations of characteristic period from 6 to 10 seconds, associated with X-ray bursts, variations of auroral intensity and cosmic noise absorption. During the main phase of storms irregular pulsations diminishing in periods (IPDP) also are known to occur. Fukushima and Abe (1961) observed the characteristics of pulsations during the great storm of 11 February 1958 and found longer period pulsations from the time of the sudden commencement. Pai and Sarabhai (1964) investigated the nature of storm-time fluctuations in the field, assuming these were due to large scale inhomogeneities in the incident Solar Plasma. From an analysis of records of several stations they deduced an average scale length of these inhomogeneities in the storm plasma to be of the order of 0.02 a.u. More recently, it has been shown by Yoshida and Akasofu (1966) that storms, during which intense *SI* (Sudden Impulse) activity occurs, are accompanied by significant Forbush decrease. In the course of a comprehensive review of the geomagnetic storm phenomena, Cole (1964, 1966) made the suggestion that a sensible grouping of the magnetic storms would be in terms of the amplitude of the geomagnetic 'noise' during the storm and that power spectrum analysis could provide a basis for the measurement of the noise. In the present communication a search has been made for periodicities in the range 2-100 mts in geomagnetic noise during the main phase of a great storm.

The great storms following the major solar events of November 1960 were characterised by intense *SI* activity and provided sufficient data for the study of power spectra of the noise. The first severe storm of the series started at 1325 hours on 12 November as a consequence of a class 2+ flare of 11 November or a class 3 flare of 10 November. While the storm was still in its main phase, a second severe storm commenced beginning with a remarkable sudden commencement at 1023 hours on 13 November (Bhargava and Natarajan 1967). The index of magnetic activity A_P (daily Equivalent Planetary Amplitude) registered the highest ever figure of 280 on 13 November 1960. During selected intervals, preceding the *SC* of 13 November and following it, quick-run (2 mm/min) records were obtained at Trivandrum and have been used for spectral analysis.

2. Data and Analysis

The horizontal force values were scaled every 2 mm (corresponding to a time spacing of one minute). Low frequency components of 'trend' was removed from the data before carrying out the computations of power spectra. This was done by removing estimated trend from the data. The estimated trend was computed from five international quiet dates of the month. The computational techniques described by Blackman and Tukey (1959) were followed. When computations are carried out by these techniques, a statistical filter is implied and by a suitable choice of the truncation length the width of the filter can be varied for desired resolution depending upon periodicities being looked for.

The spectra were computed for three separate sets of data as given in Table 1.

TABLE 1

| Set | Date | Hours (U.T.) | | No. of data points | Δt (min) | Max. lag (m) |
|-----|------------------|--------------|------|--------------------|------------------|--------------------|
| | | From | To | | | |
| 1 | 13 November 1960 | 0119 | 0938 | 500 | 1 | 100, 75, 50 and 25 |
| 2 | 13 November 1960 | 0119 | 0758 | 400 | 1 | 75, 50 and 25 |
| 3 | 13 November 1960 | 1023 | 1702 | 400 | 1 | 75, 50 and 25 |

The intervals under sets 1 and 2 are prior to the occurrence of *SSC* on 13 November and interval under set 3 is after it. The data spacing being at 1-min interval, the Nyquist frequency was 0.5 c/min.

The autocorrelation functions R_k were computed from—

$$R_k = \frac{1}{N-k} \sum_{j=0}^{N-k} X_j X_{j+k} \quad (k=0,1,\dots,m)$$

where, N is the number of data points, X_j are the data points and k is the lag with a maximum value of m .

The Fourier cosine transforms L_h of the autocorrelation function were computed from —

$$L_h = \frac{1}{m} \left[R_0 + 2 \sum_{k=1}^{m-1} R_k \cos \frac{\pi kh}{m} + R_m \cos \pi h \right] \quad (h=0,1,\dots,m)$$

The refined spectral estimates U_h were computed by smoothing the raw estimates L_h by a running application of weights 0.23, 0.54 and 0.23 with suitable adjustments for the end values. These estimates indicate the distribution of variance of the time series as a function of the frequency and also show whether a series has a tendency to exhibit periodic behaviour.

For variable resolution, the spectra were computed with autocorrelation function truncated successively at 100, 75, 50 and 25 lags for set 1 (500 data points), and at 75, 50 and 25 lags for sets 2 and 3 (400 data points each). With 100 and 75 lags, periodicities shorter than about 100 min should be obvious in the spectra. For reliability of estimates the truncation lengths were limited to one fifth or less of the number of data points. The computations were carried out on the CDS 3600-160-A computer.

3. Results and Discussion

The normalized autocorrelation function and smoothed spectral estimates with truncation length of 100 lags for the first set of 500 data points (storm of 12 November) are shown in Fig. 1. In order to ascertain whether the series of 500 data points was statistically stationary, it was cut short to 400 mts by removing the last 100 points of set 1 and recomputing the power spectra. These are shown in Fig. 2. The spectra indicate that the significant peaks in the two data samples occur at the same frequencies. The periods corresponding to peaks around which the power varies comparatively slowly with frequency (indicating stability of estimates) are centred at 14.3, 5.0, 3.7, 3.4 and 2.4 min. The test of significance from the number of degrees of freedom and the corresponding χ -square value shows that the periodicities corresponding to 14.3, 3.7 and 2.4 min are significant to 90 per cent or better confidence level.

The autocorrelation function and power spectra of the series formed by 400 data points commencing immediately after the great *SC* of 13 November with truncation length of 75 lags are shown in Fig. 3. The autocorrelation function of this series indicates several periodicities, a feature which was not present prior to the *SC*. The principal peaks in the power spectra correspond to 25.0, 10.5, 6.7, 4.3 and 2.9 min. Of these, all periodicities except 2.9 min are significant to better than 90 per cent confidence level. For this set, the spectra indicate no periodicities shorter than 2.9 min, zero powers having been reported at the high frequency end of the spectra.

As stated earlier, the spectra have been computed from observations immediately before and after the *SSC* of 13 November. The period considered before the *SSC* was during the main phase of the great storm which began on 12 November and the period after the *SSC* was during the

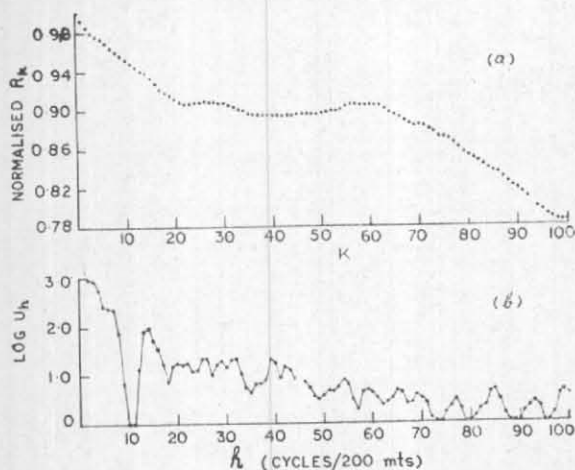


Fig. 1

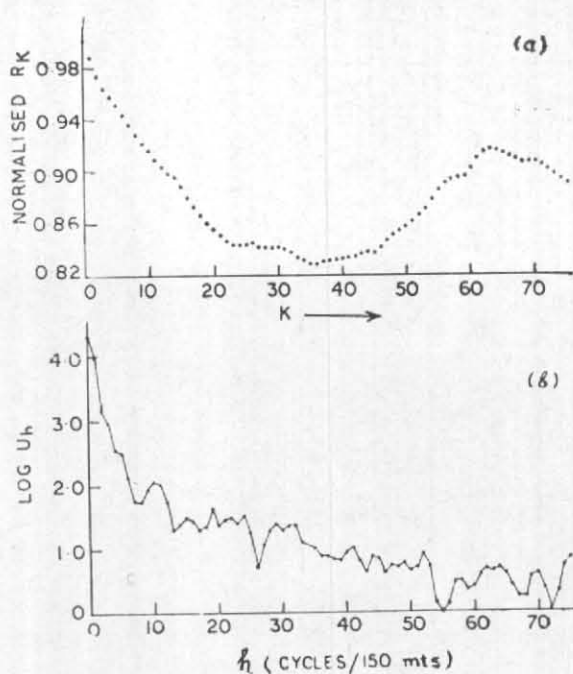


Fig. 2

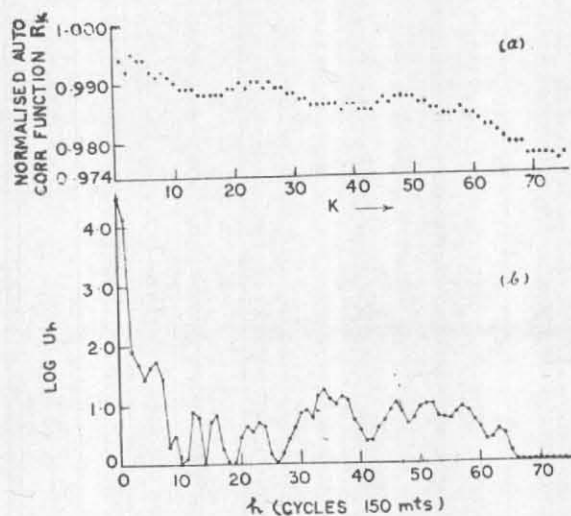


Fig. 3

initial and main phase of the storm of 13 November. The source flare for this storm was the great cosmic ray flare of 12 November. Both the storms were classed as severe and were marked by intense *SI* activity. The three consecutive 3-hr K_p indices preceding the *SSC* of 13 November were 9-9-9₀ and those following the *SSC* were 9₀ 9-8+. While short periodicities in the power spectra have been found to exist. During both the periods some differences are noticed in the spectral estimates. These are —

(a) During the later part of storm of 12 November the periodicities (for which

results are significant at 90 per cent or better confidence level) were shorter (14.3, 3.7 and 2.4 min) than during the main phase of the storm of 13 November (25.0, 10.5, 6.7 and 4.3 min). The longer periodicities were, therefore, associated with the storm whose source flare was an important cosmic ray flare.

(b) Spectra for sets 1 and 2 indicate that powers were present at frequencies greater than 0.5 cycles/min before the *SSC* of 13 November but after *SSC* powers were confined to frequencies shorter than 0.35 cycles/min.

In his theory of the main phase of magnetic storms, Cole (1964) has observed that electric fields responsible for the ionospheric currents during the main phase also cause movement of magnetospheric plasma which is likely to have a 'noisy' component. The development of the ring current, according to the hypothesis, is determined by the onset, amplitude and duration of the geomagnetic noise. The starting time of this noise, rather than the SSC, has been suggested as the origin of time for any analysis of magnetic storm. In addition to the onset time, the amplitude and other characteristics of this 'noise' are also impor-

tant. The frequency range for the noise suggested by Cole is ≤ 0.01 c/s. The present analysis suggests that the noisy component has certain definite spectral peaks in the frequency range of 0.0004 c/s and 0.008 c/s which is the range proposed by Cole and that the frequency characteristics vary, only slightly, between the two storms. It is considered that a more extensive spectral analysis of pulsation activity during main phases of sudden commencement and gradual commencement storms is likely to reveal a storm characteristic leading to a new type of classification of magnetic storms.

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