

# Continuous Magnetic Pulsations (Pc3) Dependency to the Solar Wind Speed and Dynamic Pressure in 2007

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**Abstract**—This study measures the dependency of Continuous Pulsations (Pc3) amplitude to the solar wind speed and dynamic pressure at the low latitude station Langkawi (LKW), Malaysia. To show dependency, 10 days of wind data are collected in 2007 for having fastest and slowest wind speed. The Pc3 measured on the selected day's shows that the wind speed above 600 km/s produces higher Pc3 amplitude. The mean amplitude for the fast wind speed is 0.1267nT, while wind speed below 300km/s produces lower Pc3 amplitude with the mean of 0.0835nT. On the other hand, the change of dynamic pressure shows a change of Pc3 amplitude. According to the obtained result, the solar wind dynamic pressure must be related to the change of Pc3 amplitude.

**Keyword:** Pc3 Pulsations, Pc3 occurrence, Solar Wind Speed, Dynamic Pressure.

## I. INTRODUCTION

Geomagnetic pulsations are also known as Ultra Low Frequency (ULF) waves. They are naturally occurring at low frequency hydromagnetic waves in the Earth's magnetosphere with frequency band from 1mHz to 1Hz and ranges period of waves between 0.2 to 600 second[1, 2]. ULF waves are created by a variety process of magnetized plasma[3]. These waves are classified as continuous (Pc) or irregular (Pi) pulsations with each category were subdivided into certain band of frequency that separate specific type of pulsations[2]. Continuous Pulsations (Pc) are divided into five groups depending on their period, while Irregular Pulsations (Pi) divided into two groups. Table 1 shows the Pulsation classes with their period and frequency range.

Pulsation	Classes	Period, $T(s)$	Frequency, $f(mHz)$
Continuous	Pc	Pc1	0.2 – 5
		Pc2	5 – 10
		Pc3	10 – 45
		Pc4	45 – 150
		Pc5	150 – 600
Irregular	Pi	Pi1	1 – 40
		Pi2	40 – 150

Table 1: Pulsation Classes

Pc3 pulsations are continuous geomagnetic oscillations with a quasi-sinusoidal waveform. These continuous pulsations are relatively low amplitude variations of the geomagnetic field with period's range of 10 to 45 seconds[4]. The amplitude of the Pc3 pulsation ranges is from 0.1 to 0.3nT. Most of the ULF wave studies were obtained from middle and high latitude, while a little attention at equatorial and low latitude. This is because the source and propagation mechanisms of equatorial and low latitude pulsation are not fully understood[5].

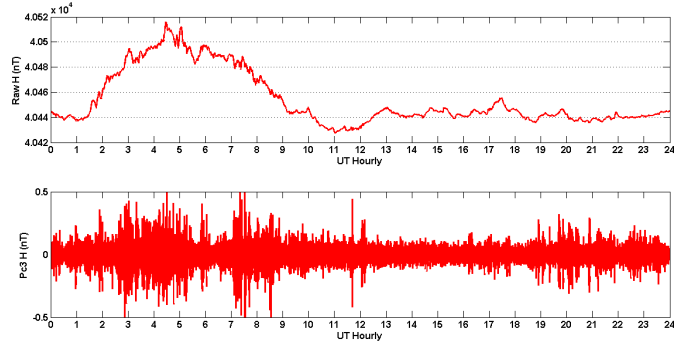
Solar Wind is known as a continuous outflow of the solar coronal plasma[6]. They are the external source of ULF waves that particularly at low frequencies around 1mHz[7]. Observations of the near-Earth solar wind activity show that there are correlations between pulsation and solar wind parameters[8]. The first correlations observed were the dependency of magnetic pulsation amplitude of due to solar wind speed and relationship between IMF magnitude and Pc3 frequency[9]. Saito and Wolfe discover that there are positive correlation between solar wind speed and Pc3 amplitude for two events in the Pc3 to Pc5 bands[8, 10].

The main goal of the research is to study and examine the relationship between Pc3 variation with the solar wind speed and dynamic pressure.

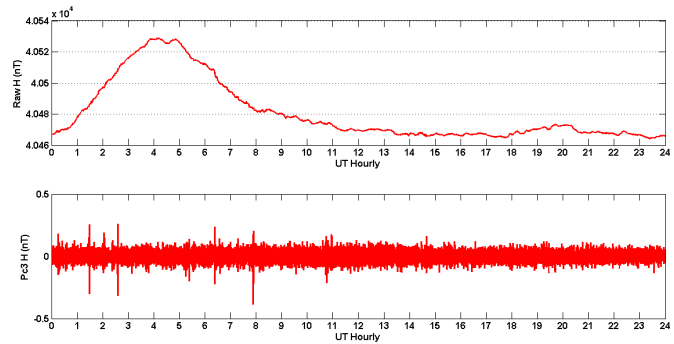
## II. DATA ANALYSIS

The research involves on the use of magnetometers to observe the magnetic pulsations activity. Geomagnetic data were obtained from the MAGnetic Data Acquisition System (MAGDAS) magnetometer located at the Langkawi Island. The 2007 data of magnetic pulsation activity were selected and examined. The selection of Pc3 events involved comparing the 24 hours of solar wind speed and dynamic pressure. The magnetic data consist of D, H and Z-component. The H-component recorded by the station was scripted using MATLAB in order to identify the Pc3 events. The Pc3 index relationship was developed. The Pc3 polarization data sets were analyzed with average of 60 minutes interval. Figure 1 show the 24 hours (0000 – 2300 UT) sample of Pc3 pulsations at the date of highest speed occurrence of solar wind activity on 14<sup>th</sup> February 2007. While the 24 hours sample of Pc3

pulsations at the slowest speed of solar wind is on 24<sup>th</sup> February 2007 shown in Figure 2.

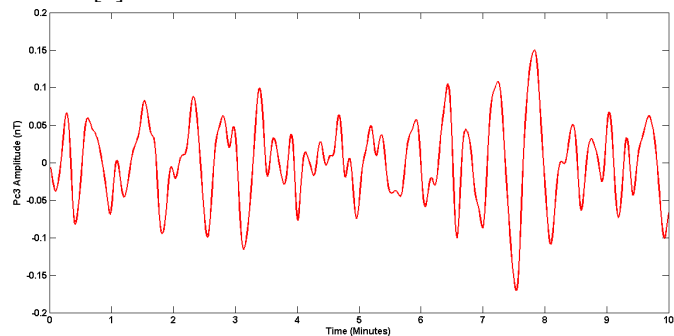


**Figure 1: Sample of Pc3 pulsation on High Speed of Solar Wind at 14th February 2007**

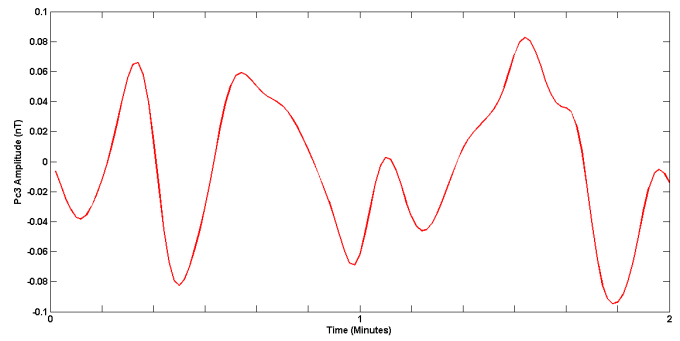


**Figure 2: Sample of Pc3 pulsation on Slow Speed of Solar Wind at 24<sup>th</sup> February 2007**

Figure 3 shows a sample of Pc3 pulsation in 10 minutes with a clear continuous quasi-sinusoidal waveform, while Figure 4 shows a sample in 2 minutes. It is evident from the figures that the wave in H-component at Pc3 pulsation were quasi-sinusoidal waveform with a period of 10 to 45 seconds[4].

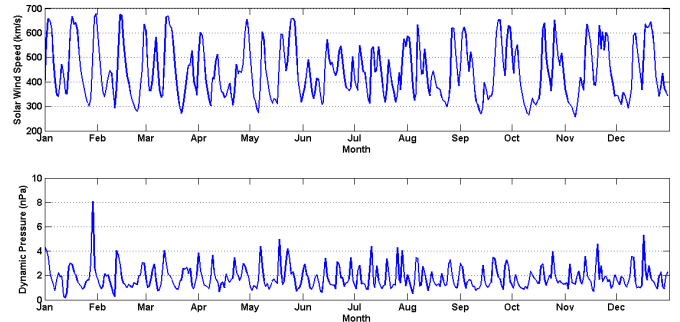


**Figure 3: Sample of Pc3 Pulsation in 10 minutes**



**Figure 4: Sample of Pc3 Pulsation in 2 minutes**

The solar wind speed and dynamic pressure from 2007 were used in this study. All the data were collected from the OMNIWeb server <http://omniweb.gsfc.nasa.gov/>. These data is used to find the high and slow solar wind speed and their dynamic pressure in 2007. It is shown that 15 days speed of solar wind were recorded to be higher than 650km/s. while there are 20 days of the speed were recorded to slower than 300km/s. 10 days of high solar wind speed and 10 days of slow solar wind were used to evaluate the relationship between Pc3 occurrence and solar wind variations.



**Figure 5: Solar Wind Speed and Dynamic Pressure on 2007**

Table 2 shows 10 dates of high daily average of solar wind speed recorded on 2007 while Table 3 shows 10 dates of slow daily average of solar wind speed were been selected. From these selected dates, Pc3 pulsation were been examine and to find the relationship between Pc3 occurrence and solar wind speed.

Date	Daily Average Solar Wind Speed (km/s)
3 <sup>rd</sup> January	658
4 <sup>th</sup> January	650
17 <sup>th</sup> January	668
19 <sup>th</sup> January	641
31 <sup>st</sup> January	679
14 <sup>th</sup> February	674
15 <sup>th</sup> February	672
28 <sup>th</sup> February	635
13 <sup>th</sup> March	665
14 <sup>th</sup> March	669

**Table 2: 10 selected date for high daily average of solar wind speed on 2007**

Date	Daily Average Solar Wind Speed (km/s)
27 <sup>th</sup> January	300
11 <sup>th</sup> February	293
23 <sup>rd</sup> February	286
24 <sup>th</sup> February	280
21 <sup>st</sup> March	294
22 <sup>nd</sup> March	271
8 <sup>th</sup> April	303
12 <sup>th</sup> June	308
12 <sup>th</sup> September	282
14 <sup>th</sup> September	298

Table 3: 10 selected date for slow daily average of solar wind speed on 2007

### III. RESULT AND DISCUSSION

Figure 6 and 7 show the 24 hours variation between Pc3 amplitude and dynamic pressure for the solar wind speed above 600km/s using the 10 selected days. Each day is plotted and the mean amplitude for each parameter was calculated. The mean speed of solar wind is 661 km/s. While the dynamic pressure shows the mean pressure of 2.5nPa. The amplitude of Pc3 pulsation was generally above than 0.1nT (ranging between 0.1 to 0.3nT), with the mean amplitude of 0.1267nT.

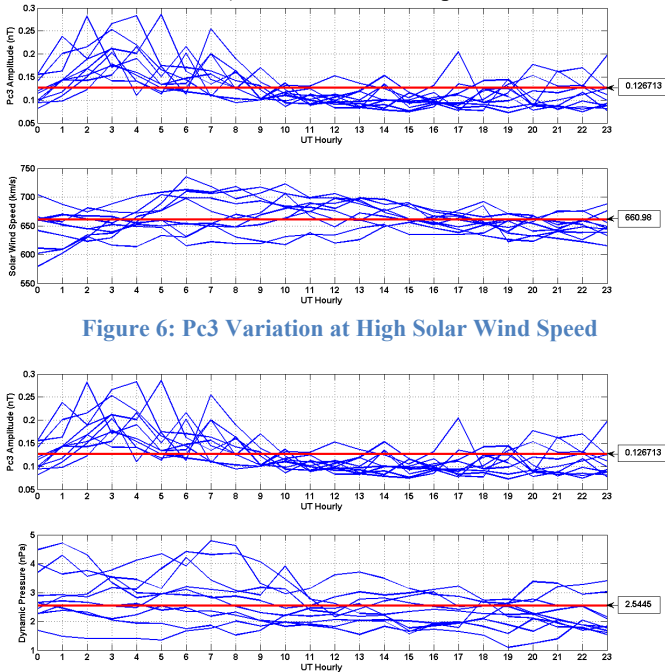


Figure 6: Pc3 Variation at High Solar Wind Speed

Figure 7: Variation between Pc3 and Dynamic Pressure at High Solar Wind Speed

While the variation between Pc3 and dynamic pressure at solar wind speed below 300km/s is shown in Figure 8 and 9. The mean speed of solar wind is 291km/s, while dynamic pressure shows the mean is 1.3nPa. Most of the Pc3 pulsation amplitude was less than 0.1nT with the mean amplitude of 0.08nT.

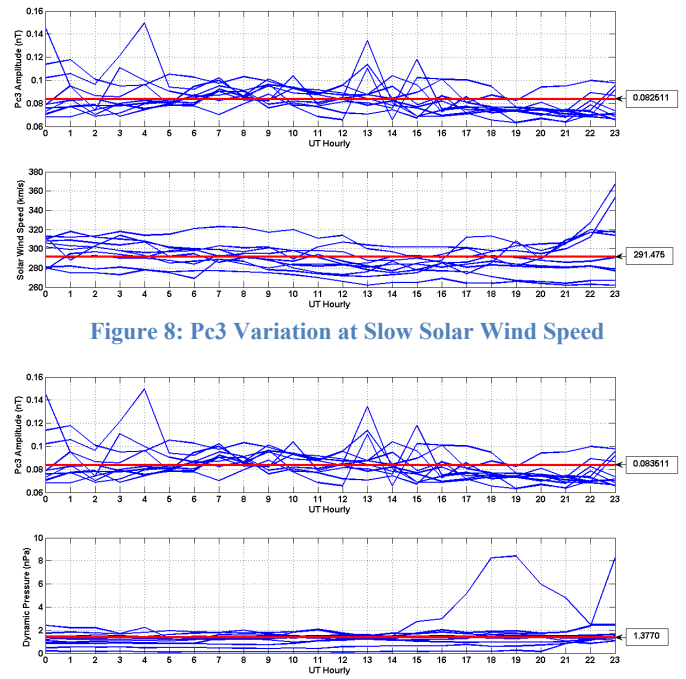


Figure 8: Pc3 Variation at Slow Solar Wind Speed

Figure 9: Variation between Pc3 and Dynamic Pressure at Slow Solar Wind Speed

From the Figure 6 and 8 showed that the mean amplitudes of Pc3 were increase as the solar wind speed increased. The pulsations amplitude dependency on solar wind speed can be understood in term of the Kelvin-Helmholtz instability at the magnetopause boundary[12]. The mean Pc3 amplitude in the solar wind speed above 600km/s is nearly twice the amplitude of speed below 300km/s. The observation of Pc3 amplitude and solar wind speed show strong agreement with the previous study made by (Singer, H)[12]. Thus, the solar wind amplitude is related to the increased of pulsations activity amplitude[13]. The mean of dynamic pressure were also increase with the increasing of solar wind speed. There are some comprehensive theory explain that Pc3 occurrence has been found dominant at the solar wind speed range of 400 to 700km/s[11].

Figure 10 shows the correlation between Pc3 amplitude and solar wind speed at high speed. The results show a low negative correlation of Pc3 amplitude at high solar wind speed with -0.12. The correlations between Pc3 amplitude and dynamic pressure shows at Figure 11. The result show the there are high positive correlation between Pc3 amplitude and solar wind dynamic pressure with correlation value of 0.74.

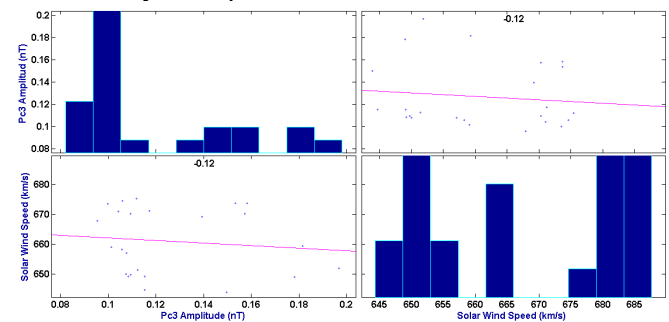


Figure 10: Correlation between Pc3 amplitude and Solar Wind at High Speed

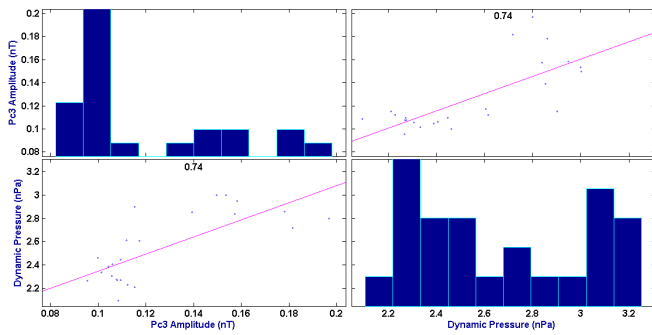


Figure 11: Correlation between Pc3 amplitude and Dynamic Pressure at High Speed of Solar Wind

For slow solar wind speed, there are low correlation between Pc3 amplitude and solar wind speed at 0.12 shows at Figure 12. While for Pc3 amplitude and dynamic pressure there are negative correlation between them with -0.77 shows at Figure 13. This shows that there are dependency between Pc3 amplitude and dynamic pressure at slow solar wind speed.

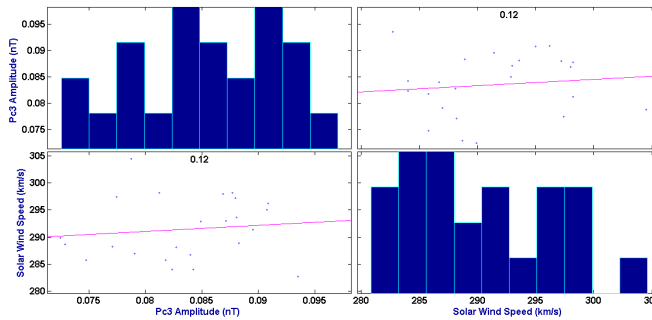


Figure 12: Correlation between Pc3 amplitude and Solar Wind at Slow Speed

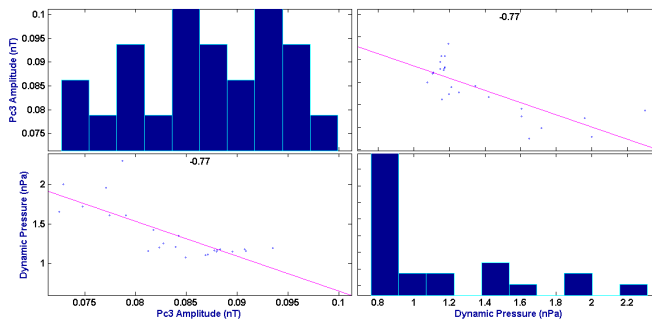


Figure 13: Correlation between Pc3 amplitude and Dynamic Pressure at Slow Speed of Solar Wind

#### IV. CONCLUSION

Based on selected date of magnetic pulsations events for Pc3 observed at low latitude MAGDAS Langkawi station on 2007, the relationship between Pc3 to solar wind speed and dynamic pressure have been observed. The dependency between Pc3 magnetic pulsations to solar wind speed and dynamic pressure were identified, the mean Pc3 amplitude at high and slow speed of solar wind was showed at Figure 6 and 8 suggested that there are relationships between Pc3 amplitude and solar wind speed.

From the correlation plot of Pc3 amplitude and solar wind speed at Figure 10 and 12. None of solar wind speed correlated with the Pc3 pulsation amplitude. The correlations

that were apparent were between various parameters and the solar wind speed. Thus, the amplitude of Pc3 magnetic pulsation was appears to be dependent mainly by the dynamic pressure than solar wind speed.

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