

# OBSERVATIONS OF Pi 2 PULSATIONS IN MALAYSIA

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**Abstract** Geomagnetic pulsations, also known as ULF (ultra low frequency) waves, are variations in the geomagnetic field on time scales of 0.1 to 600 seconds. These pulsations are the most visible sign of magnetic activity external to the Earth at low and middle latitudes. A ground base data recorded at the newly developed observatory station ( $1^{\circ} 51.3' N$ ,  $103^{\circ} 5.1' E$ ) Parit Raja, Batu Pahat, was used to study the pulsations. The data were recorded using a fluxgate magnetometer with 1 s sampling rate. Eighty-five Pi 2 pulsations events were detected ( $K_p \leq +2$ ) during the months of June to December 2005. The pulsation events were apparent in the H-component.

The Pi 2 pulsations were frequently observed around local midnight (2100 -0300 LT) and during the day (0600-1500 LT). The number of events decreases during the period of 1500-1800 LT. The ratio of the number of Pi 2 pulsations occurring on the dayside to the night side was about 77%. The frequency range of the Pi 2 wave is 2 – 25 mHz with dominant frequency range of 6 to 15 mHz. The dynamic power spectra was used to calculate the peak power at the same frequencies and spectrogram analysis was used to determine the power across the time.

## 1.0 Introduction

Geomagnetic pulsations, also known as ULF (ultra low frequency) waves, are naturally occurring low frequency hydromagnetic waves in the Earth's magnetosphere [1, 2]. These waves are short period and small amplitude oscillations of the Earth's magnetic field. The short period ULF disturbances are caused by internal processes origin in the Earth's magnetosphere as a result of plasma instabilities and as responses to fluctuation in the solar wind [2].

The geomagnetic pulsations are divided into two broad classes (see Table 1) based on their observed characteristic [2]. The first class, known as Pc with mainly continuous character covers the whole range of pulsations with periods from 0.2 to 600 sec. The Pc is divided into five sub-groups depending on their period. The second class is characterised by their irregular form known as Pi. The Pi is divided into two sub-groups [1].

Table 1: Pulsation Classes

	Continuous					Irregular	
Classes	Pc 1	Pc 2	Pc 3	Pc 4	Pc 5	Pi 1	Pi 2
$T$ (s)	0.2-5	5-10	10-45	45-150	150-600	1-40	40-150
$f$ (mHz)	200-5000	100-200	22-100	7-22	2-7	25-1000	2-25

## 2.0 The Pi 2 pulsation

The Pi 2 pulsation is the most common pulsation events detected on ground-based measurement at high-latitude, low-latitude and equatorial [3]. The Pi 2 pulsations are commonly observed during local night and daytime [4], which are impulsive, damped oscillations of the geomagnetic field in the frequency range 2-25 mHz and with amplitudes in the range 0.25-2.5 nT. Observation showed that the Pi 2 pulsations occur simultaneously with substorm expansion phase onset [5]. The excitation mechanism of Pi 2 is a transverse standing Alfvén waves along geomagnetic field lines.

## 3.0 Geomagnetic Index

The geomagnetic indices describe the state of the magnetic field from their data recording [2, 6]. These indices have become useful tools for providing a global picture of geomagnetic disturbances levels. One of these indices is the global  $K$  index or  $K_p$  index. The  $K_p$  index is originates based on maximum fluctuations range of  $H$ -component field distributed 3 hours from 13 standards set of the observatories, which lie between 46 and 63 degrees North and South of the geomagnetic latitude stations. This index is considered to be a general picture of global magnetic disturbances level. The  $K_p$  index is prepared by the University of Gottingen, Germany.

## 4.0 Methodology

The magnetic pulsation events were identified based on the waveforms, frequencies and amplitudes. Daily analysis of the  $H$ -component during periods of quiet magnetic activity identified the only Pi 2 pulsation event that occurred during the seven-month observation period between June to December 2005. The horizontal magnetic components  $H$ -component data was the primary source used to identify the pulsations events during quiet days ( $Kp=0$  to  $+2$ ). In the low latitude, the  $H$ -component was commonly used to scan the Pi 2 pulsation with a success rate of more than 81% [7]. The  $H$ -component data are obtained using a fluxgate magnetometer with a one-second sampling rate at the newly developed magnetic observatory station at Parit Raja, Batu Pahat [8, 9].

A one-hour data interval set was selected in this investigation to identify the Pi 2 pulsation event. During this study, the visual inspection methodology was adopted [7]. First, the Pi 2 was identified when a sudden change of the  $H$ -component with amplitudes in the range 0.25-2.5 nT and it was followed by the appearance of a damped oscillation. Then, the period range of the bandpass filter was applied to the  $H$ -component from 40 to 150 s. Finally, the spectrogram and dynamic power spectra density were calculated to determine a peak power at the same frequency as well as a cross-time range peak power of each data set.

## 5.0 Data analysis

The unfiltered and filtered magnetograms in Figure 1 indicates Pi 2 pulsation occurred on 17 December 2005 from 0015 to 0030 LT. The magnetic activity was at a minimum during this time ( $Kp=0$ ). An irregular Pi 2 pulsation waveform was detected from a higher frequency band ( $\sim 13$  mHz) to the lower band ( $\sim 8$  mHz), as shown in the spectrogram (by FFT technique) and dynamic power spectra in Figures 2 and 3. The Pi 2 pulsation's peak power reaches more than 40 nT<sup>2</sup>/Hz. The Pi 2 events observed at the ground observatory were the result of two waves sources; the substorm current wedge (SCW) during the development of a magnetospheric substorm and the magnetospheric cavity resonance wave in the inner magnetosphere [10, 11]. More recent studies show the day and night Pi 2 pulsation ( $\sim 5$ -20 mHz) waves propagating down the ionosphere can cause the oscillations in the Doppler shift of the HF radio transmission [12, 13].

The total of 85 Pi 2 pulsation events were detected between June and December 2005. The Pi 2 pulsations observed occurred frequently from 0000-0300 LT. Figure 4 shows the distribution of Pi 2 pulsations with the highest events occurring during the night and early morning. The number of events decreases during the day especially from 1500-1800 LT. Of the 85 events, 48 were observed during the night (1800-0600 LT) and 37 occurred during the day (0600-1800). The ratio between the daytime and nighttime events observed is 77% (37/48).

## 6.0 Discussions

In this study, the Pi 2 pulsations were successfully observed at Parit Raja area during the quiet magnetic activity ( $Kp \leq +2$ ). The  $H$ -component data was used to detect the pulsation events. Eight-five Pi 2 pulsation events were observed during seven months observations, with frequently occur around midnight (2100-0300 LT) but they were observed even during the day (0600-1500 LT). The ratio of the number of Pi 2 pulsations that occur from day to night is about 77% (37/48). The frequency range of the Pi 2 wave is 2 – 25 mHz but the dominant frequency of  $\sim 6$  to  $\sim 15$  mHz was observed at Parit Raja.

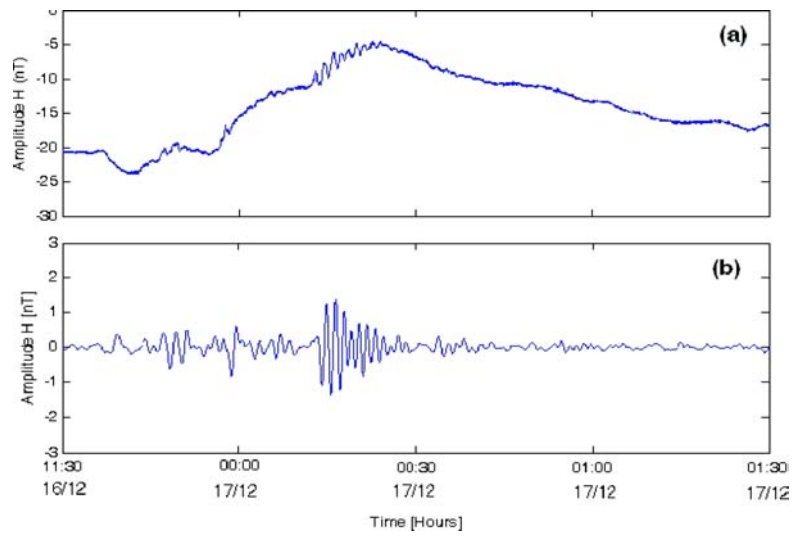


Figure 1: The magnetograms of  $H$ -component observed during P1 2 pulsation occurred (a). Unfilter data, and (b). Filtered data

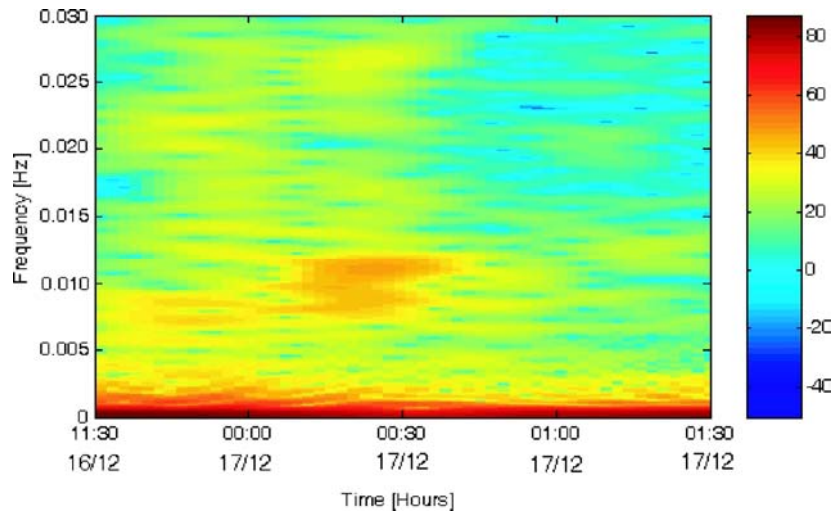


Figure 2: The spectrogram of the  $dH$ -component identified power peaks occurring at frequency ranges of  $\sim 8$  to  $\sim 13$  mHz

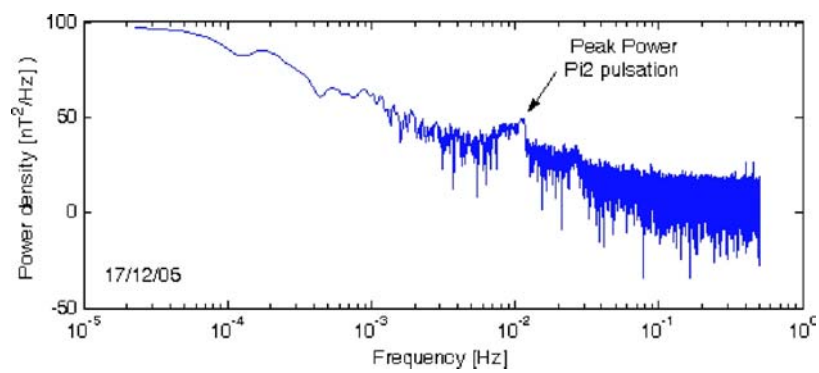


Figure 3: Power spectra density of the  $H$ -component confirmed the power peaks occurred at frequency ranges of  $\sim 8$  to  $\sim 13$  mHz

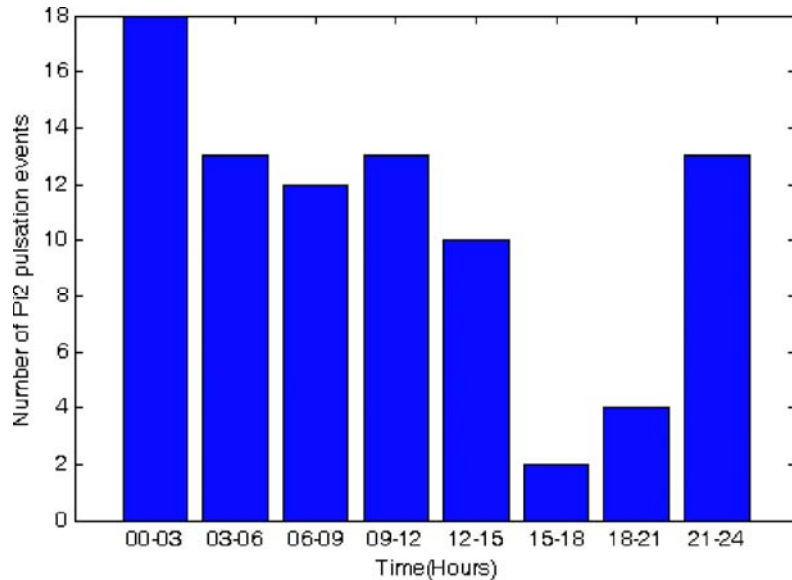


Figure 4: The histogram of Pi 2 pulsation occurrence during the seven months of observation at the newly developed observatory

## 7.0 References

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