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# 146-day signal in the geomagnetic field—a probable association with the periodicity of the solar flare index

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**Abstract.** Results on the spectral analysis using geomagnetic field at three low latitude stations and the planetary magnetic activity index have shown peaks in the power densities in a broad band centred around 146-day period. This periodic behaviour appears to be close to that shown by the solar flare activity index for the same interval. It is suggested that the geoeffectiveness of the flare activity signal in different phases of the solar cycle can be better worked out using long series of ground-based geomagnetic data.

**Keywords.** Flare index; 146-day period; geomagnetic planetary index; geomagnetic field.

## 1. Introduction

Recently, Rieger *et al* (1984) have shown clear evidence of regularity ($\simeq$ 154 day period) in the occurrence of energetic solar flares. This effect was recognized and worked out for flares giving emissions of > 300 keV which produce soft X-rays. They attributed the origin of these periodic solar flares in the deeper layers on the sun, possibly at the sub-photospheric layers. Ichimoto *et al* (1985) have examined the periodic nature of solar activity using the parameters like sunspot number, calcium plage areas and flare indices. According to them, the temporal variation of the flare activity on the sun based on $H_\alpha$ data during the years 1965 to 1984, has shown evidence for 155-day and also 17-month periodicity of the activity. Also, they have taken into account the location of the flares on the sun to further confirm the reality of the derived periodicities.

If there exists the periodic behaviour in the sporadic nature of certain flare activity on the sun, its effect can be discernible in the processes involving the geoeffectiveness of the flare activity. One such process is the temporal variations of the geomagnetic field. With this objective, this paper reports our search to detect the signal corresponding to the cyclic variation of the flare activity using the data on planetary index of geomagnetic activity and the geomagnetic field at three low-latitude stations in the Indian region.

## 2. Data and analysis

Daily mean values of the horizontal component of the earth's magnetic field ($H$) at Hyderabad (dip $\simeq$ 20°N), Alibag (dip $\simeq$ 25°N), Sabhawala (dip $\simeq$ 44°N), the three low-latitude stations in the Indian region far from the influence of the equatorial electrojet, for the interval starting from 1 January 1979 to 31 December 1983 are taken for the analysis. This interval is nearly the same as the duration of the special experiment conducted by Rieger *et al* (1984) which was from February 1980 to September 1983. For the same interval of $H$ data, daily planetary index of geomagnetic activity, $A_p$, derived internationally, was also considered for analysis.

As both the $H$ field and $A_p$ series are known to have significant contributions from the annual and semi-annual variations and considering the fact that the wavelength at 180-day corresponding to the semi-annual variation is closer to the suspected signal of flare activity at 154-day, it is essential to filter the data to eliminate the annual cycles. The annual and semi-annual components (amplitudes and phases) are estimated for each of the calendar years separately via Fourier analysis and the synthesized values from the analysis are uniformly subtracted from the daily values. These residual daily series of $H$ and $A_p$, which are free from annual and semi-annual components, form the basic data set for further analysis. Using the time series of 1826 filtered daily values over five years duration, spectral estimates via fast fourier transform (FFT) are obtained on each of the $H$ and $A_p$ series separately using Cooley and Tukey (1965) algorithm. Prior to the spectral analysis, the length of the time series is extended upto 4096 data points by appending zeros at the end of the zero mean based time series for increasing the resolution. The amplitude spectra of $H$ at Alibag and $A_p$ against the harmonic number for the first 35 estimates are shown in figure 1. Similar results in respect of Hyderabad and Sabhawala are shown in figure 2.

## 3. Results and discussion

The results in figures 1 and 2 show that there is an increase in the amplitudes of $H$ in a band of frequencies, spanning from 164 to 132 day peaking at 146 day, at all the three low-latitude stations as well as in the spectra of $A_p$ series. Apart from the peak at 146 day, all the spectra have shown two more peaks at 241- and 683-day periods. However, the amplitude of the peak at the estimate corresponding to 146

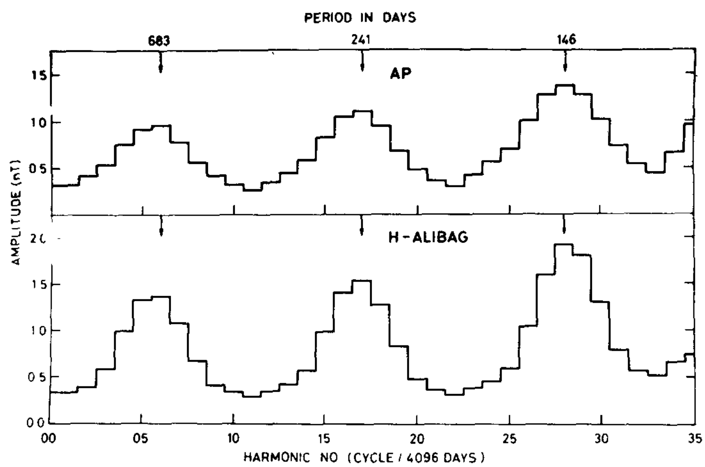


**Figure 1.** Plot of the amplitude spectra of the daily mean horizontal component of $H$ at Alibag and the daily planetary index of magnetic activity, $A_p$ in units of nT against the first 35 harmonic numbers (units of cycles/4096 days).

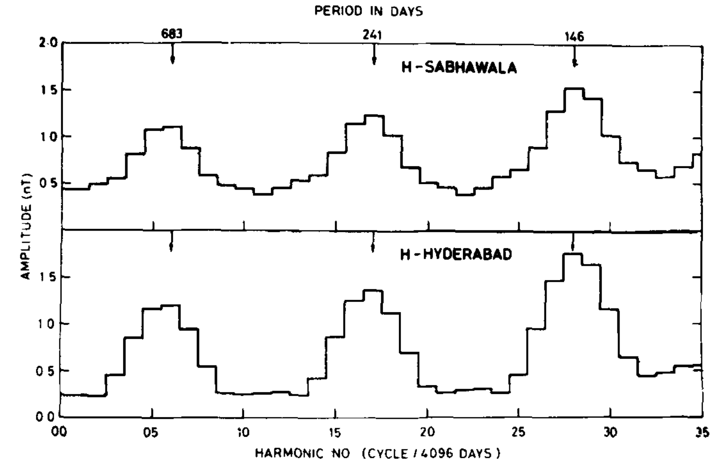


**Figure 2.** Plot of the amplitude spectra of the daily mean horizontal components of $H$ at Hyderabad and Sabhawala against the first 35 harmonic numbers (units of cycles/4096 days).

**Table 1.** Spectral results (146-day period).

| Parameter | Amplitude (nT) | Phase angle (degrees) |
|---|---|---|
| $H$-Hyderabad | 1·7 | 275 |
| $H$-Alibag | 1·9 | 280 |
| $H$-Sabhawala | 1·5 | 284 |
| $A_p$ | 1·4 | 106 |

day period is the highest in the field and $A_p$ results. The amplitudes and phases of the spectra corresponding to peak are given in table 1.

The number of degrees of freedom ($\nu$) of the spectra computed via FFT is approximately $2N/m$ where $N$ is the total number of data points and $m$ the maximum 'lag'. As the spectra are computed in FFT to half that of $N$, $m = N/2$. Thus $\nu$ works out to be 4. Assuming $\chi^2$ distribution, the confidence limits of power spectra are 3·6 and 83·0 at 95% confidence level (Munk *et al* 1959). The continuum level under the 146-day signal in both the field and $A_p$ spectra in figures 1 and 2 exceeds 100% and hence are considered to be statistically significant at 95% or beyond the confidence limits. Moreover, more reliable and purely empirical tests of significance, free from any assumptions, would be to produce spectra for several different samples and then compare spectra. Such methods are substantiated by Tukey (1961) who states that there is no substitute for some sort of repetition as a basis for assessing stability of estimates and establishing confidence limits. A simple and useful 'rule of thumb' is expressed by Stuart *et al* (1971) by which criterion a spectral line is considered to be significant if it contains at least three computed points which deviate from the noise and has a maximum twice greater than the surrounding noise level. It is also stressed by them that independent tests, by repeating the computation with different parameters or digitized data, are the only accurate method of eliminating doubts. Thus, the fact that the spectra computed with data of three different stations and also the global index, whose results are given in table 1, will pass through tests of significance and stand out as the significant peak at 146-day period.

To further substantiate the reality of the observed signal, cross-spectral analysis, via FFT, has been performed between $A_p$ and the $H$-field values at Alibag. The same filtered values, as were derived for auto-spectrum analysis earlier, are used. From the results of cross-spectrum analysis, it is found that the phase lead of $H$ at Alibag over $A_p$ is 175·4° and the magnitude of coherence is 0·99 at 146-day period. This high coherency and the near antiphase relationship observed support the contention of the origin of the same periodicity in both the series of $A_p$ and the field.

The fact that statistically significant peaks are observed in the $H$ field at three low-latitude stations and also in the globally derived parameter $A_p$, in the vicinity of 154-day period, suggests that these may be associated with the periodic nature of the high energy flares during the interval.

Ichimoto *et al* (1985) have done extensive analysis on flare activity using $H_\alpha$ flare data of importance 1,2 and 3 during the solar cycles 20 and 21. The periodicity of the flare activity was examined by them subjecting the weighted flare numbers for cycles 20 (1965–1975) and 21 (1976–1984) to the maximum entropy power spectral analysis. A distinct peak in the spectrum at the period near 155 day is observed by them in both the solar cycles suggesting that the flare activity shows an inherent characteristic of periodic activity. The time longitude distribution of flares which can be compared with that of magnetic fields on the solar surface between 5°N and 15°N heliographic latitudinal zones for the interval January 1976 to February 1984, has shown two regular strips of long-lasting magnetic features. The power spectra of the daily number of flares that occurred in these two strips separately peaked between 150 and 160 days thereby suggesting that each stream has a tendency to produce many flares separately with a period of ≃ 155 days. According to them, the probable origin of this periodicity is the temporal variations in the strongly magnetized regions which lasts for a long time and drift in longitudes due to the differential rotations.

In conclusion, it is shown that the geoeffective parameters of the flare indices viz the ground geomagnetic field at low latitudes respond to the periodic behaviour of the flare regularity. The long term associations are being worked out in different phases of the solar activity and the same will be published elsewhere.

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