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Variations Of Magnetic Micropulsations With KP Index At Low Latitude In India

M.T. Khan
Associate Professor, Department Of Physics, G.F. College, Shahjahanpur- 242001 (UP), India

Abstract
Oscillations of the geomagnetic field with periods between 10 sec and a few minutes have been studied using the Earth current technique at Indian Institute of geomagnetism at Navi Mumbai. For Pc4 pulsations, the diurnal variation of average period was 'u' shaped having longer periods at night than during the day. There was no simple relationship between period and K_p *index and, unlike Pc3, the percentage occurrence does not increase linearly with* K_p *index. Pc4 occurred most frequently just pre-dawn, this is in contrast to the noon peak observed at middle latitudes and under the equatorial electrojet. Pc3 occurrence frequency peaks at mid-day, the period was found to depend on* K_p*, thus T (in sec) = 36 – 2.2* K_p*. During times of moderate geomagnetic activity (*$K_p \sim 3–8$*) there was a distinctive variation of Pc4 period having the maximum period soon after local midnight and the minimum period around mid-day. Pi2 events were also* K_p *dependent, the number of events increasing approximately linearly with* K_p *(up to* $K_p = 4$*) and the period T (in sec) = 79 −11.4* K_p*.*
Keywords: *MHD waves, ultra-low frequency waves, magnetic micro-pulsations, interplanetary magnetic field, KP indices*

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I. Introduction

Magnetic micropulsations, particularly Pc4 and Pi2 pulsations, are observed at low latitudes in India. Studies have focused on their occurrence, dependence on various parameters like Kp index and Interplanetary Magnetic Field (IMF), and their relationship with ionospheric activity. These pulsations are thought to be related to wave energy transfer from the solar wind into the magnetosphere and ionosphere. The amplitude of the Pc 3-4 pulsations [peak to peak] ranges from fraction of a nano Tesla (nT) to a few nT[1-3]. The characteristics of ULF waves observed on the ground contain information not only about the generation processes but also about the regions through which they have propagated [4]. Most of the ULF wave studies have relied on data obtained from middle or high latitudes, while the equatorial and very low latitudes have received a little attention. Consequently, the source and propagation mechanisms of the equatorial and very low latitude pulsations are not fully understood and they might be related to either upstream waves or the mechanisms of pulsations at higher latitudes [5]. A number of studies indicated an attenuation of the Pc 3 amplitude at the equatorial region [6-8]. On the other hand, some studies at the equatorial region showed an enhancement in the Pc 3 amplitudes at dip equator. However, for short period Pc 3 pulsations (< 20 s), the equatorial Pc 3 amplitude has been reported to suffer attenuation rather than amplification The study of the latitudinal dependence of geomagnetic pulsations at very low latitudes particularly near the dip equator is very important to identify the propagation mechanism of the low-latitude pulsations, i.e., a direct incidence of the compressional waves on the equatorial ionosphere or a leak of the ionospheric current caused by the pulsations at higher latitudes [9-11]. The latitudinal dependence of the geomagnetic pulsations can be studied by a meridional array of stations. In the present study, we investigate Pc4 pulsations are typically in the 6.7–22.2 mHz range, while Pi2 pulsations are in the 6–25 mHz range with Kp

II. Data Analysis

The research work is supported by digital 1s geomagnetic sampling data from three Indian stations located in a latitudinal array. From 01 January 2005 to 31 December 2005, the Earth's magnetic field's X (north–south), Y (east–west), and Z (vertical) components were measured using three pivotal flux-gate magnetometer clusters at the station: Hanle, Nagpur, and Pondicherry with 1s sampling data. In India, locations of the stations were at very low latitudes. The IIG, Navi Mumbai, set up and operated the magnetometer cluster. The exact locations for these stations, as well as the schematic depiction of their location are represented individually in Table 1.1 and Figure 1.1. Time is constantly taken to in Universal Time (UT), i.e. IST= UT + 5:30 hr [12].

The data from a large number of stations was evaluated in a single second. The digital dynamic spectra of 24-hour time interval were built for all three sites in 2005 via MATLAB programming. We were able to identify the pulsation events to these dynamic spectra. On various days, we detected micropulsation occurrences at all sites. Generally, pulsation events occurred at frequencies ranging from 10 to 30 mHz. The tables 3.2, below show the pulsing event that has a frequency and time range for Nagpur, recording station independently from January to 2005.

Table 1.1: Coordination of recording station details

Recording stations	Geographic co-ordinates		Geomagnetic co-rdinates	
	Longitue °E	Latitude °N	Longitue °E	Latitude°N
Pondicherry (PON)	79.92	11.93	152.00	02.52
Nagpur (NAG)	79.01	21.11	151.83	11.70
Hanle (HAN)	79.07	33.01	152.09	23.22

Table 1.1: Nagpur Magnetic Pulsation occurrences (January-05)

Date	Time range (UT=IST–5:30 hr)	Frequency range (mHz)	Comment
01-01-05	17:10 – 20:11	10 – 30	Event observed
02-01-05	16:20– 18:25	05 – 25	Event observed
06-01-05	16:13 – 20:26	10 – 25	Event observed
08-01-05	17:02 – 18:26	10 – 30	Event observed
10-01-05	12:40 – 17:30	05 – 25	Event observed
11-01-05	19:00 – 20:11	10 – 30	Event observed
24-01-05	05:00 – 06:34	10 – 25	Event observed
27-01-05	15:39 – 20:23	10 – 25	Event observed
28-01-05	17:02 – 19:35	10 – 25	Event observed
29-01-05	15:40 – 18:40	05 – 20	Event observed
31-01-05	16:17 – 20:26	15 – 30	Event observed

Following the determination of events of pulsation, the data was chosen in a short span of time, and chosen data were "filtered for the observed frequency range". The filtered data were plotted displaying the reasonable pulsation event. The power spectral densities were then calculated using the filtered data. Figures 1.2, 1.3, 1.4, and 1.5 show the plotted time-series, dynamic spectra, filterd spectra, and power spectra for the pulsation event that occurred at Hanle on January 28th, 2005, respectively. The X and Y components were chosen by all three sites in 2005.

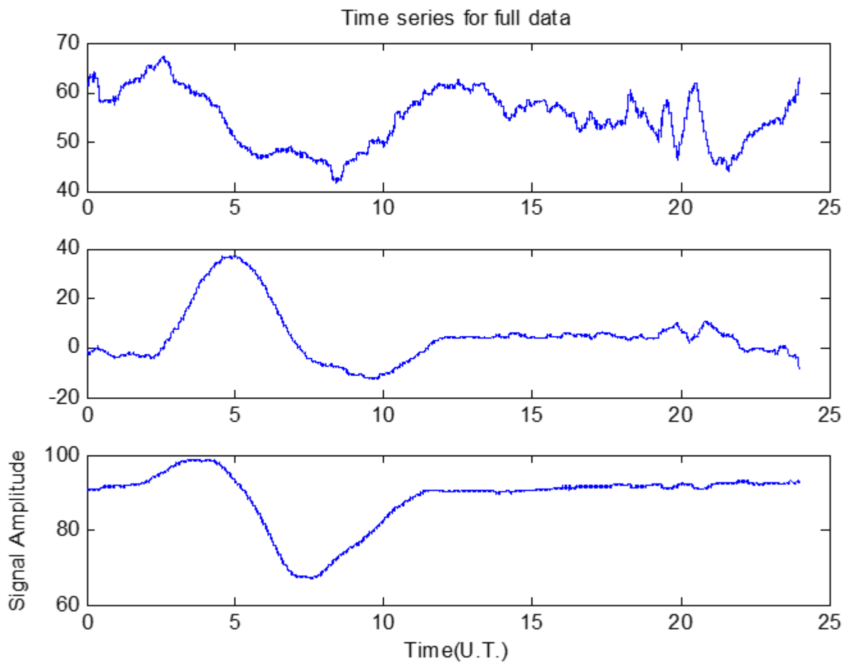

Figure 1.2: Time series of data of 28th January-2005 (Hanle)

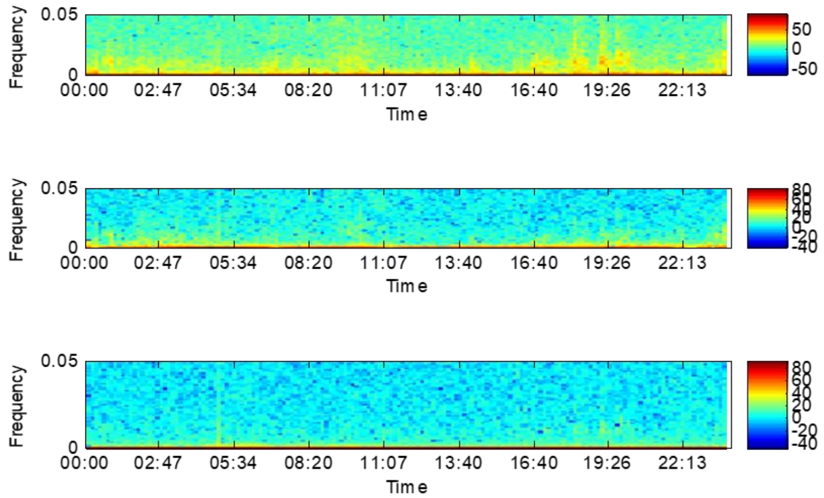

Figure 1.3: Digital Dynamic Spectra (DDS) of pulsation occurrence 28th January-2005 data (Hanle) in UT. (The X, Y, and Z components are represented by the top, middle, and bottom panels of the spectral spectrum, respectively, with different colors indicating relative intensities on a logarithmic scale.)

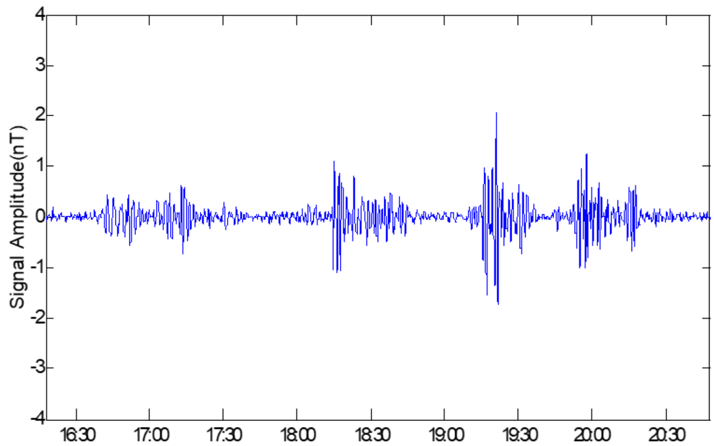

Figure 1.4: A time-series of filtered data for January 28, 2005 (Hanle), in UT.

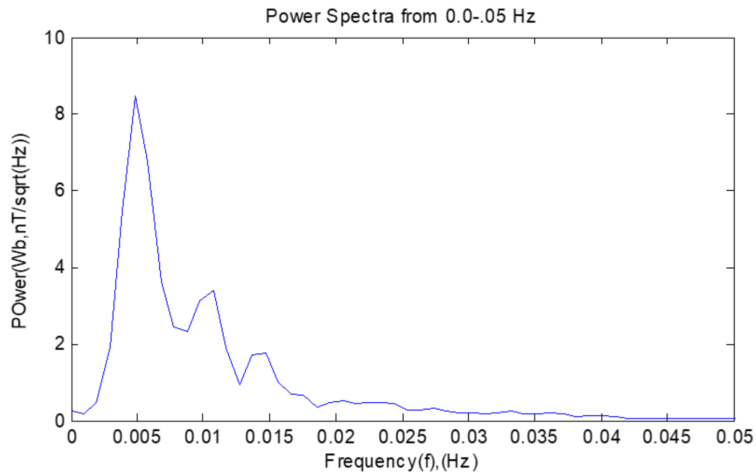

Figure 1.5: Power Spectra of pulsation event of 28th Janaury-2005 (Hanle)

III. Result And Discussion

Figure 2.1 shows the monthly occurrence of Pc4 with Kp in January 2005 at all three stations (Hanle, Pondicherry, and Nagpur) [166]. The X-axis depicts the Kp values, while the Y-axis depicts the total time of occurrence in minutes for the full month. It is clear that events were observed in each of the month's Kp values, with the primary occurrence of Pc4 was observed at Kp= 4 having duration of 325 min, 248min, and 290 min at Hanle, Nagpur and Pondicherry respectively. At Kp= 6+, additional peaks in the Pc4 occurrence of 264 min, 268 min and 228 min duration were detected at Pondicherry, Nagpur and Hanle respectively. Additional minor peaks in Pc4 occurrences having less duration were observed at Kp = 6- , 6, 3+, 3- and 8-, at all the three stations and some other minor peaks were also observed in the Pc4 occurrence at all three stations for Kp = 7, 7+, 8-, and 8. Very little Pc4 occurrence were observed at Kp = 1-, 1, 1+, and 2-at all stations. Due to a data gap for Nagpur and Hanle on January 20 and 16, Nagpur's occurrence peak was lower than the other stations.

Figure 2.2 depicts the seasonal variation of Pc4 occurrence with Kp for all three stations during the Winter 2005 season. It is clear that events happened for all Kp values during the month, with major occurrences of Pc4 occurring at Kp= 3 for periods of 905 minutes, 568 minutes, and 833 minutes in Hanle, Nagpur, and Pondicherry, respectively. Additional Pc4 occurrence peaks were identified at Kp= 3+ with periods of 684 min, 584 min, and 675 min in Hanle, Nagpur, and Pondicherry, respectively. Additional modest peaks in Pc4 occurrences with shorter durations were found at Kp = 2-, 2, 2+, 3, 4-, and 4 at all three sites. Minor peaks were also observed in the Pc4 occurrence at all the stations for Kp = 0+, 1-, 6-, 6 and 6+. Very little Pc4 occurrences were obtained at Kp = 0, 1, 1+, 5-, 5+, 7-, 7, 7+, 8- and 8 at all the three stations [166].

Figure 2.2 shows that the variance in Pc4 occurrence was nearly identical in Hanle and Pondicherry, but different in Nagpur. The lack of data at Nagpur on December 21, 28, 29, 30, and 31 explained this behavior.

Figure 2.3 shows the annual variation of Pc4 incidence with Kp for all three stations. It is clear that the events happened for all Kp values throughout the year, with utmost occurrences of Pc4 occurring at Kp=3 with durations of 2170 min, 2279 min, and 2554 min at Hanle, Nagpur, and Pondicherry, respectively. Additional peaks in the Pc4 occurrence were observed at Kp= 3- having durations of 2089 min, 2075 min and 2513 min at Hanle, Nagpur and Pondicherry respectively. Additional minor peaks in Pc4 occurrences having less durations were observed at Kp = 1-, 1, 1+, 2-, 2, 3+, and 4- at all the three stations respectively. Minor peaks were also observed in the Pc4 occurrence at all the stations for Kp = 0+, 2+, 4 and 4+. Very little Pc4 occurrences were obtained at Kp = 0, 5-, 5+, 6-, 6, 6+, 7-, 7, 7+, 8-, 8, 8+ and 9+ at all the three stations respectively.

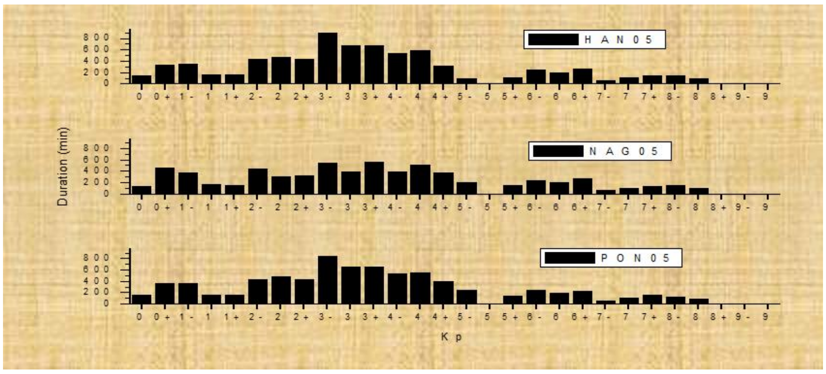

Fig 2.1: Diurnal Pc4 variation occurred in the month January 2005 at all three stations: Pondicherry (POND), Hanle (HAN), and Nagpur (NAG).

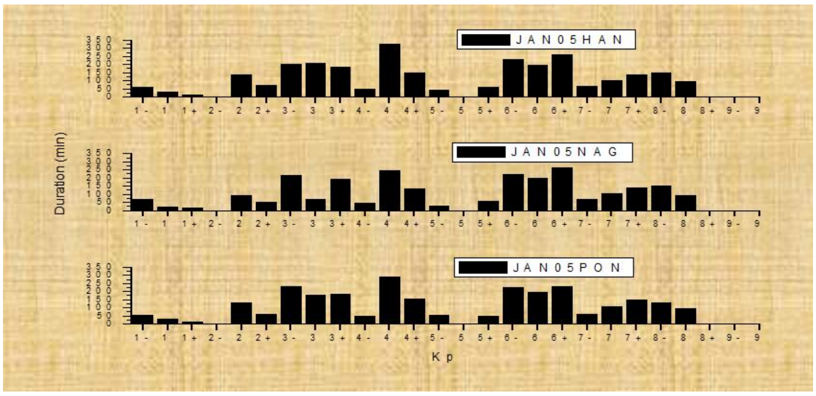

Fig 2.2: Seasonal variation in Pc4 occurrence in winter season 2005 at HAN, NAG, and POND stations.

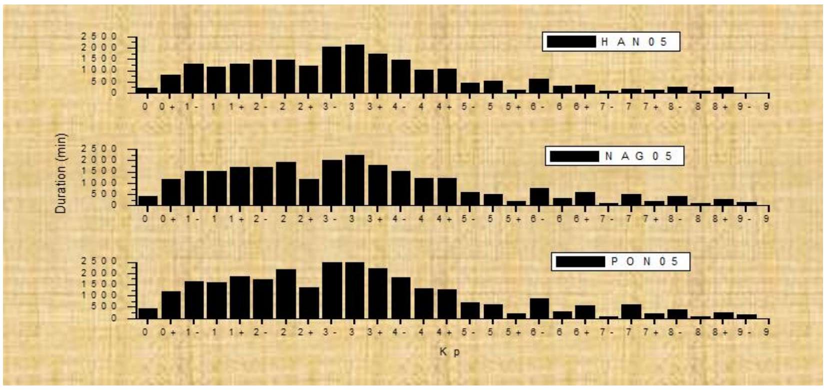

Fig 2.3: Pc4 occurrence varied yearly at all three stations in 2005: HAN, NAG, and POND.

The graphs for each month of Feb to Dec, 05 show varying shapes with frequency for every month with eminent Pc4 maxima. The monthly variation of Pc4 frequency occurrence with Kp index for each and every station (Nag, Han and Pond) for each month of February to December 05 are depicted in this paper. The range of average frequency (AF) at all three stations lied in between 9- 14 mHz giving average approx 11.50 mHz. The higher frequencies (HF) range was 11 to 22 mHz while the lower frequencies (LF) range was allying 7- 8 mHz. Most of the peaks in Pc4 occurrence with Kp were found over the 0+ to 5 Kp ranges and show no variation for Kp<5. This concurs with the precursory studied of Voelker [9], Orr and Channon [10], Gupta and Stening [11] and others. The seasonal variation in the frequency of Pc4 occurrence with Kp dependence for every station for the winter season 05 is depicted in Figure 4. Most of the peaks in Pc4 occurrence of average frequency and higher frequency with Kp were found at all the 0+ to 8 Kp ranges and lower frequency with Kp were found over the 0+ to 6- Kp ranges and show no variation Kp<6. There were observed no variation in the whole graph in between 5 to 5+ Kp range. The reason of this difference is the deficiency of the input data in winter season. The seasonal Kp dependence shows that Pc4 frequencies variation with Kp for Autumn and Spring seasons is more or less similarity for Kp≤5 and is consequently, unconventional of seasons over this range of Kp indices. In the seasonal Pc4 occurrence the prominent peaks were perceives at Kp = 3-, 3 for every seasons. Although supplementary peaks were detected at Kp = 1-, 1 and 1+ for the autumn season. It is also worth noting that Pc4 in winter was observed during intense magnetic activity when 5+ < Kp < 8+ [12-14].

In the view of the aforementioned discussions, excitation mechanisms and the perusal of the results of the diurnal as well as cyclic deviation of low latitude Pc4 pulsations; it is revealed that the upstream waves are a principal source of Pc4 pulsations observed at the night side, which were begun at the dayside and mostly by an augmented region of ULF waves. Furthermore, it is recommended that the plasmaspheric cavity mode resonance may have played significant role in filtering the broadband input to the magnetosphere. The observations presented in the study were also in concurrence with the characteristics of ULF upstream waves claimed by Heilig [13].

Many authors also reported the correlation of the IMF magnitude with the Pc3-4 pulsations recorded at ground. [14]. The strength of IMF is very important factor that governs the frequency of these MHD waves, although cone angle may have effect in frequency determination as reported by Le and Russell [15]. A study is presented by Vellante [16] based on the MHD pulsation events found simultaneously by satellite CHAMP in space and by SEGMA at the ground and showed that the compressional wave frequency recorded by CHAMP was exceptionally near to the anticipated frequency of foreshock origin upstream waves as forecasted with the empirical formula f (mHz) ≈ 6 BIMF (nT). By comparing the distribution of energy of reflected ions in the transition region, as recorded with the satellite ISEE 3, with the compressional wave frequencies in the magnetosphere, Yumoto [17] showed his agreement with the ion cyclotron resonance mechanism model for upstream wave excitation. Findings of these studies indicates that upstream waves in the foreshock having frequencies correlated to the interplanetary magnetic field strength possibly convicted through the transition region and go forward in magnetosphere during small cone angle condition. In magnetosphere it may spread as compressional mode with having coupling with other modes of hydromagnetic wave and are registered as ultra-low frequency magnetic pulsations at the ground stations.

Measuring the monthly occurrence of ULF waves; their seasonal variation is fruitful for quantifying their proliferation and generation mechanism. Aiming the results of the different analyses of diurnal variations in the event of Pc4 geomagnetic pulsations for the whole year 2005 recorded at three stations located at low latitudes in India have been presented in this study. The seasonal deviation in the periodic observations (hourly) occurrence of these pulsations was investigated and presented. The most of the finding of Pc4 experiments in our investigation in between Kp= 3 to 5+ has also been presented in several earlier studies [21-25]. Various Pc4 experiments in local day time were also observed in the study of the present investigation. Finding of the investigations are in coherence with previously suggested by Takahashi [17]. They reported that pulsations observed in the nightside initiated in the dayside and mostly by an extended region of ULF waves against the bow shock; not from processes occurring in the nightside magnetosphere because there was nonappearance of substorm onsets or intensification. The same results were also presented by Villante [18]. The key peaks in Pc4 observation at local winter and autumn observed at the same time at all the three stations in accordance with the earlier studies of Ansari [20] and Kuwashima [19]. In these investigations, the main occurrence peaks in winter and equinox remain the same with time. The stations array was spread over a latitudinal range of 21° only; consequently, it was insufficient for observations of latitude dependence of Pc4 pulsation occurrence as the data from large-scale latitudinal separation is necessary for the investigations.

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