

ANALYSIS ON EXTRA LOW FREQUENCY  
(ELF) SIGNAL DUE TO EARTHQUAKE  
ACTIVITY

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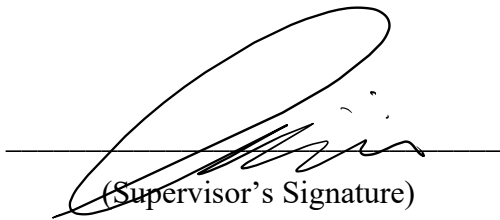
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ANALYSIS ON EXTRA LOW FREQUENCY (ELF) SIGNAL DUE TO  
EARTHQUAKE ACTIVITY

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Thank you

## ABSTRAK

Gempa bumi melepaskan EMT semasa kejadiannya. Selalunya, seismometer akan digunakan untuk mengesan aktiviti gempa bumi. Namun begitu, disebabkan radius pengesanan yang sangat rendah, teknik alternatif pengesanan dengan menggunakan Pengesan ELF akan diperkenalkan. Pengesan ELF berkeupayaan mengesan sejauh 1000km. Pengesanan ini akan tercampur dengan ELF signal daripada pelbagai aktiviti bumi termasuk guruh dan gempa bumi. Tujuan kajian ini dilakukan adalah untuk mengenalpasti tanda gempa bumi daripada signal ELF. Tanda ELF ini akan dibandingkan dengan data daripada gempa bumi *United States Geological Survey* (USGS) dan data taburan hujan *Japan Aerospace Exploration Agency* (JAXA) bagi memastikan tanda ELF tersebut adalah daripada isyarat gempa bumi. Untuk mengatakan ianya adalah isyarat ELF gempa bumi, taburan hujan hendaklah di ketepikan. Sekiranya ada aktiviti hujan di kawasan dan waktu yang sama, kami tidak mengambilnya sebagai isyarat gempa bumi bagi mengelak kekeliruan. Penemuan ini sangat menarik kerana kami Berjaya mengenalpasti isyarat gempa bumi dari arah Sumatera Indonesia. Pada waktu yang sama tiada aktiviti hujan di kawasan tersebut daripada data JAXA.

## **ABSTRACT**

Nature phenomena such as earthquake (EQ) release electromagnetic (EMT) wave during its process. A seismometer is often used as the detection tools for EQ detection. However due to its low detection radius, an alternative way which is by EMT wave detection is proposed. ELF sensors may detect lightning and earthquake activity with a range radius of thousand kilometers. Many data will be mixed in one ELF signal that needs to analyze and identify the EQ data based on the ELF data and from other sources. This purpose of this project is to identify the EQ from the ELF data analysis and verify with EQ activity from USGS. JAXA data was used to know the location of lightning event. Its data is used to deny lightning activity at the time of EQ occurrence. It is interested to notice that an we are able to identify an EQ activity from ELF signal for an event occurred in Sumatera Indonesia. No lightning activity are noticed from JAXA data.



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# CHAPTER 1

## INTRODUCTION

### CHAPTER 1: INTRODUCTION

#### 1.1 OVERVIEW

Extra Low Frequency (ELF), Very Low Frequency (VLF), and Extra Low Frequency (ELF) are the same function as one of the sensors that can be used as a magnetometer to detect seismic activity in the area. The study of ELF electromagnetic fields is of essential importance from the viewpoint of natural electromagnetic phenomena such as lightning and earthquakes[1]. ELF is the main part to collect the data whether the data is from the storm or earthquake activity because ELF can detect both the activities. It has a north-south and east-west area to ensure the angle where is the signal activity from. ELF is a search coil magnetometer with a magnetic core. It has a diameter and weight with a frequency range of 0.1 Hz to 1000 Hz[1]. To get world data, we set the radius from the center point to 1000 km. In the region radius of 1000 km, many data can collect from the United States Geological Survey (USGS). The region got many data of the earthquake that need to be set into the specific day, time and years and also need to set a specific maximum and minimum magnitude of the earthquake. USGS has all the data day to day for important research. ELF sensor can predict the earthquake when it happens because before the earthquake happen, ELF will detect the seismic activity and it will show the condition of the graph is always in ascending.

An earthquake occurs when the earth's crust trembles or shakes. Most earthquakes are caused by a sudden displacement at a fault. A fault is a breach or fissure in the earth's crust where pressure or movement is constant. Earthquakes occur when the constant movement of the earth's crust creates a tremendous deal of pressure and stress, which can lead to a sudden movement at a fault. This unexpected movement, which may result in

rock cracking, generates enormous energy. The focus is the area where there is a lot of quick movement or shattering of rocks[2]. The epicenter is an area below ground level. The energy produced is carried along by seismic waves through the earth. The earthquake was detected by Seismograph, ELF sensor and using a Global Positioning System (GPS). Seismographs are used to measure and record the vibration produces by earthquakes. ELF sensor is the magnetometers that detect the extra low-frequency magnetic fluctuation which is produced days or weeks before the earthquake[3]. For GPS is for a navigation and precise-positioning tool used in earthquake studies to measure tectonic motion during earthquakes.

In this project, software Matlab will be used to show the data that have been recorded from the ELF sensor. The data file will process through Matlab and it will display some plotting graphs. The graph has many points of the XY that can use for the atan function which is  $\text{angle} = \arcsin(x/y)$ . The point of the XY needs to show in one file. To collect all the point on the graph, a brush indicator needs to use because the function of the brush can take the point of XY and it will shade the area at the line graph to take out the value of the XY and to put it in one file at the workspace Matlab. The value of the XY can save as a file named value XY. When opening the value XY file, Matlab already arranges the data of the XY based on how much the graph is shaded by the brush. How many points have been shaded, we are available to know on the workspace of the Matlab.

Next, the data XY will be used to find the angle from the plotting graph. If we got the angle, we will available to know where is the location data from using a Draw Radius Map and another website named Measure Distance Map. Draw Radius Map used to know where is the radius 1000km which is the center point is from pekan. In this region, we will get the data from this region by using a USGS because USGS has all the data on the earthquake data graph. Measure Distance Map is to use the distance from one location to another location. The distance is important to ensure that the ELF sensor can detect seismic activity within a radius of 1000 km.

The challenge is to get the angle position on the graph at the same time the data on that angle needs to be the same as our data. If not the same, that means the data is from another location and a different angle. A graph got many points, so when having many points of XY, there are many angles that we can get from a graph. The graph to find the



angle is voltage vs time, while to find the location graph is angle vs time. Time in a graph is important because on the time we can check the exact the earthquake or storm happens from the meteorology data. That need to find back to get the exact angle at a certain location.

## **1.2 PROBLEM STATEMENT**

Malaysia is surrounded by the Eurasian Plate of the earth which expose to earthquake activity. Getting data on earthquakes in Malaysia region is very hard because Malaysia peninsula is covered by Indonesia Sumatra. While the Borneo region which is Sabah and Sarawak are near the Philippine-Pacific tectonic plates[4]. Many earthquakes are happening in this world that can cause a natural hazards to humans. An earthquake happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. This slip will release an electromagnetic field that can sense by ELF. By using the ELF sensor, it can detect signal earthquakes through the magnetic field antenna and can detect lightning with a radius of 1000km. If ELF is used in Malaysia, we can determine the angle from both activities which are earthquakes and lightning occurred. There are two devices according to detection of an earthquake which is seismometer and ELF sensor. Seismometers are the device to detect the shaking of the land while ELF detects through magnetic waves produced by an earthquake. The radius for the seismometer is smaller compared to ELF which is 1000km. Cost installation for ELF is cheaper than seismometer because the process to install a seismometer are complex and need more component such as a vault, seismometer, seismograph, etc while ELF only needs an ELF sensor and magnetic field antenna to receive the signal.

Indonesia is the nearest country to the tectonic subduction zone which can expose the earthquake activity. [5]. From other research about the analysis of earthquake waves, by using the ELF sensor, we can predict the earthquake before it happens because ELF can detect seismic activity. Before the earthquake happens, it will produce an electromagnetic field that the ELF sensor can give the early reading from the seismic activity[6]. In Malaysia doesn't have a station for ELF because in Malaysia earthquakes are not happen often.

The problem while doing this research is to get the angle from the data because the data got many angles detected by the ELF. To solve it, need to use a Matlab to show the plotting data. Here there are several processes to get the angle graph which are needed to use the Schumann resonance and Out-going longwave radiation (OLR) [6]. This process is to remove the noise on the graph. All sensors when detecting some activities are much noise because of the environment, human noise and so on. ELF is very sensitive when detecting something activity that is in the sky (storm) or on the ground (earthquake). When the analysis ELF sensor is done, Malaysia has one system that can give a prediction of the earthquake and also can know where the data came from.

### **1.3 OBJECTIVE**

The objective for this project is:

- i. To identify EQ and ELF signal
- ii. To determine angle EQ.
- iii. To suggest the possibility of earthquake detection by using an ELF antenna.

### **1.4 SCOPE OF PROJECT**

The scope of this project is as follows:

- i. Detection of earthquake within the range of 1000km.
- ii. Time taken that earthquake occurred
- iii. The date of the earthquake occurred
- iv. The magnitude in Scala Richter
- v. Source from the website USGS, WLLLN, Meteorological data

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter provides a brief overview of important data from the verified theories method and gaps in the existing research.

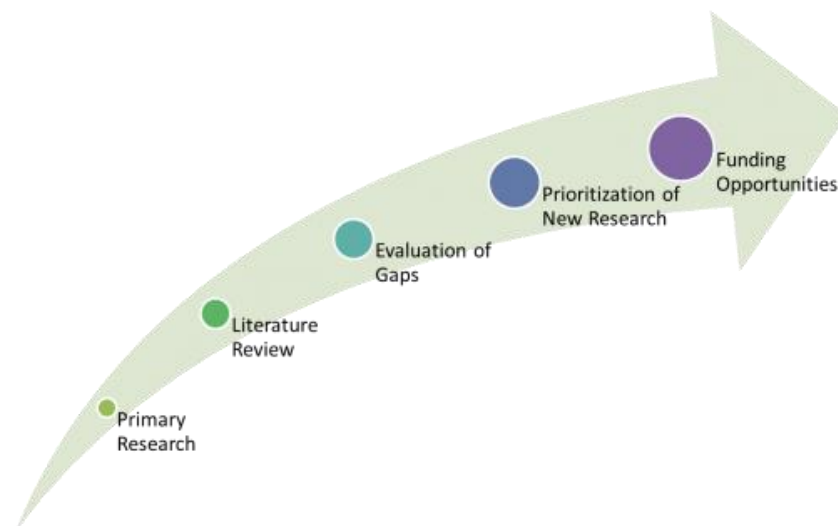


Figure 2.1 Literature view flow

A good literature view does not just summarize sources, but it analysed, synthesizes, and critically assesses to provide a clear picture of the state of knowledge on the subject. This chapter will discuss the literature studied regarding the analysis of the Extra Low Frequency (ELF) due to the earthquake. The discussion includes the element involved in the project that can be accessed through the various research paper. All the components in the topic are referred differently to obtain a clearer understanding of this study.

The main part of the topic itself is the ELF function to detect the electromagnetic due to the seismic activity. The literature review is going through the project process that is already being conducted by other resources which can be adapted to this project. These resources include journals and the research paper materials obtained from the website for the research paper.

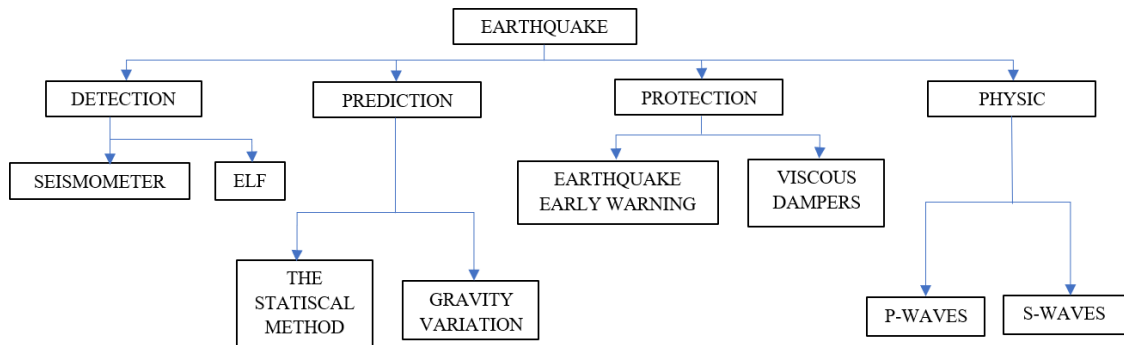


Figure 2.2 Overall literature view on earthquake

Many earthquakes are happening in this world that can cause a natural hazards to humans. An earthquake happens when two blocks of the earth suddenly slip past one another[7]. The surface where they slip is called the fault or fault plane. This fault will produce shaking on the ground that can cause damage to the surface of the earth called the epicenter. Because damage from an earthquake can give affect human life, many research has been done to review an earthquake. Based on figure 2.2, there are four reviews about the earthquake which is detection, prediction, protection and physic.

## 2.2 Detection earthquake review

The first element of research about an earthquake is detection. This research is more focused on detection part because ELF is the main part of detection of an earthquake. There are two types of detection which is seismometer and ELF sensor.



Figure 2.3 The ELF sensor

Figure 2.3 shows the ELF sensor that will be buried inside the earth. ELF will connect to the antenna to receive the signal from the electromagnetic field because the antenna ELF sensor is based on an electromagnetic field antenna. It will record the signal and save it into storage and transmission data for analysis in ELF research. ELF sensors are used to detect electromagnetic waves inside of the earth and space such as lightning[8] and earthquakes [9]. When the earthquake happens, it will generate electromagnetic that can sense by the ELF. Then the magnetic field antenna will transmit the signal to the computer.

The advantage when applying the ELF sensor in this research is the low cost of the installation. Cost is low because the equipment to install ELF is an antenna, sensor, and computer. Second is easy to install because not too much equipment for the installation. Next, diameter range detection is 1000km. From Pekan, location detection of the lightning and earthquake can detect until Indonesia, Singapore, South Vietnam, and South Thailand. Lastly, the frequency range is 0.1 Hz until 1000kHz. Because the frequency is low, the area detection to detect earthquake and lightning are wider and the process of transmitting data are also can begin from a far location. The disadvantage of the ELF sensor is fragile because if something is broken on the sensor, the reading to get the data will not accurate.



Figure 2.4 The seismometer sensor

Figure 2.4 is the seismometer sensor. Seismometers are another type of sensor to detect seismic activity. Seismograph is usually used to give information about the earth's crust that happen inside of the earth because the earthquake happens naturally cause factor of platonic earth that are always in pressure that can cause a fault to slip. But for seismometer will detect by shaking of the land and then it will be recorded by using a seismograph[10]. It will record until the EQ is stopped. This will record the magnitude that comes from the EQ.

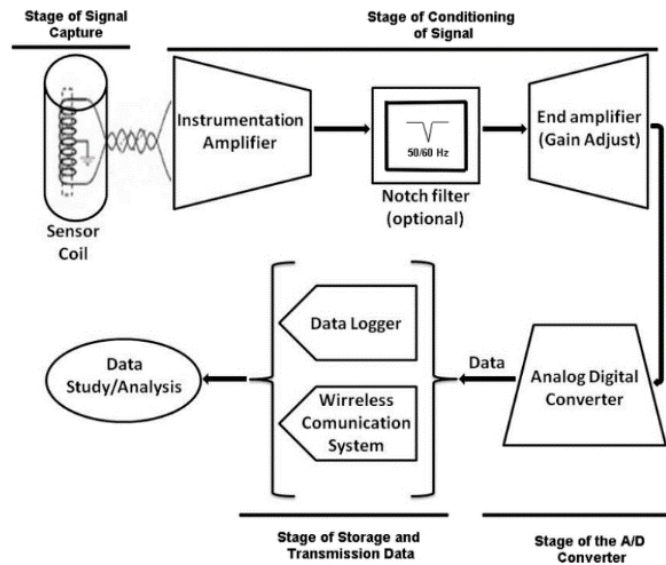


Figure 2.5 The process data from the ELF sensor

Figure 2.5 shows how the ELF data transmit to the storage.[11] As the diagram shows, the structure entails a set of stages from signal capture and local real-time processing to transmission to the station and the inclusion of processed data kept on the interactive database. The measuring system has several stages. First stage is stage of the signal captured that is formed by the ELF magnetic sensor. This first stage is the hardware which means the ELF sensor detect the magnetic wave inside of the earth. Second stage is conditioning of signal, represented by a high gain differential amplifier and a level scaled adapter. By this process, an appropriate signal is attained at the input to the next stage, the lowest output clipping and with a maximum dynamic range input.

There is one filter that implements in this diagram which is a passband filter with a range frequency from 3 to 100 Hz. The objective of this filter is to mitigate signals beyond the desired band, avoiding unrequired signal intermodulation or cross modulation phenomena. Third stage is the Analog/Digital converter where this stage has two channels for each sensor. It will convert analog signal into a 24-bit sample per channel with a sample rate of 196 sample/s. The last stage is the storage and transmission of data. This is the place where all the data will be stored. It formed by regional info storage (data logger) which is the data transmission from the A/D converter to the digital radio link. From here, all the data can use to do the study or analysis.

For seismometer is used to detect the earthquake shaking at a certain place and the wave graph will be recorded by using a seismograph[12]. A seismometer only can detect

earthquakes with a small radius. Compared to ELF, it can detect earthquakes and lightning with a range radius of 1000km. The cost for the installation of a seismometer is more expensive and complex because needs more requirements before a seismometer can fully operate.

### **2.3 Earthquake Prediction: Global review and local research**

In the prediction of the earthquake, there are two factors that the research about prediction earthquake which is the statistical method and the gravity variation. The first method is about the statistical method. In the statical method, there are other two method algorithms such as M8 and M8S[13]. M8 was designed by retroactive analysis of seismicity before the greatest earthquakes worldwide while M8S is more focused to predict an earthquake of moderate magnitude.

The obligation basic for the method are a comprehensive listing of earthquake for the province to be studied and made researched. The result will take time in long-term approximations of Time of Increased Probability (TIPs) of the existence of a maximum-sized earthquake. Before the earthquake happens, there are gravity changes occur that are called internal gravity waves or acoustic gravity waves. The gravity inside of the earthquake suddenly change from time to time using seismic software. Because of this factor, people can prepare before the earthquake will occur.

### **2.4 Protection Earthquake**

There is a technology that can protect such as the building destroyed or damaged because of an earthquake. The technology that has been created is viscouse dampers [14]. Dampers are a suitable requirement that needs to install in the building or skyscrapers because dampers are one device anti-shaking that can ensure the building from taking damage because the dampers can reduce shaking of the earthquake and also can stable the building during the earthquake. The capability improves earthquake performance due to substantial energy dissipation and the ability to produce forces that are out of phase with displacement[15].

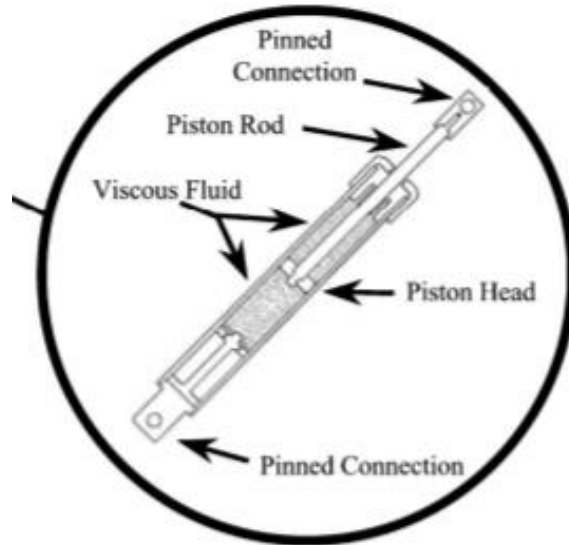


Figure 2.6 The viscous dampers

Figure 2.6 is the one type of dampers hardware for viscous dampers that implement in the building to reduce the vibration and keep the building stable when earthquakes happen. There are many components inside dampers which are pinned connections that function to connect the dampers to the building. The piston rod is one of the components that work with the piston head to control the vibration and pressure because of the earthquake. Next is viscous fluid or another name is seismic dampers are sometimes referred to the hydraulic at the dampers. The function of viscous fluid is to dissipate energy that produces by seismic events. These dampers will absorb the vibration that comes from the earth

#### 2.4.1 Earthquake Early Warning (EEW)

Concept earthquake early warning is same as the system missile warning which is it will give warning to people before the missile hit the target. Earthquake detection is based on the rapid detection of a seismic event. This system has been created in 1868 which can provide an early warning for incoming ground shaking before the earthquake happened. The purpose of this protection is to approximate in a fast dependable way before the earthquake shaking strong hits the target. There are four principles and the methodologies of the conceptual problem[16]. The first is event detection and the location of the earthquake. It is a conceptually simple problem because many systems use a standard procedure of methodologies to utilize non-real-time networks. Otherwise, the approaches are precisely created for real-time operation and can support faster



hypocentral determination. Second principle is a magnitude estimation which is a conceptually difficult problem.

To make it fast, the magnitude has to be approximated from the start of a few seconds from the recorded signal. This operation implies the development of empirical regression among numbers determined by the early detection on the seismogram and also the final magnitude. If this happens often, it will lead to low accuracy when doing the estimate and determination. Next, peak ground motion to do a prediction at the site. This is a well-established problem, but it is critically reliant on the precision of attenuation law. It basic idea about the source and dissemination models is often required. The last principal methodologies of earthquake early warning systems are alert notification that essentially varies in uncertainties associated to the obtain necessary parameters and peak ground motion inference. The design must be followed the standard procedure according to the target application and must contain a probabilistic evaluation of false alarms to avoid people getting the wrong notification from the warning alarm.

## 2.5 Physic earthquakes happen

Several factors can cause earthquakes occur in certain places. Much research about the factor earthquake occurs. It happens inside of the earth in a platonic place.

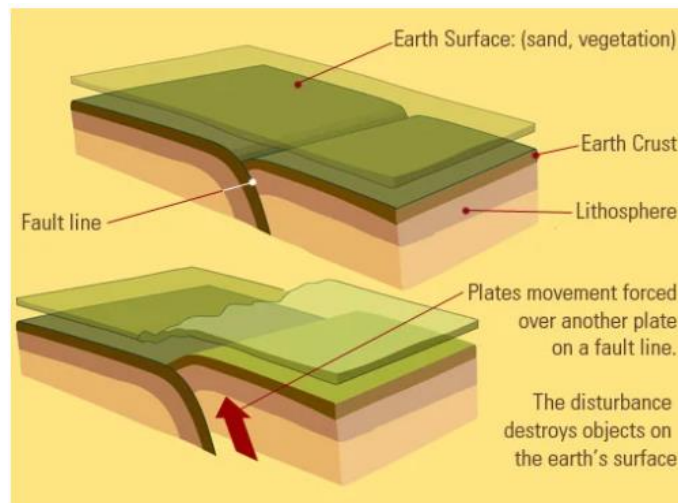


Figure 2.7 Process how earthquakes occur

The factor of the earthquake is caused by a sudden slip on a fault. Figure 2.7 shows the process of earthquakes happens. The tectonic plates are always moving in slowly conditions. But sometimes the plates will stick at their edge which can cause friction.

Stress will occur on the edge affects the friction and it will release the energy in a wave that can move to the earth's crust and cause the shaking at the same time, it will produce electromagnetic that can be detected by ELF. From here, ELF will get the reading of the wave graph and can do the analysis.

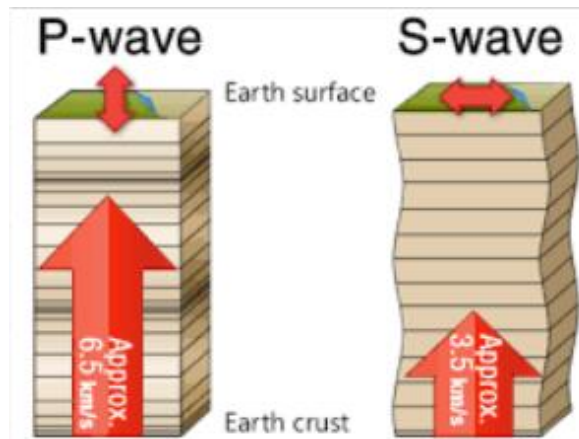


Figure 2.8 P waves and S waves from the earth's crust

Figure 2.8 show the waves of the earthquake. There are two types of a wave when earthquakes occur which is P-waves and S- waves[17]. P-waves is a Primary Waves will leave behind a path of compression and refraction on the moderate P-waves path through. An animal can feel the P-waves before the earthquake reaches the crust. But for humans only can sense the ramification when hits on the crust. For movement wave for P-waves is from up and down while S-wave is from left to right. The characteristic of these two types of waves below: To easily understand the comparison of these two wave, Table 2.1 shows the comparison between P waves and S waves below.

Table 2.1 Comparison between the P-waves and S-waves

<b>P-waves</b>	<b>S-waves</b>
- The first wave to hit the seismograph	- Second wave to hit seismograph
- Is compression waves	- Is shear waves
- Can move through solid and liquid	- Only can move through solid
- Shake the medium in the direction in which they are propagating	- Shake medium in the direction perpendicular to which they are moving

## **2.6 Systematic Earthquake Detector**

In many places or countries in the world, when an earthquake has been occurred, it can cause death, injury, and disruption. Malaysia also has an earthquake that happen in 2015 at Sabah. The magnitude that has been recorded is magnitude 6 based on United States Geological Survey data. There are four purposes which are to know the varied keyword that will be used in this research, to know the different types and effectiveness of the earthquake detector, and to examine the output generated by the earthquake detector through the current detectors. Identification, screening, eligibility, and inclusion are the four processes involved in this section Each phase illustrates the process of determining references from a search of resources.

Earthquake incidents can cause damage and loss of life. A small earthquake detector has been shown that it was suitable for citizens to warn that earthquake incidents will occur[18]. Technology is an instrument of the seismic detector and telecommunication needs to do more performance and upgrade more computerized systems in earthquake detection early warning. For example, the system can give a warning before the appearance of tough ground shaking caused by the earthquake. When technology earthquake detector has been used to give the warning earlier, it can save more lives and do some preparation before the earthquake occurs.

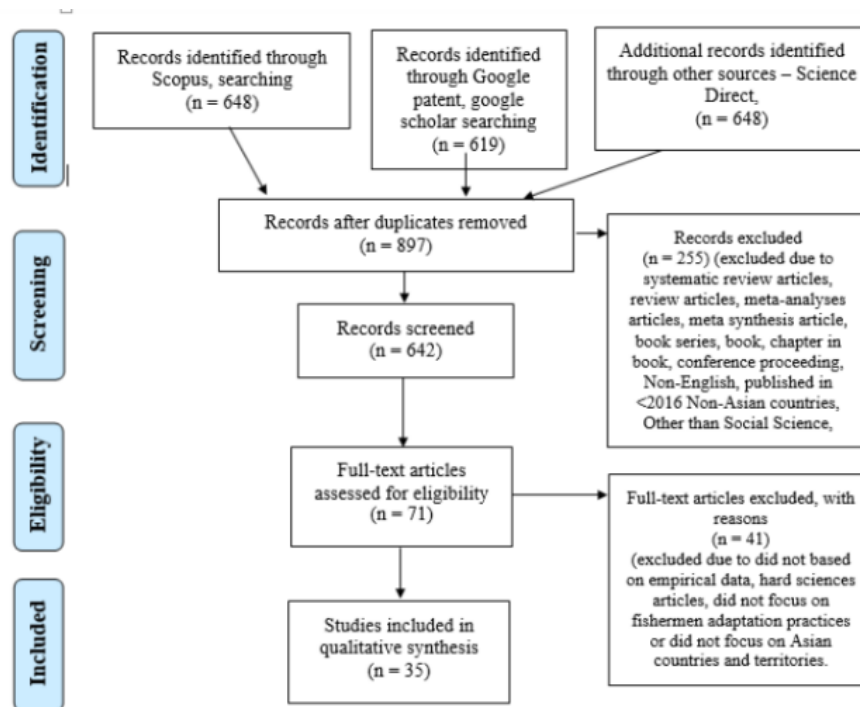


Figure 2.9 Determination records

Figure 2.9 shows the steps of the determination record to easier for us to understand the record that is appropriately linked with the research project. All steps consist of the method such as identification, screening, eligibility and included. The first process is to identify the method which is to make a record that has been determined by using the research source website such as Google Scholar, Science Direct, etc. Second process is screening all the data related to the topic, name of the author and year of the publisher. Similar records are removed when the process occurs to avoid reading the same data. Next is the eligibility process where the full text record is rejected because the purpose is not suitable data for research. The last stage is involved where the real correct record related to the research is determined and then the data will be examined.

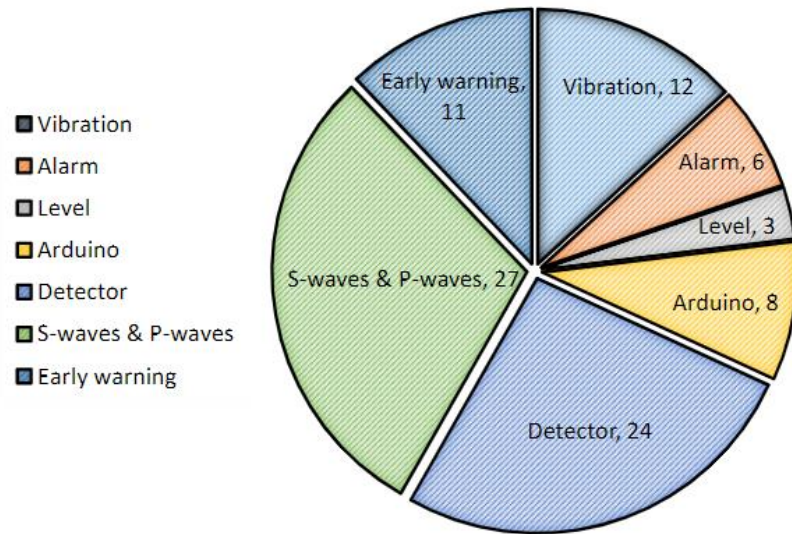


Figure 2.10 Type of earthquake detectors

Figure 2.10 shows the type of earthquake detector analysis. Each journal will identify a type of wave which are S or P waves or both waves. Usually, S and P waves are regularly used in creating an earthquake detector because it can decrease the effect after an earthquake occur. All of the effects are based on the type of material that has been selected. The vibration is regularly utilized to determine the level and magnitude of earthquakes. Sensor vibration can sense the vibration of the earthquake which also can prevent false warnings in humans. Additionally, detection of the earthquake has a decisive impact after being installed at certain places to give early warning to humans. Then, the human can make a preparation further and the cost and loss of life can be reduced.

There are two types of seismic waves which are P and S waves. The P wave is the particle that starts to move in a consistent path that the wave is going in. That means the path of the energy is moving in that process called the direction of wave propagation. Another type of wave is the S wave or called a Secondary wave. S waves will move the particle of rock up and down direction or side to side vertical to the path that the waves are moving in. Although, P waves will assist to verify the false signal early warning by signal waves that push and pull the air.

## 2.7 New ELF observation system and assessments of acquired data

This ELF observation is to measure the magnetic field band at certain places to assess the data acquired by the new system. ELF sensors are very sensitive to the noise if have some noise in the environment such as humans or a building area that produce the electromagnetic signal, it can be detected and will become the noise when the result is shown to the researcher. A signal processing is given for the estimation of Schumann resonance spectra to demonstrate the advantages of the system. Through this process, the result will appear whenever the local lightning is active.

### 2.7.1 Magnetometer LEMI-116

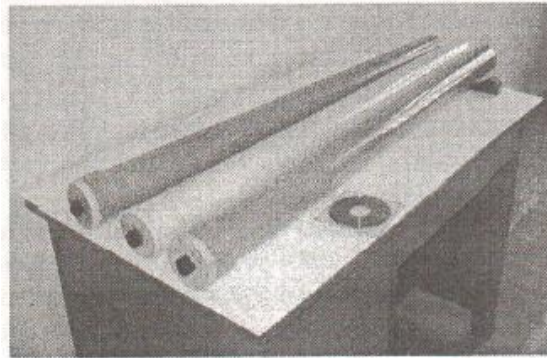


Figure 2.11 Is the ELF sensor that will use to get a data on seismic activity

Magnetometer or other name is Extra Low Frequency (ELF) sensor that shown in figure 2.11 is a coil magnetometer installed with a magnetic core. The characteristic for length is 1215mm, the diameter ELF is 96mm and the weight is 8kg. This ELF was designed to measure the electromagnetic field inside of the earth in the frequency range 0.1Hz to 1 kHz [1]. This ELF sensor is waterproof. So, if the ELF sensor is wet because of the humidity inside of the earth, it should not be a problem to measure the data electromagnetic field. The filter used is a low pass filter built inside to filter the aliasing effects in the discrete Fourier Transform. A low pass filters a suitable filter for the ELF because the ELF only use a low frequency to detect the seismic activity. The output of the ELF signal is in differential mode and then it will convert into a shielded twisted pair (STP). In differential mode, the potential difference between the two terminals is observed, the two terminals of the multipole are considered to be isolated, and a current enters the system through one terminal and exits the system entirely through the other terminal.

### 2.7.2 Assessment of data required and the environment electromagnetic of the site

The figure below shows the time series of sampled data that have been collected. The dominant part of data is 50 Hz and the signal will perform the harmonic signal radiated come from the power supply and the magnitude about on range from 0.07 until 0.23 nT peak to peak for the north-south component and also for the south-west component. It is considered a local configuration of the power supply. The figure below shows the magneticfield measured by the ELF system.

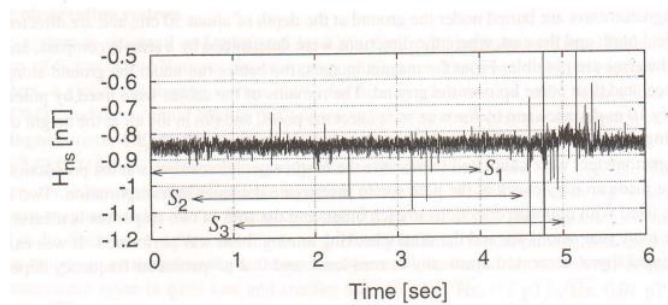


Figure 2.12 The north-south component. The embedded symbols S1, S2 and S3.

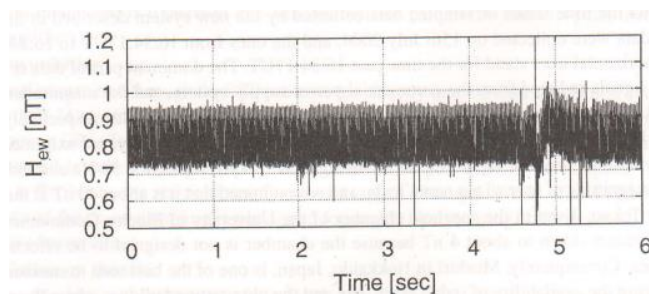


Figure 2.13 The east-west component.

### 2.7.3 Estimation of spectrum density of Schumann resonance

Schumann resonance (SR) is the new term in this research. When using the SR method, has an advantage when use the Schumann resonance. The advantage is can collect the process data. Which can give any kind of filter, causal or non-causal for the signal processing into the similar data that can be separately. Figure 2.12 and figure 2.13 demonstrate an estimation spectrum density of the SR. The main objective to use this method is to set the frequency range from 50 Hz and for the long-term variance of the spectra. Because there are unique frequencies where the spectrum curve shows remarkable peaks, such as radiation from commercial power supply systems, improvement is required for the spectrum density prediction in this instance. To estimate

the SR spectra are very crucial to consider which the presence of the impulse signal is created by the lightning strike in the vicinity of the observation point.

## 2.8 The Ionospheric Precursor to the Earthquake is based upon observation obtained from the pacific subionospheric ELF network.

ELF sensors have detected the seismic activity of the Japan earthquake which happen at the sea near the plate type of the earthquake (EQ). There are many stations of the ELF around the world to record seismic activity. A remarkable anomaly was detected by the propagation path from the USA transmitter. It has been recently that the electromagnetic occur to earthquake activity. Ionospheric perturbations, which correspond to the second category of electromagnetic precursors considered to be the most reliable because of the significant amount of the ELF work is being compiled. Recently, it was shown that lower ionospheric disturbance observed by subionospheric VLF/LF propagation is statistically strongly connected with EQs occurring inside the wave-sensitive area of the seismic.

The data for the subionospheric frame network comes from the former Nasda to establish the ELF propagation. To start, this network observation has been running continuously. The main of the station at Japanese area are Moshiri (MSR), Chofu (CHF), Kasugai (KSG), Kochi (KCH) and Tsuyama (TYM).

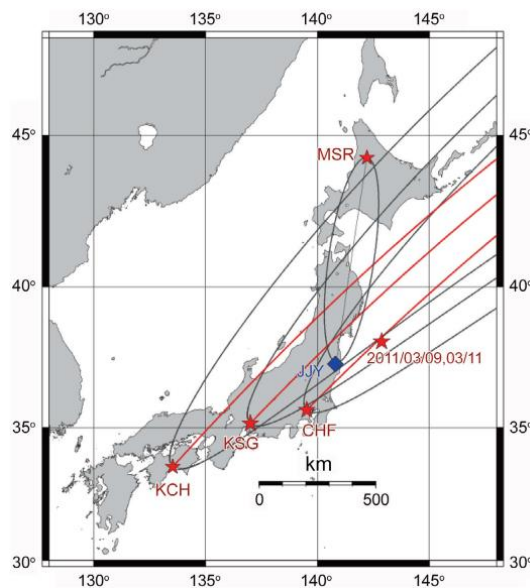


Figure 2.14 The relative location of the Japanese ELF transmitter.



The figure 2.14 shows the location of the transmitter in the Japanese area. Starting from the indicator blue diamond is the JJI Miyazaki and JJY (Fukushima) and the red star is the receiving station. The signal-sensitive region represented by the Fresnel zone which is in the elliptic zone for the propagation channel of JJY to MSR is presented as well for the propagation signal of the station from US, Seattle (NLK) station is plotted. Furthermore, on the red line is the great circle paths and the black line is the corresponding wave of the sensitive area. The black line indicates for the location of NLK to KSG and from NLK to KCH. Red stars represent the epicenters of the mainshock and its foreshocks, as well as the accompanying dates. By using a full of the subionospheric ELF network, from the observation that has been merged in a possible relation of the Japanese earthquake. There is no anomaly detected from the 3 of propagation paths that come from the JJY to MSR, JJY to YSH and JJI to YSH. Otherwise, On the other hand, for the two propagation channels of the Japanese station, apparent and significant propagation abnormalities have been discovered.

## **2.9 Fractal analysis of electromagnetic Emission in possible association with earthquake**

A natural disaster which is earthquake (EQ) is the fracture phenomenon in the earth plate and the problem from the vital in the short term is that earthquake prediction is known as the precursor of the earthquake (e.g., Hayakawa and Hobara, 2010). When a heterogeneous crust is stretched, its nonlinear progression toward the eventual rupture is defined by local nucleation and coalescence of microcracks, as well as self-organization toward the critical point. Both characteristics of the electromagnetic emission in a wide frequency range for the elf then up to the Very High Frequency (VHF) are created by the microcracks during the EQ preparation phase. By using fractal analysis, it can investigate extensively the lithosphere in the nonlinear dynamics. There are two device types of seismogenic emission which is the ELF electromagnetic emission and the very high frequency electromagnetic noise. Big differences in the fractal structure of those electromagnetic emissions are detected before an earthquake, which can predict the earthquake to happen.

When a heterogeneous material such as the Earth's crust is stretched, the nonlinear progression toward the eventual rupture is defined by self-organization into the nucleation and coalescence of microcracks inside of the earth. Both characteristic

electromagnetic emissions in a frequency wide for the ELF is less than 1 Hz while for the VHF frequency wide from 30 until 300 MHz are created from the microcrack that occurs inside the earth which can be defined as a precursor of the general rupture of an earthquake[19]. Fractal analysis may be used to examine the nonlinear dynamics occurring in the Earth's crust during the rupture of the earthquake. When the fractal analysis is performed, the first attempt of the fractal analysis of the ELF emission is based on the spectra slope and analyzes the significant that has been observed before the earthquake happen. There are several kinds of different analysis methods that have been created to extend previous mono fractal analysis to the multifractal analysis to know the structure that has been changed before the earthquake happen. This type of fractal analysis has been regularly used in other frequency range too. Include the DC emission of the seismic electric signal and also the very high frequency or low frequency emission.

### **2.9.1 Fractal analysis of seismogenic ELF Emissions**

Based on the research based on mono fractal analysis made by the ELF electromagnetic emission by using a slope of the spectrum, there are a lot of research about using a fractal analysis in the ELF range but also, there are other types of the frequency range. Furthermore, to analyze more detail about the fractal features such as using a mono fractal analysis, the analysis can be extended into multiple of the fractal analysis.

### **2.10 The Extra Low Frequency magnetic disturbance associated with the earthquake.**

The extra low frequency (ELF) is known as the electromagnetic emission sensor and is one of the most used in the short term for earthquake prediction. There are several evidence from a previous review using the ELF emission before the three major of earthquakes. There are different phenomena from the electromagnetic that are detected by the ELF in a wide frequency range due to the earthquake. From this situation, these seismoelectromagnetic effects will be useful data for earthquake prediction and associated mitigation of the earthquake hazard. There are two methods of principle to observe the earthquake signature (Uyeda et al., 2009; Hayakawa and Hobara, 2010). The first is from the direct inspection of the electromagnetic emission which is known as natural emission emit from a region of the lithosphere. Another method is to detect

another of the seismic activity effects making an appearance in the atmosphere and ionosphere (Molchanov and Hayakawa, 2008). All the method is based on the idea that the electromagnetic emission known as natural emission is radiated from the earthquake hypocentre due to generated of the electric current coming from the tectonic effect during standby for the preparation phase.

In this ELF are using a frequency range of less than 10 Hz can be used to find the electromagnetic emission. For the second method is based on the idea to appear the anomalies at the region's atmosphere and also at the ionosphere during the earthquake happen. This signal will be detected leading to the abnormal propagation of the transmitter signal. There are many from the review for the ELF variation of the magnetic field fluctuation as a result of the precursory lithospheric effect. Higher frequency components cannot propagate over long distances in the lithosphere based on significant attenuation while the ELF wave might ascend to an observation location point near to the surface of the earth with a minor attenuation while the radio emission was created as a pulse in the earthquake hypocentre. This will have the advantage for the seismogenic ELF emissions.

### 2.10.1 Three major ELF events

Based on the report of three reliable events, there are found a major the earthquake by the ELF magnetic field variation due to the major earthquake which is based on the data below:

Earthquake	<i>M</i>	Depth /km	Epicentral distance/km	Analysis method	Characteristics	References
Spitak earthquake in 1988	6.9	6	129	Amplitude (3 components)	An increase 3–4 days before the EQ, and a sharp increase four hours before the EQ. Gradual decrease to the normal level in one month.	Molchanov et al. (1992), Kopytenko et al. (1993)
Loma Prieta earthquake in 1989	7.1	15	7	Amplitude (Only one component)	The first maximum one to two weeks before the EQ. Then a quiet period, an increase a few days before the EQ, and a sharp increase a few hours before the EQ. Relaxation in a few months.	Fraser-Smith et al. (1990), Molchanov et al. (1992)
Guam earthquake in 1993	8.0	60	65	Polarization and fractal method	Abnormal increase in polarization one month to a few days before the EQ.	Hayakawa et al. (1996, 1999)

Figure 2.15 The three major ELF events.

The physical characteristics of these EQs, as well as the attributes of ELF emissions for these three EQs, are summarised in Figure 2.15. The distance of the epicentral is around 129 km from Spitak earthquake, at Loma Prieta is around 7km and Guam earthquake the epicentral is 65km. This is the reference for the researcher to analyze the data produced by the ELF sensor.

### **2.10.2 Analysis methods of the ELF magnetic field variation.**

ELF sensors are installed at a certain place because ELF is a highly sensitive sensor. ELF sensors also bring the different sophisticated signal processing to required detect and observe weak seismogenic ELF emissions even have the electromagnetic noise on the environment. The complexity of the background from various environmental and man-made sources, and also the low possibility of identifying a sensor near the epicenter of a huge magnitude EQ, are two important issues that require in the investigation of EQ characteristics in ULF data. From a data statistical analysis, it will come out with an important for the issue such the statistical for analysis probability will plot the ELF magnetic field (Koons et al., 2002). When applied the method to get the result from the ELF data, It can be compared to the distribution fluctuation data at the same time period detected by the sensor. For example, the researcher does research data from Corralitos they observed and do a comparison between Seikoshi data and Corralitos data earthquake are similarly based on the distribution.

### **2.10.3 Principal Component analysis**

When the data are already observed in simultaneously at a certain ELF station, ELF detects a few noises by using a method of component analysis. This method was applied to the ELF data due to the place at Japan Izu island earthquake because the researcher has the equipment of the magnetometer. By using the ELF data to observe the near station of seismic activity, the researcher can have several sets of data that can enable to divided into three possible sources. Each of the seismic stations has a combination signal and will have a few effects such as the variation for the geomagnetic at the area of the magnetosphere based on the solar activity that has been occurred in the area. Second is the noises such as the human noise or the environment of the electromagnetic noise. The last effect is the other effect includes the seismogenic emission[20].

### **2.11 Interstation Transfer function method (ISTF)**

This method is optional for the transfer function method, to compare the ELF data with other reference stations located at certain places with a low electromagnetic noise environment. By using the correlation method to variate at one of the stations with reference data, it will be able to execute the global effect such as the solar-terrestrial effect and will be available to know the regional or the local effect of the seismogenic. (Hattori, 2004). The researcher already uses this method to analyze time dynamics in a short-term variability of the geoelectrical potential differences and also to observe the geomagnetic field located at a few stations ELF. The study about simultaneous geomagnetic field changes from the source maybe come from underground because the polarity pattern is observed at the station.

### **2.12 Polarization ellipse method**

This method is to find the direction that has been created by one of the researchers which is Dudkin. This application is to polarize the ellipse technique. The component of the magnetic field is related to one of the bands spectral which is dominated by the seismoelectromagnetic field known as the polarization ellipse plane. The intersection from a line defined as the method mentioned before is to identify the source of the region. When applied the new direct finding and implement into ELF electromagnetic emission, it can observe the distance between two stations seismoactive region.

### **2.13 Summary**

From the several journals, all of them mostly do research about the ELF due to seismic activity events and all the research has found many new terms in paper research. By taking a close look, at this research in earthquake review the ELF sensor is in the detection category. This several research can determine the location of the earthquake occur. Based on cost installation, ELF is cheaper and not too complex to install. The interesting part of the ELF is not only the cost are cheaper but the detection is wider and not only detects earthquakes but also detect lightning activity.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 Introduction**

This chapter will describe the methodology used during the project. It will provide some information concerning the method used in this research as well as a justification for using this method. This Chapter also will describe the variety of each stage of this research, which includes the data collection process and the process of the simulation. This project will explore the challenges faced by the simulation. This project will run on the Matlab software and the ELF data will execute and run into a Matlab. Otherwise, many websites are used to continue this research to get the exact data.

### 3.2 Workflow

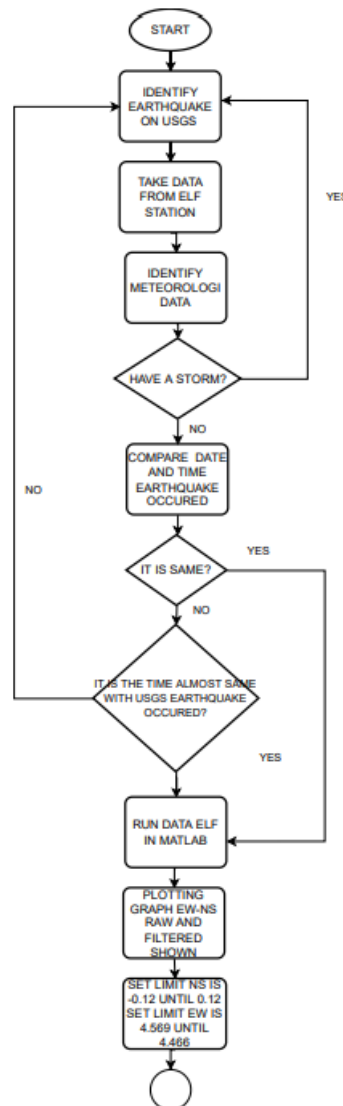


Figure 3.1 First project flow

Figure 3.1 is the way process of analyzing data from the ELF sensor. First, we need the reference to know where the location of the earthquake occurs. USGS is a useful website to use for us to get the reference to continue the analysis. It will show the location with a specific time, date, and minimum-maximum magnitude. The ELF data file will show the time and date. From here we can compare data from ELF with USGS. After identifying both of the data, we need to ensure data from the meteorological data to recognize the weather at that time. This is to make a confirmation on that location that there is no storming that occurred during that time because our focus is more on the location of the earthquake based on data that have been detected from ELF. Then, compare it with USGS and ELF data because if yes, it can run or execute in Matlab. Next,

can plot a graph for North-South (NS) and East-West (EW) and execute ELF data by using MATLAB to show the plotting graph which is Time versus Voltage. Here MATLAB will show the North-South (NS) with East-West (EW) raw and filtered graph. Set the threshold for NS from -0.12 until 0.12 and EW from 4.569 until 4.466.

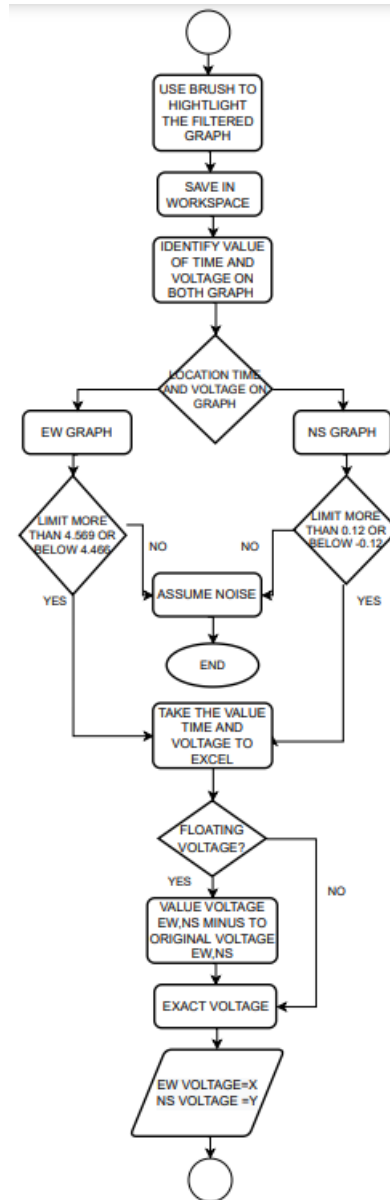


Figure 3.2 Second part project flow

The second part shown in figure 3.2 is to highlight the whole of both filtered graphs and need to save them into a new workspace in Matlab to know the value of time and voltage. Next is to set the limitation for EW and NS. In this research, the limitation for NS is 0.12 volts until -0.12 volts which means if the data are upper than 0.12 volts and also the data are below -0.12 volts are considered ELF data. Other than that will consider



noise. Same as the graph for EW, the limitation is 4.569 volts and 4.466 volts. Take the filtered graph to continue the analysis. When both graphs have been shown, we set the limitation to get the value time and voltage. Transfer the time and voltage value from the workspace into excel. Value from the workspace which is the voltage are in floating voltage. Because of that, the voltage value from EW and NS needs to be minus the original value for each of the starting voltage reading from the ELF. Then, we will get the exact voltage and voltage values from EW are considered as X while the NS is considered as Y. By using the formula

$$\theta = \arcsin(x/y) \tag{3.1}$$

$$\theta = \arccos(x/y) \tag{3.2}$$

will get the angle of each column. Now the angle is found, but not for the actual angle yet. The next process is to find the quadrant. In angle have 4 quadrants that need to find.

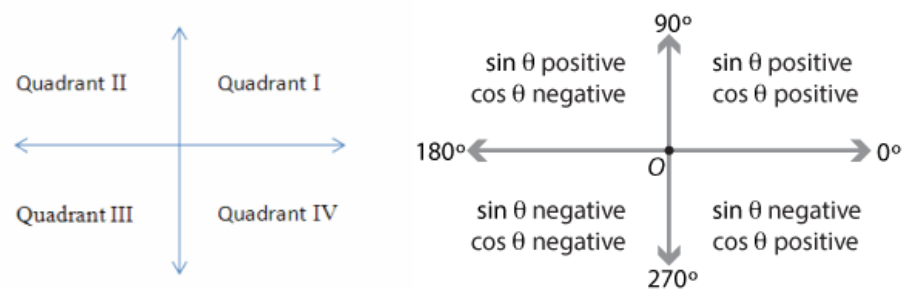


Figure 3.3 The position of the quadrant for sin and cos

Figure 3.3 shows the quadrant that can find the angle. The purpose to use the quadrant is to get the location angle at which quadrant [21]. If using only arcsine or arccos, it still can cover 2 quadrants only. So, the angle we get is inaccurate. All the fourth quadrants need to cover by combining the angle by using arccos and arcsine to cover all the fourth quadrants and then can cover to get the angle from 0° until 360°. By using arcsine and arccos, it will be able to find the truth quadrant which means from those 4 quadrants, it must be 1 quadrant that is exactly true for the angle. In excel are already set the value of the angle in the condition if false the quadrant will become zero, if true it will show the angle. The resulting angle is now available to detect from 0° until 360°. This is to identify the angle and compare it by using a map. Protractor tools extension is

used to find the angle by using a map. Identify the angle from Pekan to desired location earthquake at Sungai Penuh, Indonesia. Finally, compare the angle on the map with the angle graph in excel.

Table 3.1 Condition of Quadrant

QUADRANT	CONDITION
Q1	IF:
	Arcsine $\theta$ : NUM1 > 0
	Arccos $\theta$ : NUM2 > 0
	THEN :
	True : NUM1 False : 0
Q2	IF:
	Arcsine $\theta$ : NUM1 > 0
	Arccos $\theta$ : NUM2 < 0
	THEN :
	True : NUM1 False : 0
Q3	IF:
	Arcsine $\theta$ : NUM1 < 0
	Arccos $\theta$ : NUM2 < 0
	THEN :
	True : 180 +  arcsine $\theta$    False : 0
Q4	IF:
	Arcsine $\theta$ : NUM1 < 0
	Arccos $\theta$ : NUM2 > 0
	THEN :
	True : 360 -  arcsine $\theta$    False : 0

Table 3.1 shows the condition of quadrant. Each of quadrant has a different condition to get the angle. This process needs to find 1 by 1 because excel can run the code without looping and also each quadrant has a different code mathematical. That code will show the result whether the result is true or not. If true, it will show the angle but if not it will become a zero. NUM1 in this case is come from arcsine while NUM2 comes from arccos. The meaning of “NUM1<0” means arcsine is negative while “NUM1>0” means arcsine is positive. “NUM2<0” means arccos is negative while “NUM2>0” means arccos is positive. The purpose to do this is to get a range from 0 to 360 when plotting a graph.

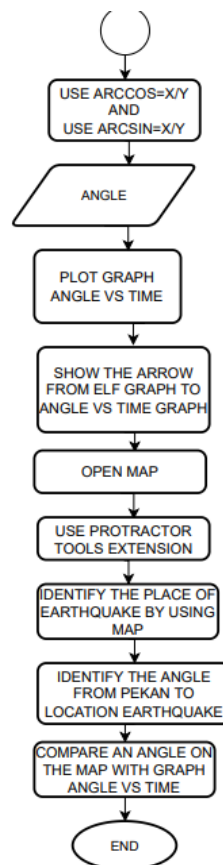


Figure 3.4 Third project flow

The last project flow shown in figure 3.4 is to use the function of trigonometry which is arccos and arcsine to get an angle. All the processes to get the angle are already explained in the above figure. When able to get the angle, plot the graph Angle versus

Time and at the same time show the location peak from ELF graph to angle versus time graph. Next is to open the map and use the protractor extension to identify the angle. This is to make a comparison between the angle from ELF data and the protractor. On the map, recognize the location of the earthquake that occurred by using a protractor. Then can compare the resulting angle from the protractor and ELF data.

### 3.3 Explore website United State Geological Survey (USGS)

There are several websites about earthquake activity around the world. One of the websites is the USGS. This website shown in figure 3.3, will be able to take data on the earthquake that happens within a specific region, date, time, and minimum and maximum magnitude. The highest magnitude will be recorded in this research to analyze the data from the website. USGS website is used to be a reference place to identify the location of the earthquake occurring after analyzing ELF data. From this website also, the wave data can able to see from a millisecond to a second by using Swarm software.

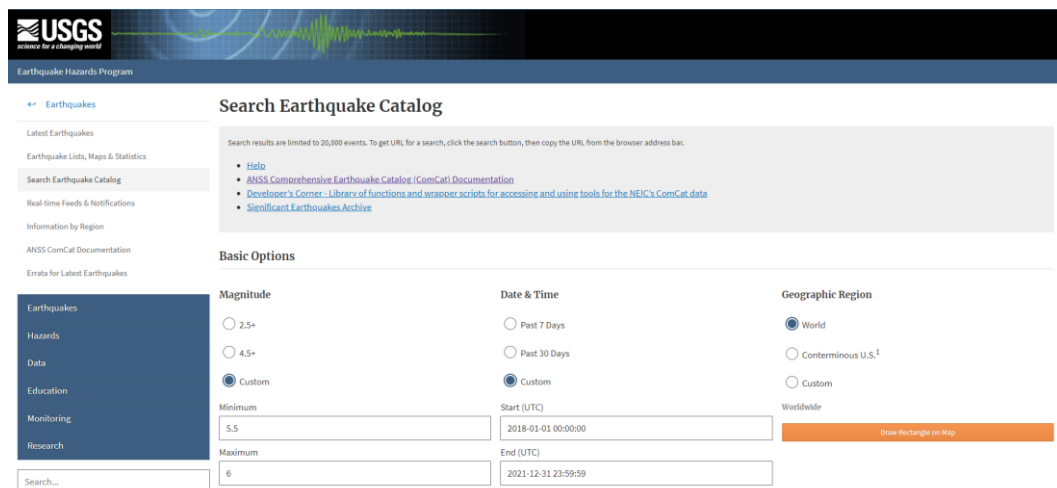


Figure 3.5 Interface of USGS



Figure 3.6 Set radius in 1000km center from Pekan

Because there are many places where EQ occurs, firstly needs to highlight the region in the map for the area location of the EQ shown in figure 3.4. This is the setting that has been set to take the data of the earthquake from the USGS. After clicking “use this region”, only data on that region will show up.

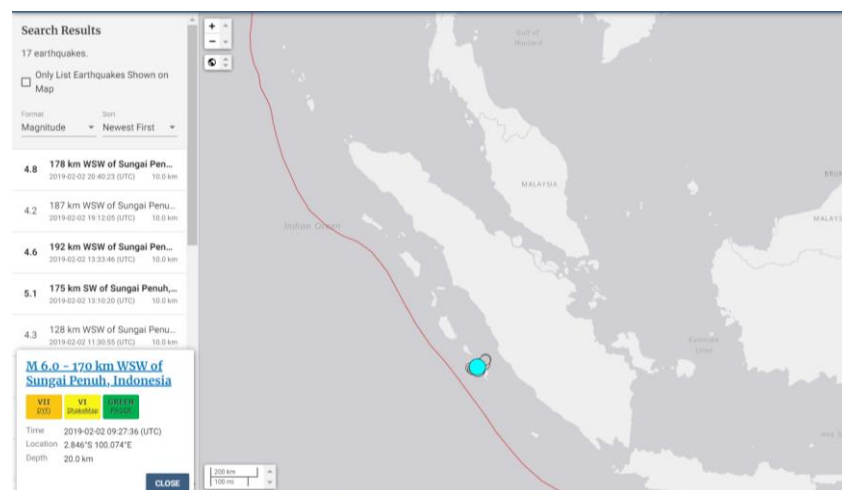


Figure 3.7 Data EQ

This is the data of the EQ that has been showing up. The location is at Sungai Penuh Indonesia with the date 2/2/2019. There are 17 EQ has been recorded by USGS at

different times. The earliest EQ is at 9.03 am and the last EQ on that day are at 8.40 pm. The highest magnitude that has been recorded is 6 magnitude at 9.27 am.

### 3.4 Jaxa Global Rainfall Watch

Meteorological data are important in this research to identify the location where rain occurs or not. If that time and date are clear, the earthquake location can be confirmed. But, if rain occurs, the ELF cannot determine the data if that is earthquake activity because it might have a lightning activity at that time. This website saves the meteorological data date by date and free to access the website to identify the condition of the weather at a specific time and date.

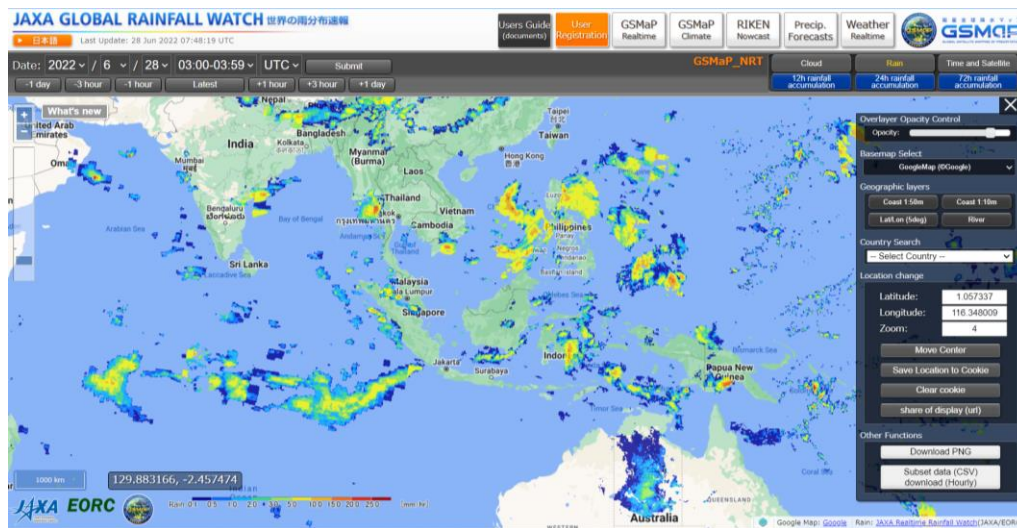


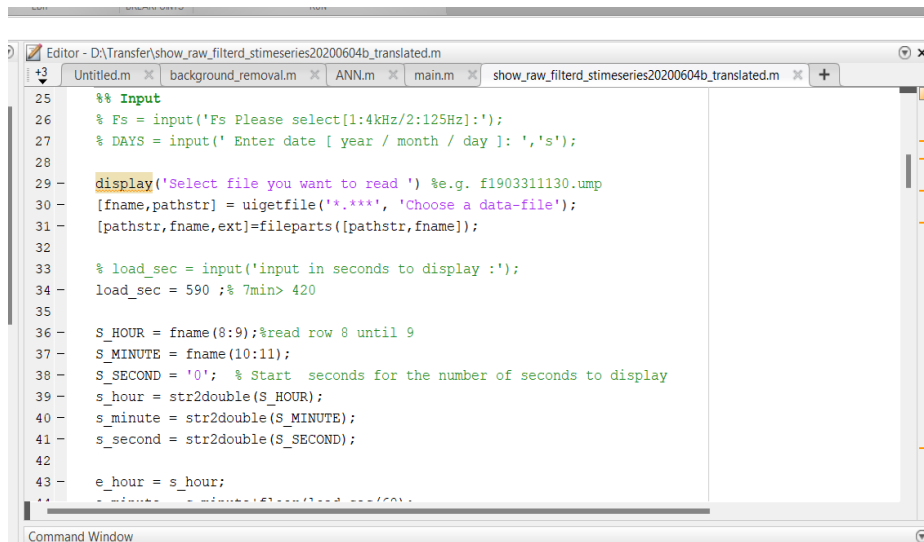
Figure 3.8 Is the Jaxa Global Rainfall Watch website

### 3.5 World Wide Lightning Location Network (WWLLN)

This website will record the storm that happens in the world. Many storms have been saved so that people can access this website to know what is the name of the storm that has been recorded. All the records will save the time duration storm that occurred, time, date, name, region, and storm number. Related to this research is to identify the place and find the name of the storm if happens at the time that is already set in USGS. Unfortunately, there are no storms recorded at that time and the research can continue.

### 3.6 Generated coding ELF

The coding below is to convert from ELF data into Matlab to show the plotting graph because ELF data are in binary form that humans cannot understand the data. The plotting graph will show the time versus voltage graph then the research can continue to analyze the data.



```
25 %% Input
26 % Fs = input('Fs Please select[1:4kHz/2:125Hz]:');
27 % DAYS = input(' Enter date [ year / month / day ]: ','s');
28
29 display('Select file you want to read ') %e.g. f1903311130.ump
30 [fname,pathstr] = uigetfile('*.***', 'Choose a data-file');
31 [pathstr,fname,ext]=fileparts([pathstr,fname]);
32
33 % load_sec = input('input in seconds to display :');
34 load_sec = 590 ;% 7min> 420
35
36 S_HOUR = fname(8:9);%read row 8 until 9
37 S_MINUTE = fname(10:11);
38 S_SECOND = '0'; % Start seconds for the number of seconds to display
39 s_hour = str2double(S_HOUR);
40 s_minute = str2double(S_MINUTE);
41 s_second = str2double(S_SECOND);
42
43 e_hour = s_hour;
```

Figure 3.9 ELF coding in Matlab

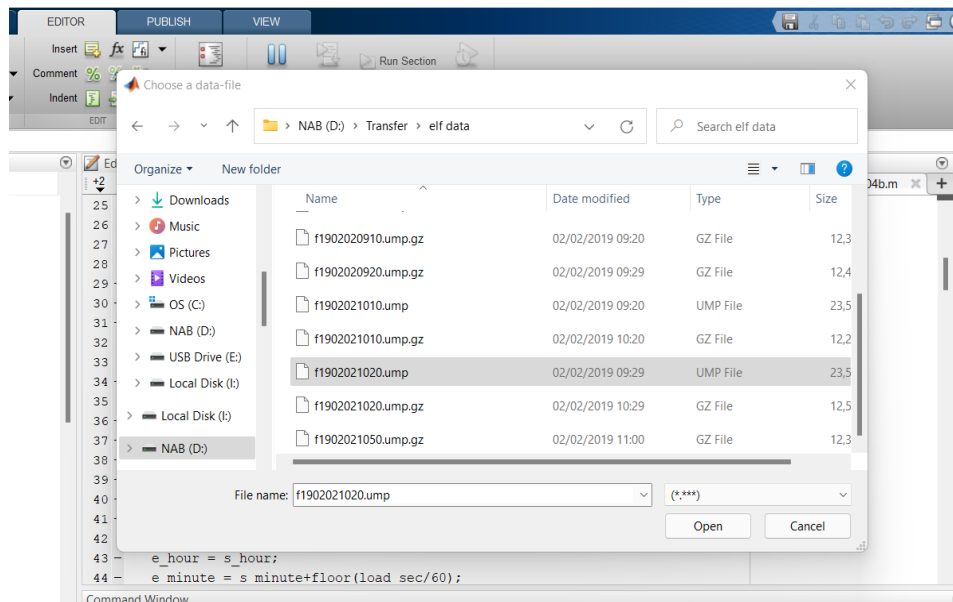


Figure 3.10 ELF data in a binary file

From figure 3.10, the file for ELF data has been chosen at 2/2/2019 and the time is 9.29 am because on the website USGS has to detect earthquakes at that time.

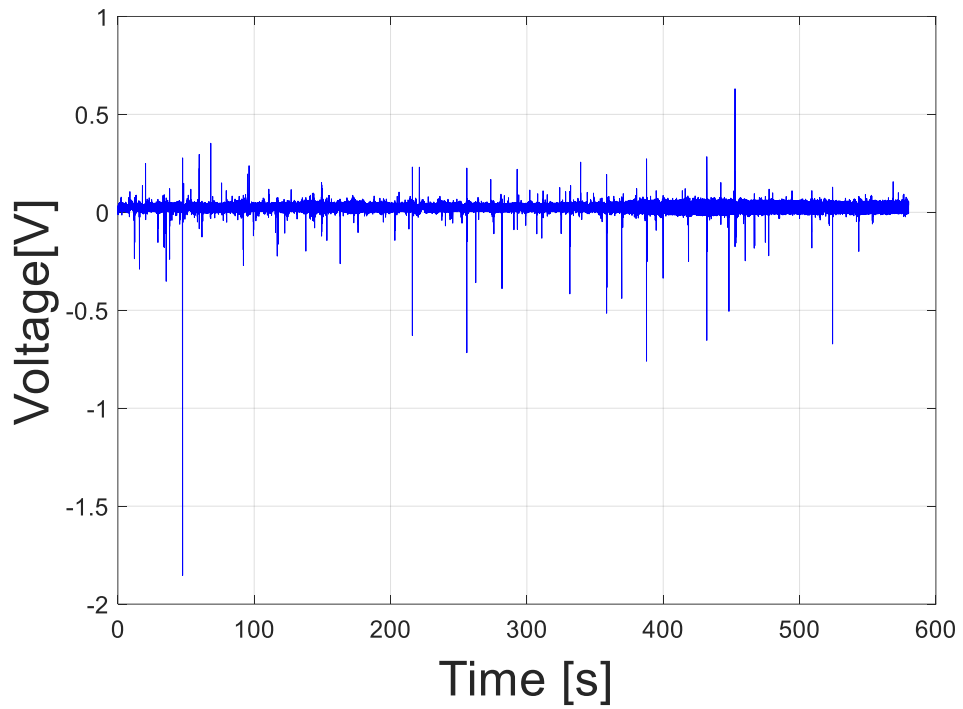


Figure 3.11 Raw data in North-South

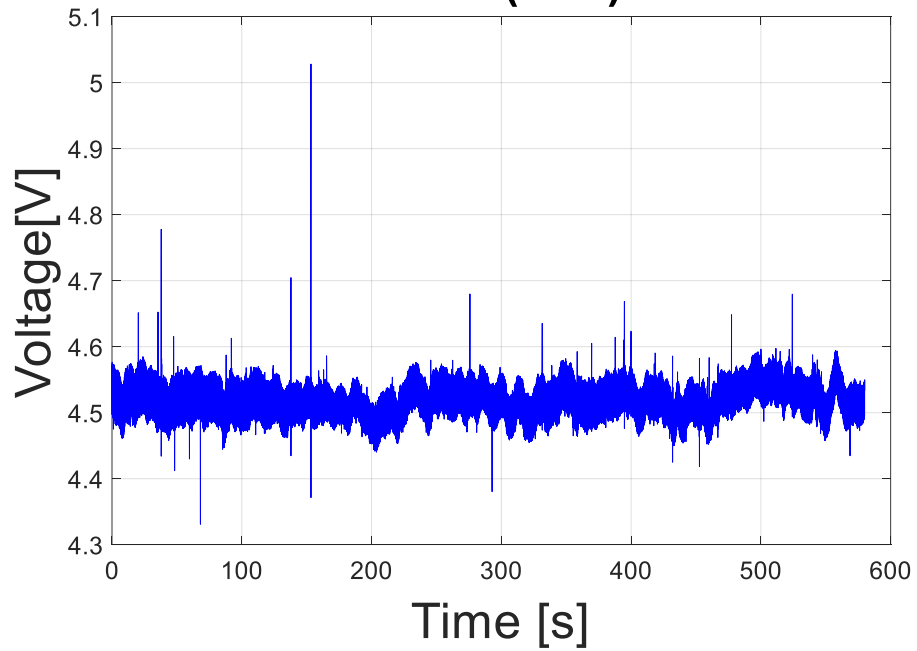


Figure 3.12 Raw data in East-West

This is raw data when executing in Matlab and the graph shows much noise in the data. On the data ELF has taken the reading in 600 seconds. All of this data has a million peaks in 600 seconds.



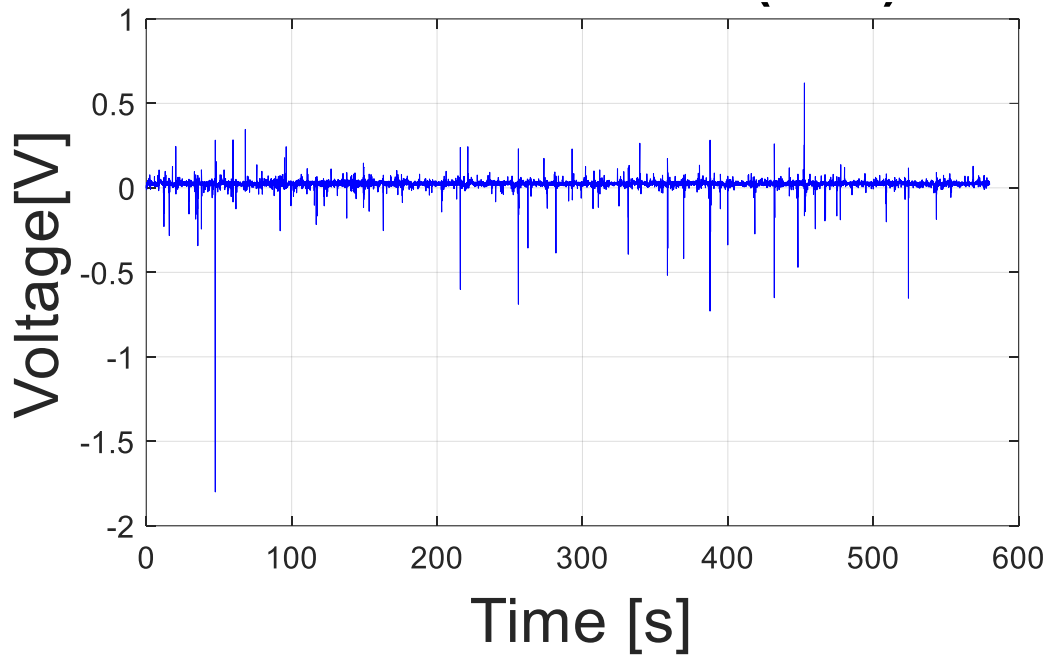


Figure 3.13 Filtered data in North-South

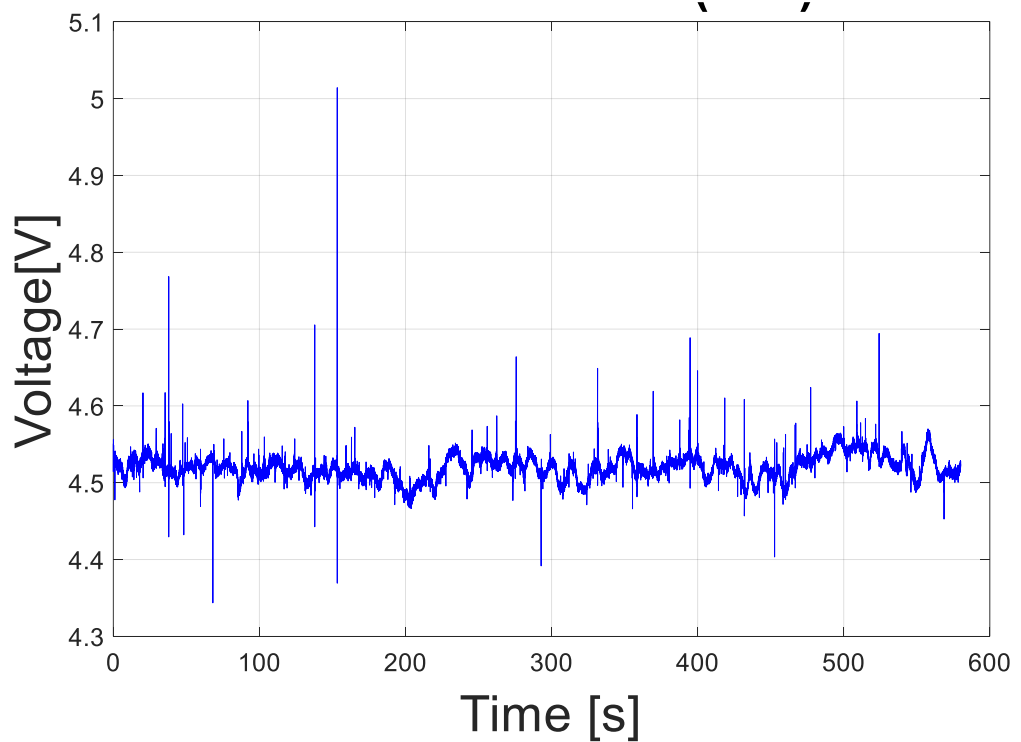


Figure 3.14 Filtered data in East-West

The filtered data for both graphs will be used to continuously analyze the data. By using the brush indicator, all of the peaks in the Matlab graph will be saved in a workspace. In a workspace can store millions of data. Data from the workspace will be copied and then transfer to excel. The next process is to arrange the data because not all

data from the graph will be taken, only the certain peak will take and then record in excel because the next process is to find the angle from both these graphs by using the formula.

### 3.7 ISS LIS Lightning Flash Location Quickview Using Phyton 3.0 and GIS

LIS or the real name is The Lightning Imaging Sensor is linked with the Internation Space Station (ISS) to record or receive optical lightning all around the world. By using the python 3.0 script, it can access the data for visualization of lightning location. This LIS is designed to get the information about the lightning using Python only because python can generate the map in python software.

```
ISS_LIS_FlashLoc_Quickview.py - C:\Users\User\Desktop\UMP\subjek sem 8 U\fy2\data-recipes-master\data-reci...
File Edit Format Run Options Window Help
#Define the file directories
dataDir = 'C:/Users/User/Desktop/UMP/subjek sem 8 U/fyp2/data iss LIS' #File path where ISS L
csvfile = "C:/Users/User/Desktop/UMP/subjek sem 8 U/fyp2/data iss LIS/isslis_flashloc_.csv" #l

#Identify all NetCDF files in the directory
files = glob.glob(dataDir+'*.nc')

#Create empty arrays to populate lightning flash location coordinates
flash_lat = np.array([]) #latitude
flash_lon = np.array([]) #longitude

#Loop through list of NetCDF files, for each file, extract the lightning flash latitude
#and longitude, and add to the respective empty array (flash_lat and flash_lon)
for i in files:
    datafile = Dataset(i)

    flash_lat = np.concatenate([flash_lat,datafile.variables['lightning_flash_lat'][:]]) #add
    flash_lon = np.concatenate([flash_lon,datafile.variables['lightning_flash_lon'][:]]) #add

#Create CSV files of values from the populated flash_lat/lon arrays
with open(csvfile, 'wb') as myfile:
    writer = csv.writer(myfile)
    writer.writerow(izip(["flash_lat"], ["flash_lon"])) #Define headers in row (izip creates
    writer.writerow(izip(flash_lat,flash_lon)) #Define data rows (izip creates columns)

#Create plot of lightning flash location heat map
plt.figure(figsize=(20,20)) #Set plot dimensions
map = Basemap(projection='cyl', lon_0 = 0, resolution='c')
lightning = map.hexbin(flash_lon, flash_lat, gridsz=300,bins='log', cmap='jet', mincnt=1, zord

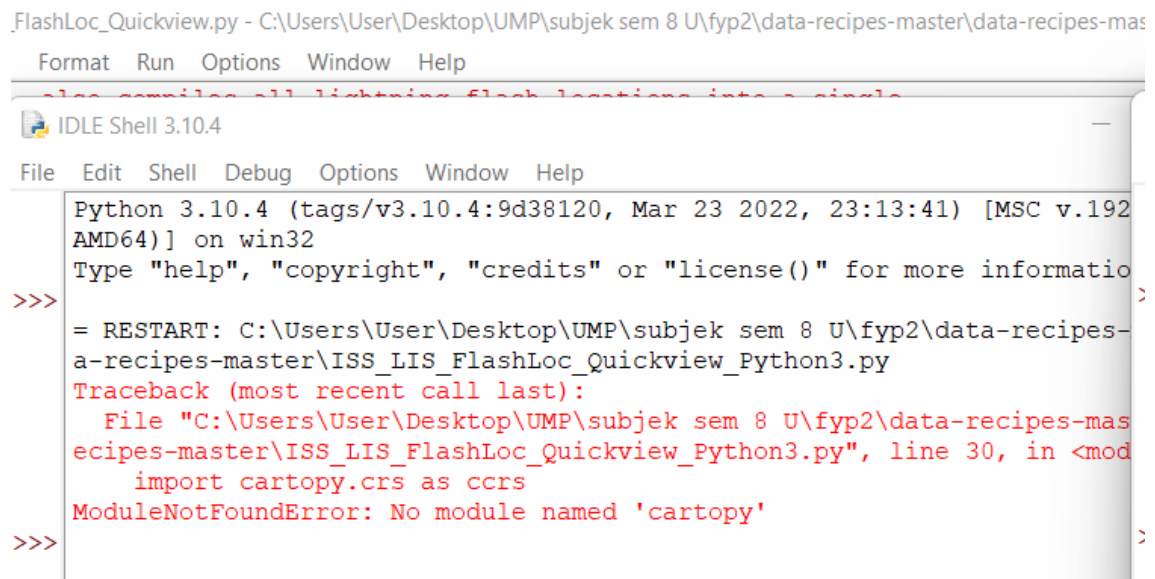
#Draw geographic boundaries and meridians/parallels
map.drawmapboundary(fill_color='k')
map.fillcontinents(color='grey',lake_color='grey')
map.drawcoastlines(color='white')
map.drawcountries(color='white')
map.drawmeridians(np.arange(0,390,30), labels=[0,0,0,1],fontsize=10, color="lightgray")
map.drawparallels(np.arange(-90,120,30), labels=[1,0,0,0],fontsize=10, color="lightgray")

cbar = map.colorbar(lightning,location='bottom',pad="5%")
cbar.set_label('Flash Count') #Remember to change label

plt.title('ISS LIS Detected Lightning Flash Locations February 2, 2019', fontsize = 18) #Remb
```

Figure 3.15 Python script

Before using this script in figure 3.15, 3 things need to do which is the “dataDir” need to put the location NC file then it will save in the computer. Next is the “CSV file”.csv file also needs to put the location in “.csv” which means in the excel file to save the data. Lastly, the “plt title” is the title on the figure after running the script. If the user is new to install python, there are a lot of modules and extensions that need to be downloaded because if not, the script will run in error.



```
FlashLoc_Quickview.py - C:\Users\User\Desktop\UMP\subjek sem 8 U\fyp2\data-recipes-master\data-recipes-master
Format Run Options Window Help
IDLE Shell 3.10.4
File Edit Shell Debug Options Window Help
Python 3.10.4 (tags/v3.10.4:9d38120, Mar 23 2022, 23:13:41) [MSC v.192 AMD64] on win32
Type "help", "copyright", "credits" or "license()" for more information
>>>
= RESTART: C:\Users\User\Desktop\UMP\subjek sem 8 U\fyp2\data-recipes-master\ISS_LIS_FlashLoc_Quickview_Python3.py
Traceback (most recent call last):
  File "C:\Users\User\Desktop\UMP\subjek sem 8 U\fyp2\data-recipes-master\ISS_LIS_FlashLoc_Quickview_Python3.py", line 30, in <module>
    import cartopy.crs as ccrs
ModuleNotFoundError: No module named 'cartopy'
>>>
```

Figure 3.16 Error script python

Figure 3.16 is the error after executing the script. This error happen because there is no module for python on the computer. For example, the error for this figure is “no module name cartopy”. This what need is to download the module in the command prompt.

```

Microsoft Windows [Version 10.0.22000.556]
(c) Microsoft Corporation. All rights reserved.

:\Users\User>pip3 install plotly
Collecting plotly
  Downloading plotly-5.7.0-py2.py3-none-any.whl (28.8 MB)
----- 28.8/28.8 MB 933.3 kB/s eta 0:00:00
Collecting tenacity>=6.2.0
  Downloading tenacity-8.0.1-py3-none-any.whl (24 kB)
Collecting six
  Downloading six-1.16.0-py2.py3-none-any.whl (11 kB)
Installing collected packages: tenacity, six, plotly
Successfully installed plotly-5.7.0 six-1.16.0 tenacity-8.0.1

:\Users\User>pip3 install netCDF4
Collecting netCDF4
  Downloading netCDF4-1.5.8-cp310-cp310-win_amd64.whl (3.0 MB)
----- 3.0/3.0 MB 154.7 kB/s eta 0:00:00
Collecting cftime
  Downloading cftime-1.6.0-cp310-none-win_amd64.whl (162 kB)
----- 162.5/162.5 KB 226.6 kB/s eta 0:00:00
Requirement already satisfied: numpy>=1.9 in c:\users\user\appdata\local\programs\python\python310\lib\site-packages (from netCDF4) (1.22.3)
Installing collected packages: cftime, netCDF4
Successfully installed cftime-1.6.0 netCDF4-1.5.8

:\Users\User>pip3 install matplotlib
Collecting matplotlib
  Downloading matplotlib-3.5.1-cp310-cp310-win_amd64.whl (7.2 MB)
----- 7.2/7.2 MB 3.9 MB/s eta 0:00:00

```

Figure 3.17 Module that has been downloaded in command prompt

This is the way to download the module when has an error while running the script by using the command prompt. There are specific codes need to write in the command prompt when want to download the module which is “pip install \*\*\*”. If want to download module cartopy just type “pip install cartopy”. Then the command prompt will download the module. As in figure 3.17, many modules have been downloaded but still got an error while running the script. This work needs to take time and needs further

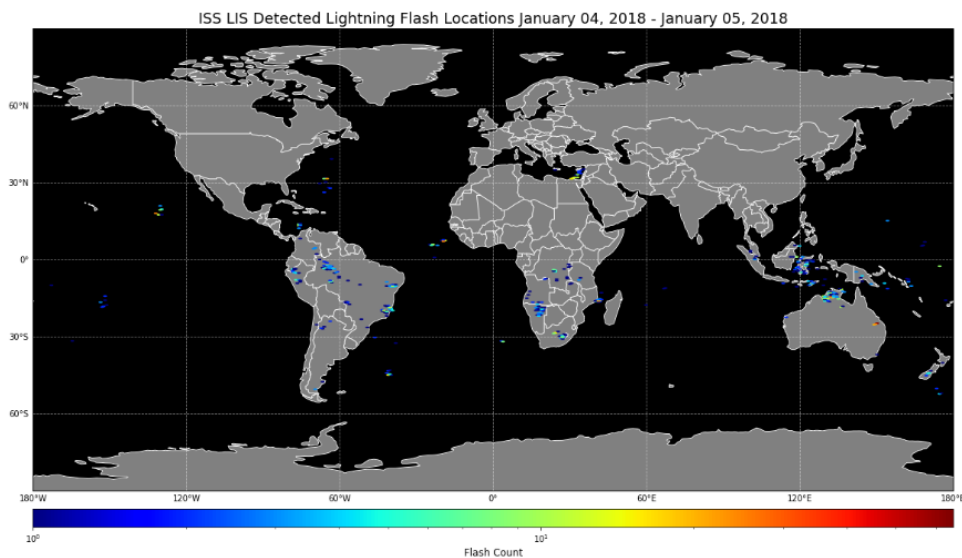


Figure 3.18 Map on python

work until can get solve the problem to explore and find the extension because not all modules are available in the command prompt.

Figure 3.18 supposedly should be the result like this to take the data lightning around the world because the script also can set time and date what happen to the lighting on that day. But the problem is still not solved yet because have an error when running the script.

### 3.8 Blitzortung website

Blitzortung is another website that records lightning events. This website develops in Germany for researchers can use their data to continue their research in their field. Blitzortung can detect in live and then it will save into the website.

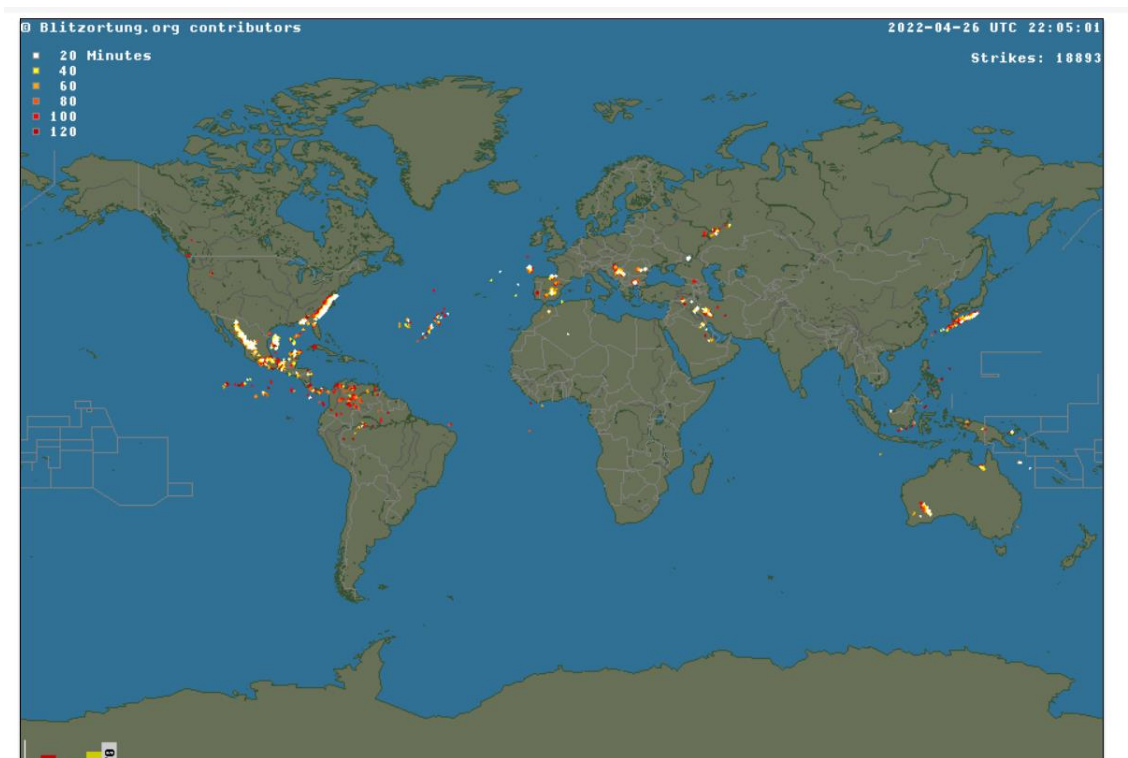


Figure 3.19 Blitzortung interface

## CHAPTER 4

### RESULT

#### 4.1 Introduction

This chapter will briefly explain the preliminary result from the peak of data North-South (NS) and East-West (EW) until getting the angle from ELF signal data. The peak of the signal has been taken to excel to plot another graph in excel. The purpose to do this is to identify how many peaks that occur at a certain time.

#### 4.2 Determine the threshold at the graph in Matlab

From the data ELF that has already been converted through Matlab, it will show the plotting graph time versus voltage where time on X axis and voltage on Y axis.

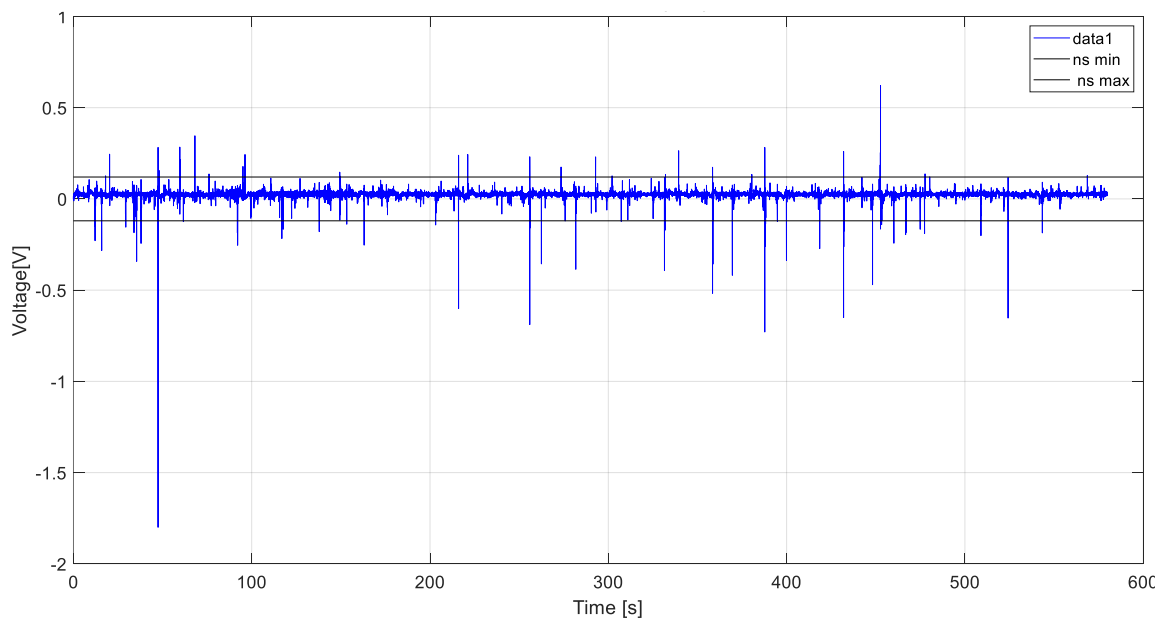


Figure 4.1 The limitation at a black line on the graph NS

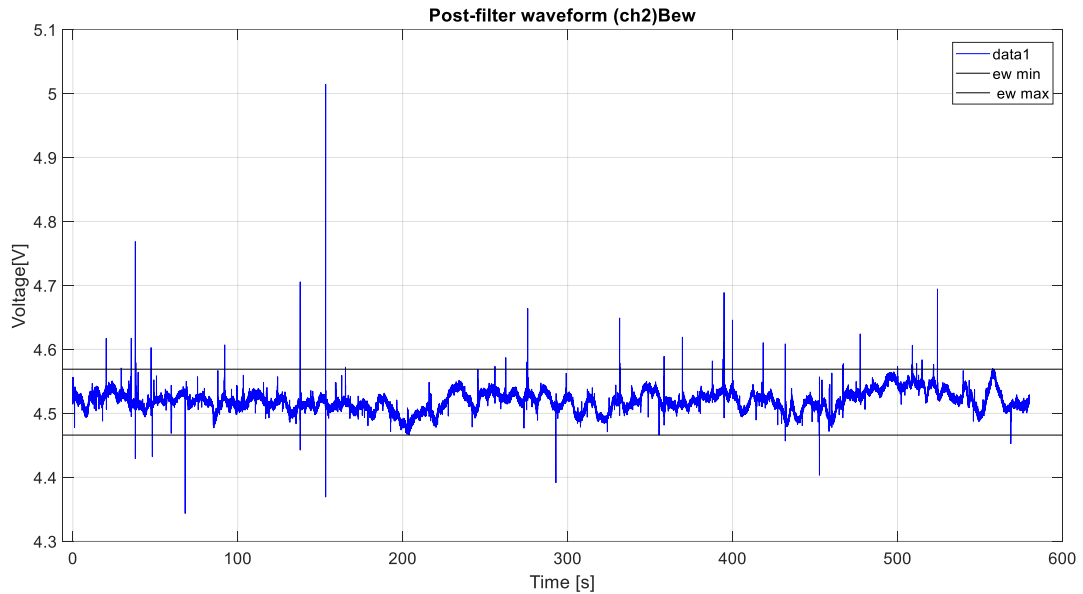


Figure 4.2 The limitation at a black line on the graph EW

The limitation line is already set for NS from 0.12 until  $-0.12$  volt while for EW shown in figure 4.2 is 4.57 until 4.47 volts. For NS limitation in figure 4.1, the peak value of more than 0.12 will consider ELF data while below that will consider a noise. But if the peak value is smaller than  $-0.12$ , it will consider ELF data. Same process to the EW data where upper than 4.57 volt consider as ELF then below than that consider as a noise. For ELF signal that is below 4.4 volts is considered ELF then upper than that consider a noise. This process needs to do because the graph has millions of peaks and the computer cannot take all the peaks. Because of that, need to set the limitation on the graph.

### 4.3 Selected peak voltage value was transferred to Excel

Table 4.1 The peak value of NS

<b>time</b>	20.293	35.4635	35.46425	37.9375	37.93775	47.48075
<b>voltage</b>	0.229317	0.057826	0.056526	0.07072	0.090534	-1.28251

Table 4.2 The peak value on EW

<b>time</b>	20.923	35.4625	35.46275	37.93675	37.937	47.481
<b>voltage</b>	-0.02002	0.066476	0.059889	0.18569	0.217555	0.051837

Both tables are the certain data peak from ELF that execute in Matlab. All the data are collected from the limitation which has been set. The value of voltage in NS will be

Y while voltage in EW will be X. By using  $\theta = \arcsine(x/y)$  and  $\theta = \arccos(x/y)$  will get the angle with a remaining same time.

#### 4.4 Using a table to get the position angle in which quadrant

Table 4.3 Calculated angle by using arcsine and its absolute value

<b>ANGLE FROM ARCSINEE</b>	-86.19	-86.26	-84.22	240.72	73.90	-78.98
<b>Absolute value of arcsine</b>	86.19	86.26	84.22	240.72	73.90	78.98

Table 4.4 The quadrant to find the actual angle

<b>QUADRANT</b>	<b>ANGLE</b>					
<b>Q1</b>	0	0	0	0	73.90	78.98
<b>Q2</b>	0	0	0	0	0	0
<b>Q3</b>	0	0	0	240.72	0	0
<b>Q4</b>	237.80	273.37	275.77	0	0	0

Table 4.4 above shows the location of the angle in which quadrant to get the actual angle. This actual angle will be used as the truth angle that can be a reference and will compare the angle by using protractor extension. First, need to find the angle from arcsine and arccos. This is to get the comparison angle in the quadrant because each quadrant has a positive or negative sin (-sin, +sin) and positive or negative cos (-cos, +cos) just shown in figure 3.2. All of the positive and negative signs from arccos and arcsine can affect the quadrant at a certain angle. Next is to ensure the angle change to the positive. In sin will have the negative angle that needs to remove from the negative sign (-) because in angle will depend on which quadrant will be the place that is named as “ANGLE POSITIVE



SIGN". If in quadrant 3, the angle of sin will be plus with  $180^\circ$ . If in quadrant 4, the angle for sin will be minus with  $360^\circ$ . Then, will be able to get the angle for arcsine and arccos.

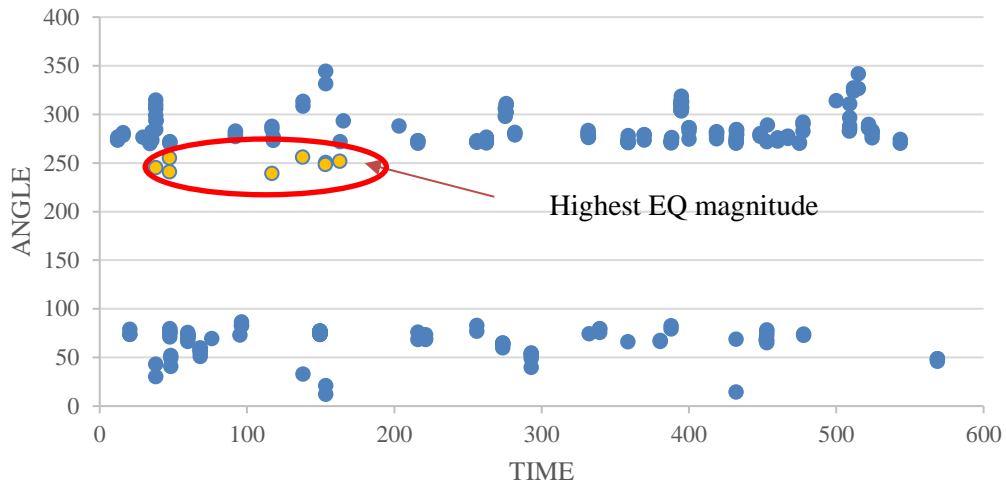


Figure 4.3 The angle of EQ vs time

The angle is already plotted in figure 4.3 Now the result will be able to find the location activity based on ELF data. The figure also has many events that have been detected by ELF with earthquake and lightning activity but from the graph is only able to detect the angle. Need further work to find the seismic event based on data that have been given from the ELF sensor. To easy to understand where the expected angle of EQ is the orange mark. The orange mark is the expected angle EQ while the blue is lightning data and noise data because filter data are not completely removed from all the noise data. The highest EQ magnitude is around on orange mark.

#### 4.5 Get the reading angle from Protractor

Before can compare the angle from the ELF signal, first what need to do is use one extension from google to help us to get the angle location of the EQ place. This extension is very useful because it can easily help to measure the distance and also the angle on a world map. This extension can install at google extension protractor.

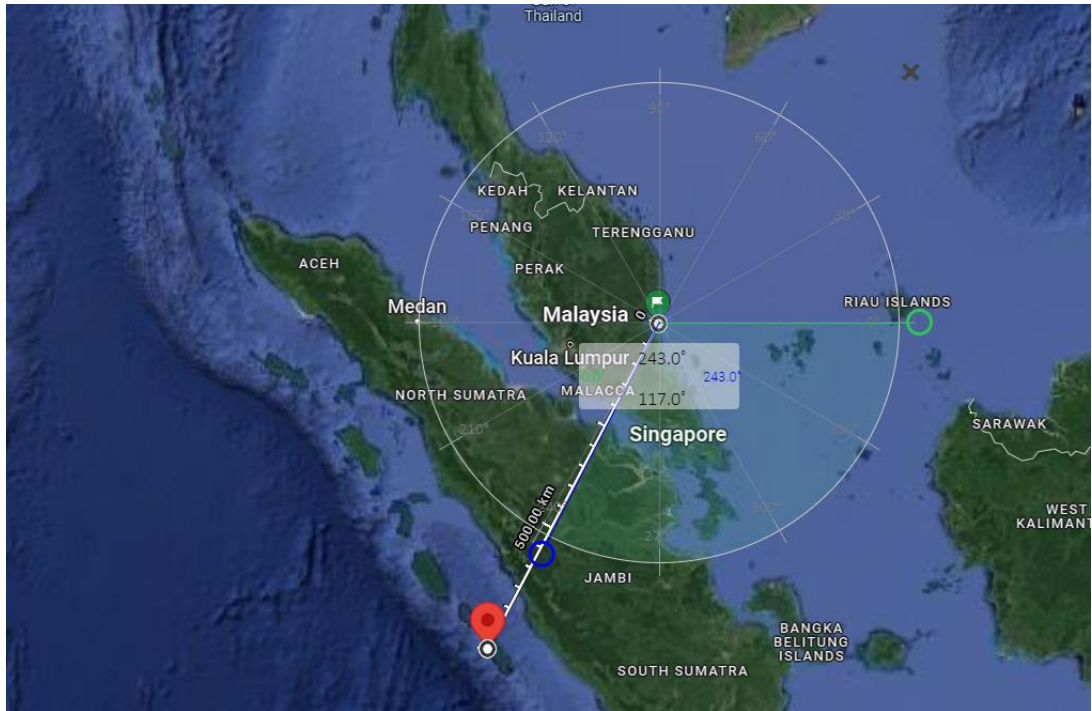


Figure 4.4 The angle that has been shown by using a protractor

From that figure 4.4, the location at Sungai Penuh, Indonesia angle  $243^{\circ}$  is the angle which is at quadrant 3 to the maximum magnitude which is 6 magnitudes because the highest magnitude of the EQ can give effect the fault line and also the earth's crust to slip near an area of the highest magnitude EQ occurred. That's why the highest magnitude of EQ is very important to take the first point before taking another magnitude EQ. EQ can happen again near the center of the highest magnitude at in anytime they can. The location of EQ will be more detected but at the same time, the magnitude will get weaker because the energy that produces from the highest magnitude will go far from them.

#### 4.6 Identifying location lightning

Based on figure 3.19 and figure 3.8 is the reference and to identify the location at area Sg. Penuh is clear from a lightning because our main target is to get the angle from EQ only. For reference, this 2 website which is JAXA and Blitzortung will be useful website to get world meteorological data

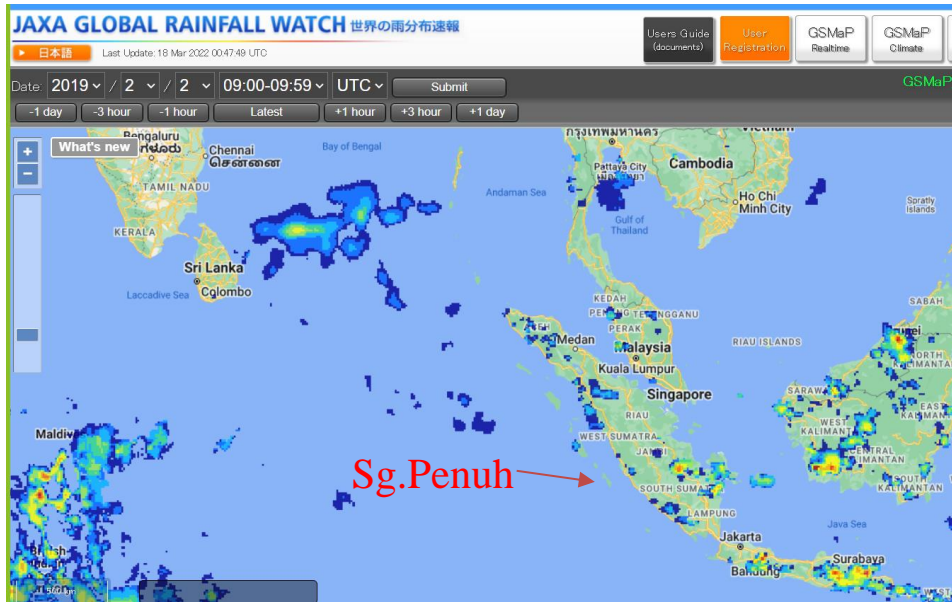


Figure 4.5 The Jaxa meteorological data on 2/2/2019

Figure 4.5 shows the current condition weather on Southeast Asia on 2/2/2019 at time 9 am until 9.59 am. Location at Borneo has heavily rain according Jaxa data and at certain place in Indonesia also has a rain on that time.

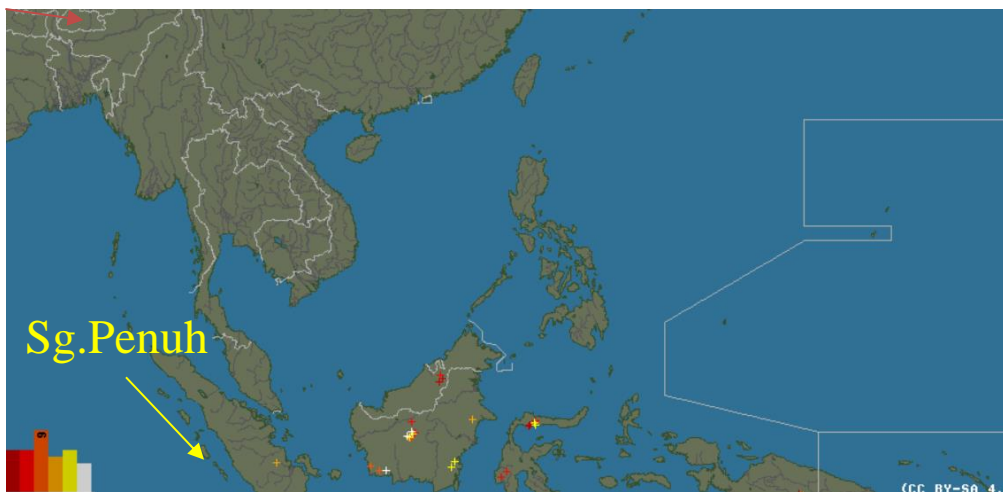


Figure 4.6 Image lightning at area Southeast Asia

From the Blitzortung website, the location of lightning occur are same because if refer to figure 4.5 at Borneo area has heavily rain. At the same time, from blitzortung data has recoreded the location lightning on that day. Location at Sg.Penuh are clearly from lightning. This will be easier for us to get the angle of EQ because no lightning event near area of Sg.Penuh.

#### 4.7 Angle of EQ

Before starting to get the angle, the frequency of the angle needs to show first. This is to get the comparison between the angle from the ELF signal and protractor extension.

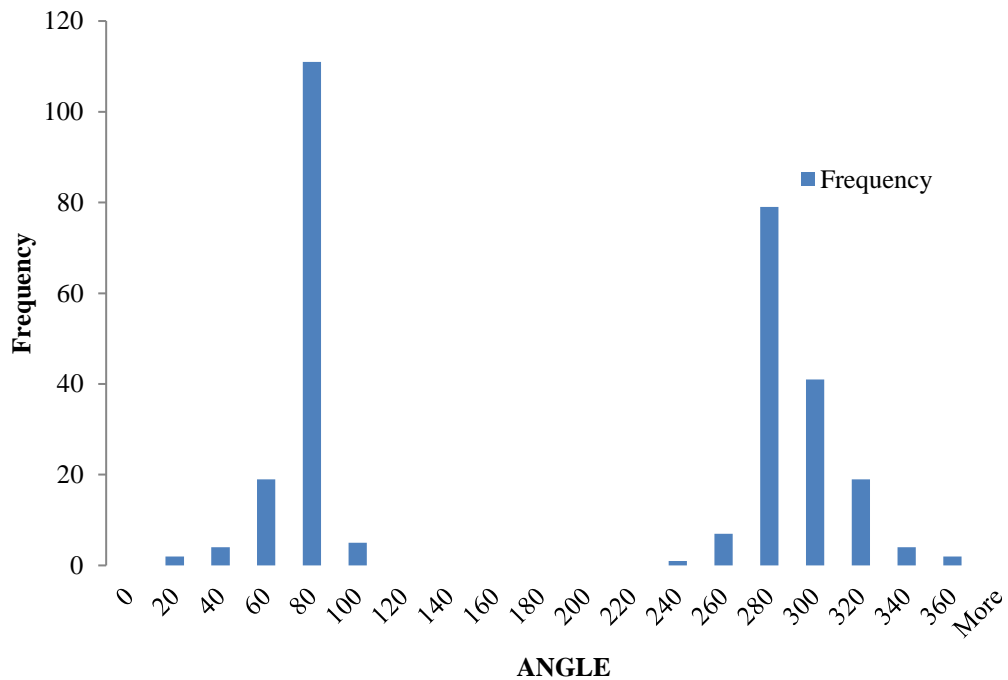


Figure 4.7 The frequency angle of EQ

This is the frequency angle in the histogram. If can see, an angle from 240°-260° is the expected angle based on the protractor that has been seen on the google map. The angle from ELF is almost similar to the angle recorded by using a protractor which is 243° based on figure 4.3. Other than angle 240°-260° is a signal from the lightning mixed with noise data because filter data also has noise data. Angle 240°-260° is an angle that refers to the highest magnitude that has occurred which means 6 magnitudes. Same like an explanation before this, when the highest magnitude has occurred, the area near the highest EQ also will give the same effect but the power of the magnitude will be lower. That's why the angle EQ is not constant due to the earthquake activity.

## CHAPTER 5

### CONCLUSION

#### 5.1 Introduction

This chapter will summarize the conclusion on finding and analysis angle from earthquake activity in range radius 1000 km center point from main gate UMP Pekan and signal Extra Low Frequency (ELF).

#### 5.2 Conclusion

To summarize, identifying the EQ and ELF signal has been achieved because based on the graph in Matlab, we can get the peak of voltage from East-West (EW) and North-South (NS) and then able to get the angle. Moreover, determining an angle of EQ has been achieved based on the angle in figure 4.3 where the angle when compared with protractor, percent error at the highest magnitude point from time versus angle is below 3%. The result shows many angles but regarding the protractor, the angle in the protractor to the highest magnitude is  $243^{\circ}$  while in a graph actual angle has  $240^{\circ}$ . From the protractor also the location of the EQ at quadrant 3. Same with graph angle  $240^{\circ}$  also in quadrant 3. Lastly, to suggests the possibility of earthquake detection by using ELF is not achieved because only one data from ELF has been executed in Matlab. There are many steps to test ELF data to get the angle from EW and NS graphs and need further work to keep continue research in Extra Low Frequency (ELF).

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## APPENDIX A

### ASCII DATA FROM ELF STATION MATLAB CONVERTER SCRIPT

```
%% New logger waveform observation program modified -> Add post-filter waveform ,
2020/06/04 Comment added YH
% 1. Raw waveforms
% 2. Filter (botheast,westnotch filtering) post-waveform
% 3. Frequency spectrum (y-axis logarithmic scale )
%Program to create more than 3 figures
%
% Purpose: To check the waveform of the new loger(IME-516DL) data for elf waveform
observation
% Main Program: show_raw_filterd_stimeseries20200604b.m
% Simple Specification: UMP specification.
% 1. Raw waveforms
% 2. Filter (both east,westnotch filtering ) two components after the waveform
%Program to create more than 4 figures
% How to use
%1. Select the file you want to read after running the program (keep the file ungzip)
%2. The number of seconds to be displayed (positive number of less than60*10 seconds since
the file is a 10-minute file)
%3. Enter the channel to be displayed (1 or 2)

clear all
close all

dir_in = '..\DATA\';
dir_out= '..\RESULTS\';

%% Input
% Fs = input('Fs Please select[1:4kHz/2:125Hz]:');
% DAYS = input(' Enter date [ year / month / day ]: ','s');

display('Select file you want to read ') %e.g. f1903311130.ump
[fname,pathstr] = uigetfile('*.*', 'Choose a data-file');
[pathstr,fname,ext]=fileparts([pathstr,fname]);

% load_sec = input('input in seconds to display :');
load_sec = 590 ;% 7min> 420

S_HOUR = fname(8:9);%read row 8 until 9
S_MINUTE = fname(10:11);
S_SECOND = '0'; % Start seconds for the number of seconds to display
s_hour = str2double(S_HOUR);
s_minute = str2double(S_MINUTE);
s_second = str2double(S_SECOND);

e_hour = s_hour;
e_minute = s_minute+floor(load_sec/60);
e_second = s_second+mod(load_sec,60);

s_time_sec = 3600*s_hour + 60*s_minute; ;% Start Time (sec)
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e_time_sec = 3600*e_hour + 60*e_minute + e_second; %End time (sec)
time_sec = 3600*s_hour + 60*str2double([S_MINUTE(1) '0']); %Reading time length (sec)

% ch = input('Select channel to display [1/2]:');
%% To read binary

Sec=e_time_sec - time_sec;
Sec2=e_time_sec - s_time_sec;
HEADER_LEN=128;%header (tk pasti sbb fungsi dkt sini saja)
AD_LEN=10;%5chx2byte (tk pasti sbb fungsi dkt sini saja)
DATA_LEN=4000; % 16bitx5chx4kHz (tk pasti sbb fungsi dkt sini saja)

% if Fs == 1
%filename = [pathstr '\' fname ext];
filename = [pathstr '/' fname ext]; %For MAC 20200604
l = length(filename);
tf = strcmp(filename(1-2:l),'ump'); %Name observers by file extension by Land 012, UMP:ump
or 012
station=filename(1-2:l)
%
if tf == 1
    basho = 'ump'; % basho = tempat
else
    basho = 'OTHER';
end

% basho = 'raft water';
Leco=4000;
% elseif Fs == 2
% filename = [dir_in 'F' YEAR(3:4) MONTH DAY S_HOUR S_MINUTE(1) '0a.uec'];
% Leco=125;
% end

fa = zeros(6,Leco*(Sec2));
time = zeros(1,Leco*(Sec2));
B = zeros(2,Leco*(Sec2));

% Read the contents back into an array
fid = fopen(filename);

fid2 = fopen('time.txt','wt');
count2 = 0;
k=0;
for j = 0:(Sec-1)
    if j >= s_time_sec - time_sec
        k=count2*Leco;
        count2 = count2+1;
    end
    [F_nums,count] = fread(fid, 128);%' % read the first 128 bytes ('%FREAD')

    fprintf(fid2,'%s\n',F_nums);

    for i = 1:Leco
        F_Data = fread(fid, 10);%' % read the first 10 bytes ('%FREAD')
        fa(1,i+k) = j+(i-1)/4000;
    end
end

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        time(1,i+k) = fa(1,i+k);
        fa(2,i+k) = byte2ad16(F_Data(1),F_Data(2));%CH1
        B(1,i+k) = fa(2,i+k); %CH1
        fa(3,i+k) = byte2ad16(F_Data(3),F_Data(4));%CH2
        B(2,i+k) = fa(3,i+k); %CH2
        fa(4,i+k) = byte2ad16(F_Data(5),F_Data(6));%CH3
        fa(5,i+k) = byte2ad16(F_Data(7),F_Data(8));%CH4
        fa(6,i+k) = byte2ad16(F_Data(9),F_Data(10));%CH5
    end
    %%%%%%%%%%% Except for specified time clear %%%%%%%%%%%
    if j < s_time_sec - time_sec
%       if j < 400
            disp('check');
        clear fa
        end
        %%%%%%%%%%%
    end
end

B = B(:,:,). *2^(-16). *20; % 1LSB is 2^(-16)*20?305?V

fclose(fid);
fclose(fid2);

%% To plot figures
for ch = 1:2 %% for both channel image storage
% ch = 1;    %%% for viewing one channel
%-- Raw waveform --%
if ch == 1
    fig1 = figure(1);
else
    fig4 = figure(4);
end
% figure
clf;
if ch==1
    plot(fa(1,1+Leco*s_second:end-Leco*10),B(1,1+Leco*s_second:end-Leco*10) , '-b');
    fig_title='Raw Data(ch1)Bns';
elseif ch==2
    plot(fa(1,1+Leco*s_second:end-Leco*10),B(2,1+Leco*s_second:end-Leco*10) , '-b');
    fig_title='Raw Data(ch2)Bew';
end
end
grid on
set(gca,'FontSize',15)
xlabel('Time [s]','FontSize',30);
ylabel('Voltage[V]','FontSize',30);
title(fig_title,'FontSize',30);
%-----%

%-- Post-filter waveform --%
if ch == 1
    fig2 = figure(2);
else
    fig5 = figure(5);
end
% figure

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clf
if ch==1
    if strcmp(ext,'.012')== 1
        filterd1 = func_notch_eastjp_00(B(1,:),Leco,1000);
    elseif strcmp(ext,'.ump')== 1
        filterd1 = func_notch_eastjp_00(B(1,:),Leco,1000);
    else
        filterd1 = func_notch_westjp_00(B(1,:),Leco,1000);
    end
    plot(fa(1,1+Leco*s_second:end-Leco*10),filterd1(1,1+Leco*s_second:end-Leco*10) , '-b');
% plot(fa(1,:),filterd1(1,:), '-b');
    fig_title='Post-filter waveform(ch1)Bns';
elseif ch==2
    if strcmp(ext,'.012')== 1
        filterd2 = func_notch_eastjp_00(B(2,:),Leco,1000);
    elseif strcmp(ext,'.ump')== 1
        filterd2 = func_notch_eastjp_00(B(2,:),Leco,1000);
    else
        filterd2 = func_notch_westjp_00(B(2,:),Leco,1000);
    end
    plot(fa(1,1+Leco*s_second:end-Leco*10),filterd2(1,1+Leco*s_second:end-Leco*10) , '-b');
    fig_title='Post-filter waveform (ch2)Bew';
end
grid on
set(gca,'FontSize',15)
xlabel('Time [s]','FontSize',30);
ylabel('Voltage[V]','FontSize',30);
title(fig_title,'FontSize',30);
%-----%

%-----%

hazon = 1; % other than 1 when not saving images (save)

if hazon == 1;
% savedir = '/Users/Yasuhide/PROJECT/ELF/elf_newlog/RESULTS/';
% savedir = './RESULTS/';
savedir = './';
keisiki = 'png';
if ch == 1
    saveas(fig1,[savedir basho '_' 'raw' fname(4:11) '_ch' num2str(ch) '_stn_' station],keisiki);
    saveas(fig2,[savedir basho '_' 'ftd' fname(4:11) '_ch' num2str(ch) '_stn_' station],keisiki);
end
if ch == 2
    saveas(fig4,[savedir basho '_' 'raw' fname(4:11) '_ch' num2str(ch) '_stn_' station],keisiki);
    saveas(fig5,[savedir basho '_' 'ftd' fname(4:11) '_ch' num2str(ch) '_stn_' station],keisiki);
end

end

end

end

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