Investigation on the Occurrence of Ground ULF and its Correlation to Space ULF Prior to the Earthquake Events

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Abstract –**These paper focuses on the occurrence of Ground ULF signal prior due to the fact that ULF frequency band is considered as most promising frequency range in ground base observation where electromagnetic earthquake precursors may be found hence the study of ULF magnetic wave is very significant. In order to reveal possible earthquake precursor through the changes of ULF Signal, 6 sets of real time data from California region is used as a study case. The observation was made on the day of the earthquake event occur. The data was taken from Quakefinder websites which owned magnetometer station along the California fault region. The results obtained, demonstrated the theory that magnetometer may detect anomaly in ULF signal several days or a few hours before main shock.**

Keywords – earthquake, ultra low frequency, magnetometer.

INTRODUCTION

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacing the ground. When a large earthquake epicentre is located offshore, the seabed sometimes suffers sufficient displacement to cause a tsunami. The shaking in earthquakes can also trigger landslides and occasionally volcanic activity. An earthquake's point of initial rupture is called its focus or hypocenter. The term epicentre refers to the point at ground level directly above the hypocenter

Earth is compose of mineral and metal alloys under pressure and temperature conditions that allow elastic wave with frequencies ranging from 0.0003 to 30+Hz to transmit through the planet with relatively little deviation from linear elasticity. In other words, an initial rapid input deformation applied to near-surfaced rock, such as that accompanying sudden stress release on a fault or an underground explosion, produces stress imbalance that transmit through earth in the form of nearly elastic P and S wave that convey the nature of the source deformation to distant locations in a way that is readily decipherable. This remarkable is akin to the transmission of sound wave through air, for which there is a direct correspondence between atmospheric pressure fluctuations produced at a source, say by specific oscillations of vocal cords, and those detected on our ear drums allowing the sound to be interpreted.[1]

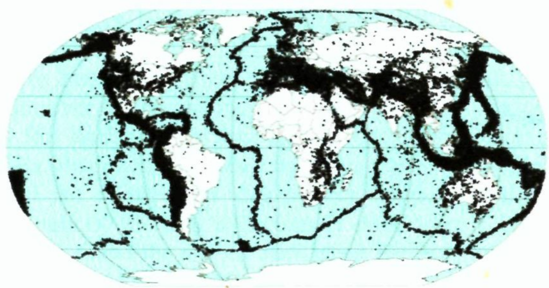

Figure 1. Global earthquake epicentres, 1963-1998[2]

The reason why we investigate the ULF electromagnetic wave is because since in ground base observations we consider this band as a most promising frequency range where electromagnetic earthquake precursors may be found. Higher frequencies would have smaller skin depths and, therefore, greater attenuation before reaching the Earth's surface.[2][2]

The Earth's ionosphere and magnetosphere consist of a number of regions filled with an ionized gas immersed into the Earth's magnetic field. The method of ground-based monitoring of the near-Earth space, relying on explorations of geomagnetic pulsations, has been designated as 'ground-based MHD-diagnostics'. It provides a realistic foundation for timely reception of regular information on the solar wind and the magnetosphere.[4] Ground-based diagnostics remain at present the main method for exploring the distribution of cold plasma in the magnetosphere, for determining the dimensions of the magnetosphere and the distance to the last closed field-lines have a natural restriction stemming from the presence of an ionospheric screen that forms a barrier between the observer on the ground and the MHD magnetospheric emitters. In passing through the ionosphere, the signal not only undergoes amplitude changes, but its composition and polarization structure are also distorted. As it is refracted in the high-latitude ionosphere and subsequently propagates to the middle and low latitudes, the ionosphere and the Earth cause significant changes in the initial magnetospheric wave pattern.[3]

The ULF-oscillations, also called 'geomagnetic pulsations' or 'micropulsations', occupy the 10^0–10^{-3} Hz range. The intensity of these pulsations is measured in thousandths (0.001) of 1% of the basic geomagnetic field value. pulsations are classified, according to their morphological properties, into continuous pulsations (Pc) and irregular pulsations (Pi); within each of these two groups they are further divided according to their period. This classification was proposed by IAGA (International Association for Geomagnetism and Aeronomy) in 1964.[3]

TABLE I: IAGA CLASSIFICATION OF GEOMAGNETIC PULSATIONS

Continuous Pulsations			Irregular Pulsations		
Notation	Period (s)	Freq (mHz)	Notation	Period (s)	Freq (mHz)
Pc1	0.2 - 5	200 - 5000	Pi1	1 - 40	25 - 1000
Pc2	5 - 10	100 - 200	Pi2	40 - 150	7 - 25
Pc3	10 - 45	22 - 100			
Pc4	45 - 150	7 - 22			
Pc5	150 - 600	2 - 7			

Pc 3-5 magnetic pulsations are ultra-low-frequency (ULF) hydro-magnetic waves generated in the dayside magnetosphere, where the amplitudes detected on the ground are modified by ionospheric conditions resulting from various physical processes. Pc5 pulsations are basically a high-latitude phenomenon. They are characterized not only by long periods (150–600 s), but by tremendous amplitudes as well. Their amplitudes are ≈40–100 nT at high latitudes, and under conditions of high activity, it can rise to 400–600 nT. The pulsations result from complicated plasma processes taking place in the solar wind, in the Earth's magnetosphere or ionosphere. Expanding to the Earth's surface, these oscillations undergo a number of changes, which enabled us, assuming a certain hypothesis of their origin, to get a definite insight into the medium they have passed through.[3]

Earthquake can give bad impact to us, human. Once earthquake was happened, it will damage everything just in seconds. The destructive power is comparable to a nuclear bomb, depending on the magnitude.[7] It is hope that the result will give early information about the occurrence of earthquake will be happened. Therefore the risks caused by earthquake could be minimized.

METHODOLOGY

In this project, '5 W's + H Concepts' were used to determine and understand this project task such as how the project flow, the objectives, advantages of the project and how the earthquake effect the ULF. After that, some theoretical studies have been made to gain more knowledge on ULF, earthquake and earthquake prediction done by reading the articles that related to the project title through internet. The journals that did the same research but focusing more on specific earthquake cases act as main reference in order to find the factors and the theories behind the appearance of ULF at the event.

For the data collection, various method and source have been used to determine the exact data need to be used for this experiment. The first data have been taken from Natural Resource Canada.[8] However after a looking through the data and making a few analyses, the data has to change because the data obtained there didn't use the specific equipment and not suitable for this project usage. The final process of the data collection is done when I have finally found the exactly data using the right method of reading ULF during the earthquake which is the Quakefinder[9][9] data resources. The California Magnetic Network (CalMagNet) concept involves placing Ultra-Low-Frequency (ULF) based sensors along the major faults throughout California as a pilot network that will lay the groundwork for similar networks throughout the world.

The data have been chosen to analyse is from the winter season. These dates have been chosen because it shows a great regularity of earthquake in California area. Furthermore, the data taken from Quakefinder is based on seasons. It is believe that ULF have an effect with different season.[10] However, this data does not give the specific location of the earthquake event. Hence, Dobrovolsky formula cannot be used to find any other station that will have the effect on the same earthquake.

$$R = 10^{0.43M} km \quad (1)$$

R = preparation zone ; M = EQ magnitude

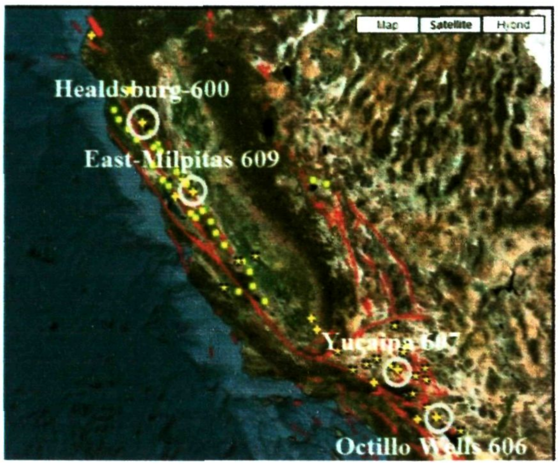

Figure 2. Shows the fault line and the station placed along the California region.[9]

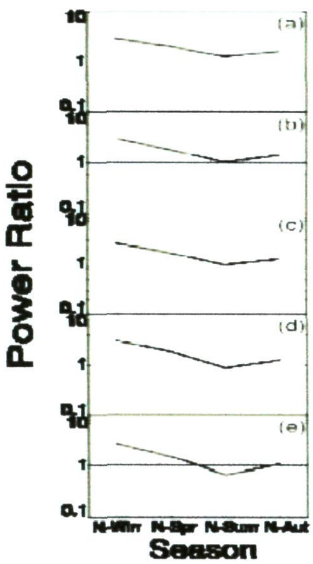

Figure 3. The seasonal dependence of the power ratio between KOT and MCQ in the frequency bands of 1-6 mHz (a), 6-10 mHz (b), 10-20mHz (c), 35-45 mHz (d), and 50-60 mHz (e). They are calculated from data observed during the interval 2330-0030 UT. Horizontal axes indicate season. Vertical axes represent the power ratio, where positive values correspond to higher power in the northern hemisphere.

The result that is shown is based on 6 events as shown in the table below. Each event represent by PC3/4 pulsations.

TABLE II: **SET OF OBSERVATION DATA.**

Set	Date of Observation	Time of Observation	Magnitude	Station
A	26-12-2009	0:00-24:00	3.90	OcotilloWells-606
B	07-01-2010	0:00-24:00	4.02	EastMilpitas-609
C	12-01-2010	0:00-24:00	4.27	Yucaipa-607
D	09-01-2009	0:00-24:00	4.50	Yucaipa-607
E	04-01-2009	0:00-24:00	4.20	Healdsburg-600
F	09-02-2007	0:00-24:00	4.21	OcotilloWells-606

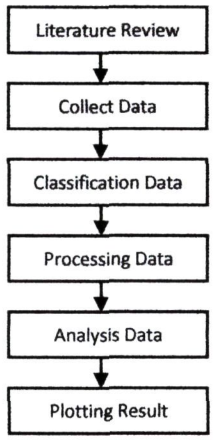

Figure 4: Flowchart

RESULTS AND DISCUSSIONS

The results of the observed ULF data are presented and discussed in this section.

A. 1st Set Data – 26-12-2009, OcotilloWells-606

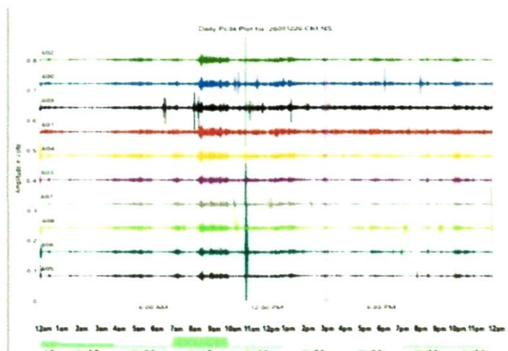

Figure 4. Daily PC3/4 channel 1 data plot for 26-12-2009.

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

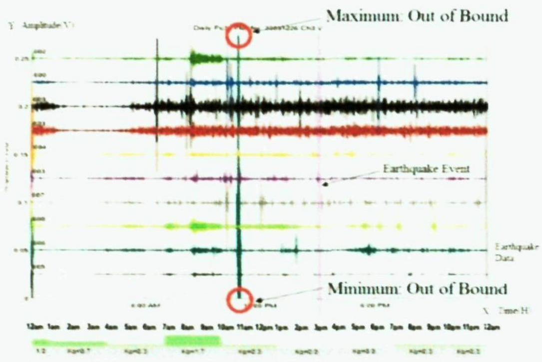

Figure 5. Daily PC3/4 channel 3 data plot for 26-12-2009.

Figure 5 shows a large anomaly on OcotilloWells-606 data after being filtered for a few times. The scale for Y-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the OcotilloWells-606 data. The maximum amplitude cannot be determined because ULF signal is exceeding maximum value which is 0.8V. The same case goes to minimum amplitude which the minimum value exceeding 0V value.

B. 2nd Set Data –07-01-2010, EastMilpitas-609

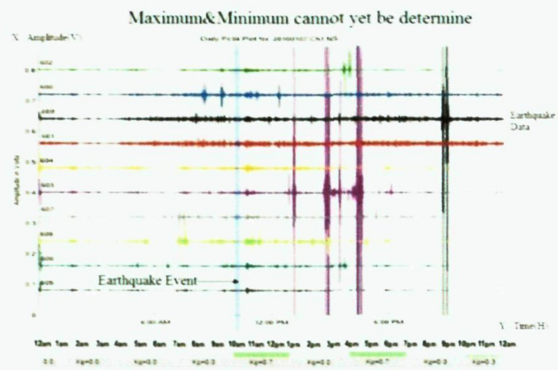

Figure 6. Daily PC3/4 channel 1 data plot for 07-01-2010.

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

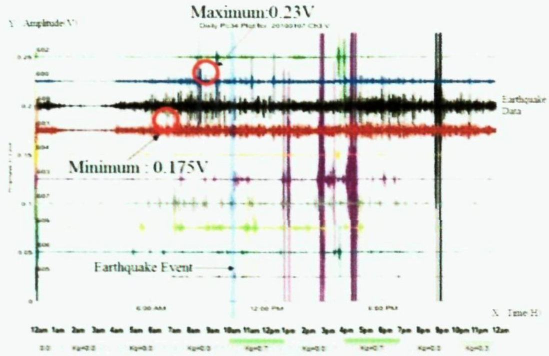

Figure 7. Daily PC3/4 channel 3 data plot for 07-01-2010.

Figure 7 shows a large anomaly on EastMilpitas-609 data after being filtered for a few times. The scale for Y-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the EastMilpitas-609 data. From this spark, the maximum amplitude is around 0.23V and the minimum is 0.175V.

C. 3rd Set Data – 12-01-2010, Yucaipa-607

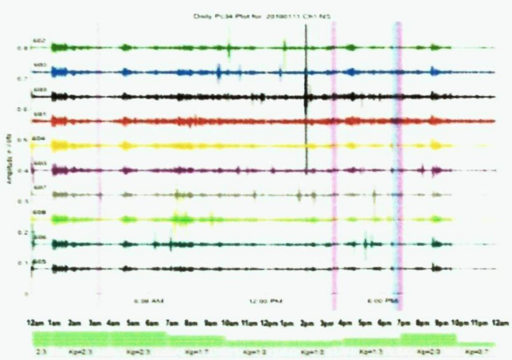

Figure 8. Daily PC3/4 channel 1 data plot for 12-01-2010.

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

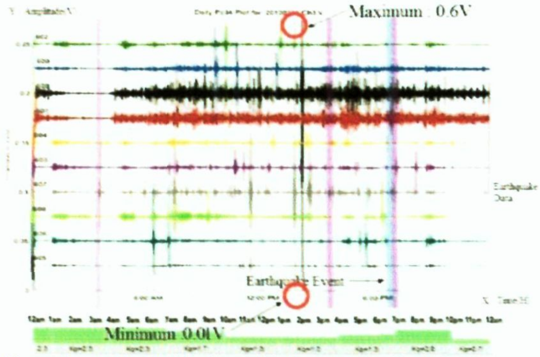

Figure 9. Daily PC3/4 channel 3 data plot for 12-01-2010.

Figure 9 shows a large anomaly on Yucaipa-607 data after being filtered for a few times. The scale for Y-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the Yucaipa-607 data. From this spark, the maximum amplitude is around 0.6V and the minimum is 0.1V. However, in this set of data, there are also a few earthquakes happen on the same day. This might have an effect on the Yucaipa-607 data

D. 4th Set Data – 09-01-2009, Yucaipa-607

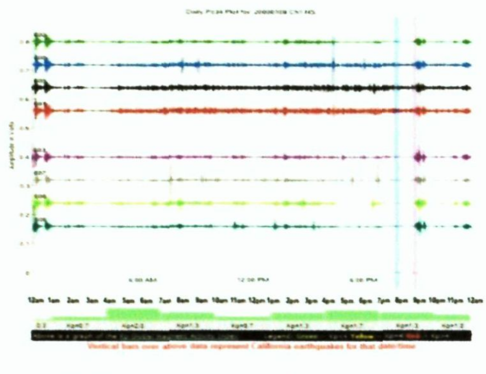

Figure 10. Daily PC3/4 channel 1 data plot for 09-01-2009

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

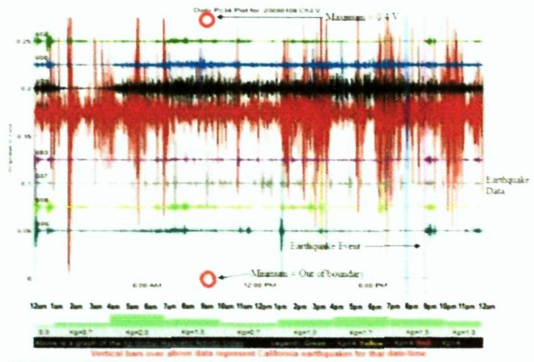

Figure 11. Daily PC3/4 channel 3 data plot for 09-01-2009.

Figure 11 shows analysis on Yucaipa-607 data after being filtered for a few times. The scale for x-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the Yucaipa-607 data. From this spark, the maximum amplitude is around 0.4V and the minimum is 0V. However, in this set of data, there is also accidentally an earthquake happen on the same day. This might have an effect on the Yucaipa-607 data depending on the distance of the station to the other earthquake.

E. 5th Set Data – 04-01-2009, Healdsburg-600

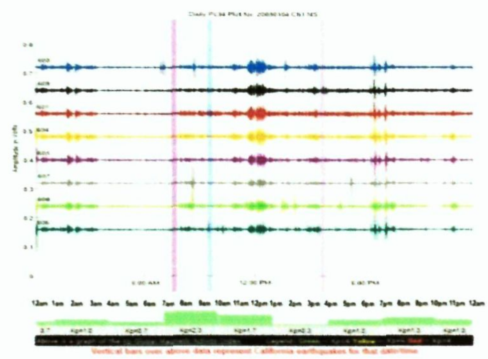

Figure 12. Daily PC3/4 channel 1 data plot for 04-01-2009

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

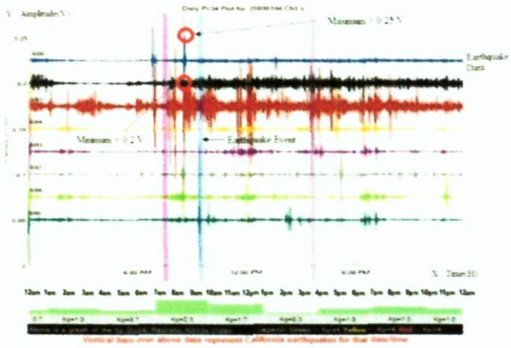

Figure 13. Daily PC3/4 channel 3 data plot for 04-01-2009.

Figure 13 shows a large anomaly on OcotilloWells-606 data after being filtered for a few times. The scale for x-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the OcotilloWells-606 data. From this spark, the maximum amplitude is around 0.25V and the minimum amplitude cannot be determined because ULF signal is exceeding maximum value which is 0V. This data also might have some sort of disturbance because there is also another earthquake happen on that day near other station.

F. 5th Set Data – 09-02-2007, OcotilloWells-606

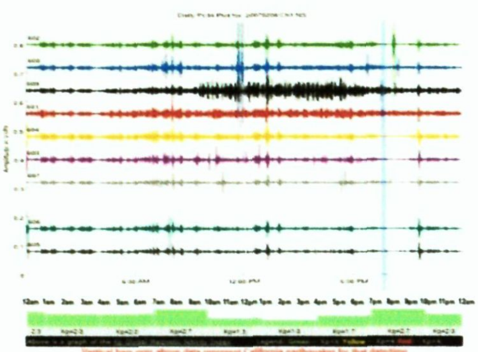

Figure 14. Daily PC3/4 channel 1 data plot for 09-02-2007

The scale for Y-axis (amplitude) for this data is 0.1V. This data shows PC3/4 data of all 600 series station on the day of event occurred.

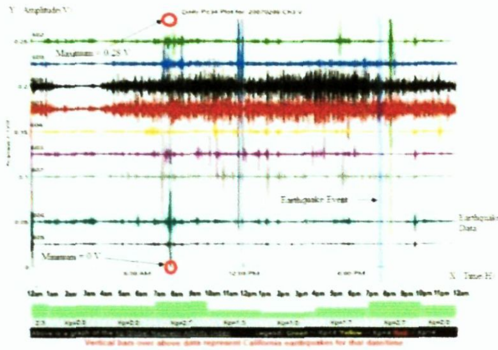

Figure 15. Daily PC3/4 channel 3 data plot for 09-02-2007.

Figure 4.6(d) shows a large anomaly on OcotilloWells-606 data after being filtered for a few times. The scale for x-axis (amplitude) for this data is 0.05V. A few hours before the earthquake, there is a large unusual spark on the OcotilloWells-606 data. The maximum amplitude is around 0.28 V and the minimum amplitude shows a reading of 0V value.

In all set of data, it can be clearly view that at least a few hours before earthquake event occurs there will be an anomaly in the ULF data.[11] This anomaly can be view by unusual spark in the ULF data. This happen because the changing in rock stresses can cause electromagnetic disturbances that generate ULF magnetic signals.The basis of this theory is that rocks near the hypocenter of the impending quake are stressed to their elastic limit and begin to crack without actually displacing (rupturing) yet. This cracking process releases a flood of charged particles. These moving charges form huge underground currents which disturb the Earth's normal magnetic field.[12] These disturbances can be detected at ULF due to the signal's ability to penetrate kilometers of solid rock only at low frequencies using magnetometers. However, the data for set C, D, and E is a little bit hard to analyze because there is a few earthquake being detected on the same day. It might affect the data on the corresponding station.

CONCLUSION

In general, this project have achieves its objective which mean it is possible to use ULF data to determine the earthquake. From this research, the result shows that ULF signal appears a few hours before the earthquake event.[13] Therefore, this finding is useful to give early information of the occurrence of earthquake. However, this research can be improved by observing a few days before. The reason why this research cannot be done that way is due to the limitation of the data.

ACKNOWLEDGEMENT

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