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Electromagnetic Anomaly As Earthquake Precursor In Pelabuhan Ratu, Sukabumi

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Abstract—**Research on electromagnetic anomalies related to earthquakes as early signs (precursors) of earthquake was performed in Pelabuhan Ratu Observatory. This research was part of BMKG's Integrated studies on earthquake precursors that carried out in stages and sustainable analysis of geophysical, geo-atmospheric and geochemical parameters. Research was focused on identifying physical parameters as an earthquake anomaly precursor in the Pelabuhan Ratu, West Java along 2013. Goals to be achieved in this research were improvement of the quality of BMKG information in the earthquake mitigation. Electromagnetic parameters used were magnetotelluric data observed at geophysical observatories of Pelabuhan Ratu in collaboration with Chiba University (Japan). The method of electromagnetic data processing was done by applying polarization ratio (ratio of spectral analysis) method and impedance of EM wave on the ULF (Ultra Low Frequency) spectrum. Results of magnetic polarization and impedance of EM wave were identification of 5-50 days anomaly before the main shock, these parameters included in short-term precursors were likely caused by electrokinetic and microcrack before the accumulation of energy released as earthquakes.**

Keywords: Pelabuhan Ratu, Electromagnetic, Earthquake Precursor)

IV. Introduction

Earthquake is a natural phenomenon that the occurrence of erratic and unpredictable consequences. Efforts to minimize the hazards of earthquakes needs to be done, one of which is to detect early signs (precursors) the occurrence of earthquakes. Earthquake precursor research requires a variety of observational data and methods, one of which is the data of the earth's magnetic.

If a material under tension / stress then some properties of these materials undergo changes that can be monitored, such as properties of magnetic, radioactive, electron content, temperature and so on. Relations regarding such phenomena in the ionosphere-atmosphere system and the lithosphere is described by reference [1] in which prior to the earthquake will be no accumulation of energy in lithosfir to micro-cracks occur (microfracturing) which resulted in the loss of ULF emissions, emissions of radon, as well as changes in conductivity [1].

Electromagnetic anomalies as earthquake precursors was one method that on progress to developed. Observation of electromagnetic waves (EM) in the earth's surface within the limits of ultra low frequncy (ULF) (f <10 Hz) is believed to be the most promising of the monitoring activity of the earth's crust due to penetrating power of electromagnetic can be compared with depth at which the activity takes place and fluctuations in the Earth's crust The electrical conductivity of the earth can be detected directly [2].

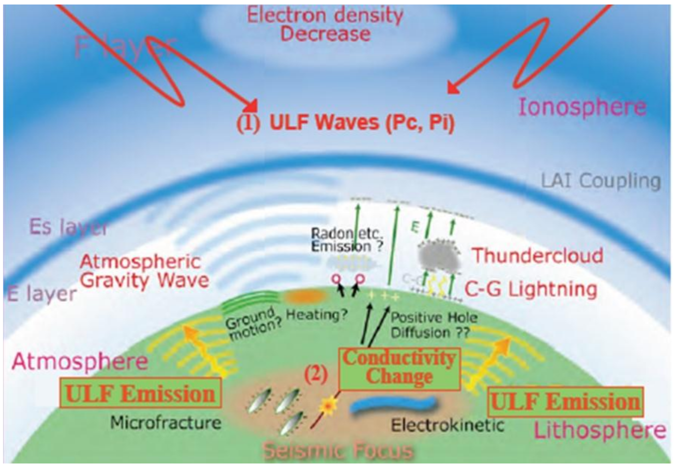

Fig. 1. **Relationship phenomena in the ionosphere-atmosphere system and the lithosphere [1]**

Yumoto et al. [3] introduced a new technique, namely the earthquake precursor studies and comparative polarization signal for the H and Z components of the technique makes it possible to separate the ULF emission of solar wind, magnetosphere, ionosphere or litosphere and derived from seismic origin (lithosphere) [3].

The purpose of this study was to analyze the characteristics of ULF electromagnetic signals in the spectrum and find anomalies that can be used to explain the phenomenon of earthquake precursors in the Pelabuhan Ratu.

V. Research Method

Data that used in this research was observational data magnetotelluric (MT) that consisting of electrical components Ex and Ey and also magnetic components X , Y , Z in January up to December 2013, that obtained from Geophysical Observatory, Pelabuhan Ratu . This station was formed from collaboration BMKG and Chiba University (Japan). Data obtained in the form of magnetic components H_X, H_Y, H_Z , and also electrical components E_X and E_Y. Ratio between electrical fields to magnetic fields (E/H) generating Electromagnetic Impedance that depend on the resistivity of medium or rock. Impedance as a function of the period provide information about the resistivity as function of depth.

Disturbance storm time (Dst) index during January up to December 2013 that obtained from WDC Geomagnetic models, Kyoto University was used as supporting data. This data is used to confirm the global external noise, which in case of magnetic storms, the magnetic anomalies encountered in the processing of data can be ignored.

Earthquake data that used as case study in earthquake precursors analysis was earthquake occurrence data from BMKG at Geophysical Observatory Pelabuhan Ratu area by calculating distance limitation based on Dobrovolsky research (1979), that the radius of the effective precursor manifestation zone depends on the earthquake magnitude and can be calculated using the empirical formula:

$$R_D = 10^{0.43 \times M_L} \quad (1)$$

With R_D is radius strain (Km) and M_L is earthquake local magnitude [4].

From January – November 2013, there were 9 event of earthquake with magnitude 3.7 until 5.5, that included in radius of precursor manifestation zone based on Dobrovolsky calculation. Earthquake data that used in this analysis was shown in Table 1 and Figure 2.

Table 1. Earthquake Data in 2013 (BMKG)

No	Date	Lat	Lon	Depth	Mag	Mag Type	Length	Radius
1	02/02/2013	-7.23	105.24	10	5.3	MLv	149	190
2	26/02/2013	-7.42	107.07	145	5.4	mb	73	210
3	06/03/2013	-6.59	106.24	132	4.6	M	58	95
4	08/04/2013	-7.29	105.95	48	5.2	Mw(mB)	75	172
5	16/04/2013	-6.25	104.72	48	5.5	MLv	221	232
6	14/05/2013	-6.8	106.62	10	3.7	MLv	24	39
7	21/07/2013	-7.43	106.15	26	4.4	M	66	78
8	24/10/2013	-7.25	106.38	108	4.7	MLv	34	105
9	13/11/2013	-6.59	106.37	139	4.9	Mw(mB)	51	128

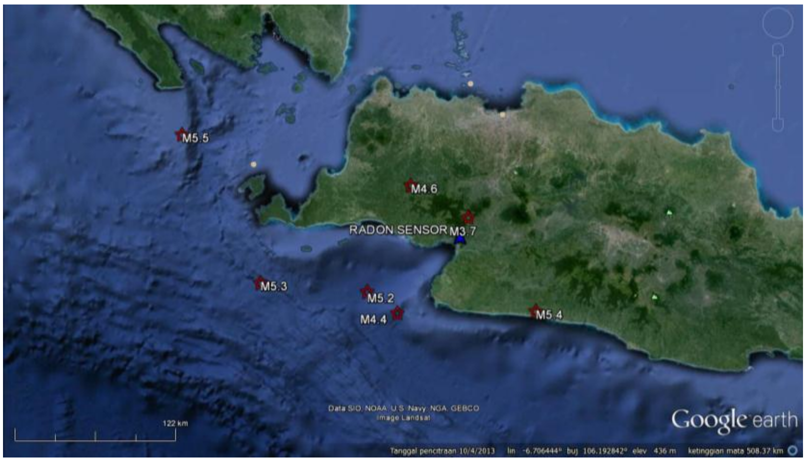

Fig. 2. **Plot distribution of Earthquake in January – November 2013**

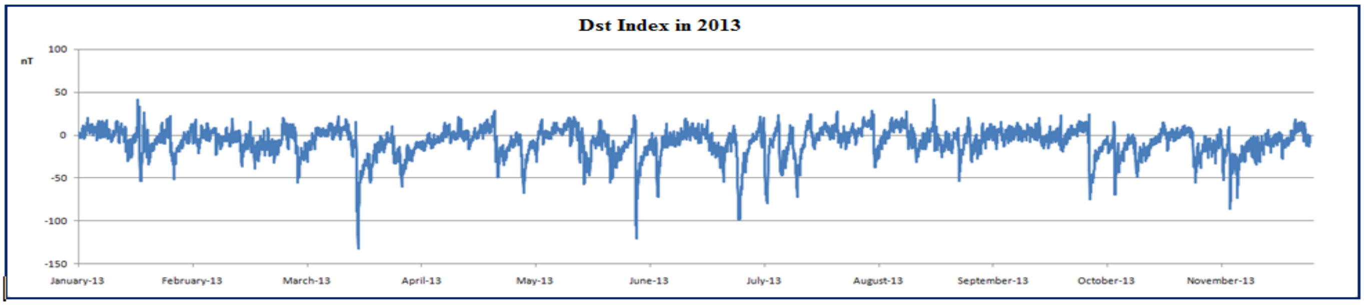

Fig. 3. **Dst Index plotting in January – November 2013 [5]**

Magnetic data processing performed using spectral polarization ratio (spectral density analysis) vertical and horizontal components (H_Z/H_H) in ULF spectrum (0.01 Hz) as introduced by Hayakawa, et. al. [6]. Analysis was performed in the evening hours 15:00 to 22:00 UTC (22:00 to 05:00 GMT) in order to avoid noise due to human activity. To convert signals from time domain to frequency domain using wavelet transform db5. In addition, the ratio of the horizontal component and annual mean (H_H/H_{HT}) and EM wave impedance changes (EX/HY) also analyzed [6].

VI. RESULT AND DISCUSSION

A. Analyze of Magnetic Polarization Ratio

Before analyze results of magnetic parameters, Dst index must be seen to determine the increase or decrease the intensity of the magnetic field variations caused by solar activity or other phenomena. Generally, negative magnetic field noise or magnetic storm indicates decrease of Earth's magnetic field [7].

In Dst index graphics (Figure 3), there are two times decrease in Dst index variations that relatively large and classified in powerful storm, on March 17th to 18th, 2013 and June 1st, 2013 so in this period should be careful to determine anomalies of magnetic data. If during a magnetic storm encountered significant anomalous magnetic data, the data can be ignored as precursors of earthquakes because the anomaly influenced by magnetic storms because most likely influenced by the anomalous magnetic storms.

Results of study show that anomaly of resistivity thought to be earthquakes precursors was impaired [8]. While polarization anomaly (Z/H) thought to be earthquake precursors according to research by Hayakawa [6], Hattori [9], and Yumoto [3] was value increase. In polarization ratio of horizontal component of magnetic variation of the annual mean (H/H_T), according to the Yumoto, et. al. [3] suspected anomalies as earthquakes precursors was value increase.

From graph in Figure 4 can be known some value increase of the magnetic polarization ratio H_Z/H_H. Then the earthquake occurrence data are also plotted as a case study at that time, so they can know the relationship between the occurrence of earthquake anomalies. ULF emissions anomaly with significant increase was found at February 9th until 19th or 7 days before earthquake event at February 26th (M 5.4) with distance 73 km and followed by earthquake at March 6th (M 4.6) with distance 58 km. On March 31th until April 2nd anomaly increase was found before earthquake at April 8th (M 5.2) with distance 75 km. Upon occurrence of this earthquake, the polarization values increased drastically which may be exacerbated due to the earthquake which happened to be near the station observations and shallow depth. This was anomaly for earthquake at April 16th (M 5.5) with distance 221 km. Then after significant increase anomaly at April 25th until 29th, earthquake was found at May 16th (M 3.7) with distance 24 km. Significant increase anomaly also found at May 30th until Juni 5th, but no earthquake after that. Then there was small ULF increase at Juni 21th until July 18th, after that earhquake was occured at July 21th (M 6.6) with distance 66 km. After this earthquake, ULF emissions tend to be stable. In August until October, there wasn't anomaly.

Figure 5 shows graph of magnetic variation ratio of horizontal component of the annual mean (H_H/H_{HT}) from January to November 2013. In the period from 7 to 16 March 2012 and the date of October 1 to 13 2012 looks absence of a significant increase in value (green) allegedly caused by solar activity as seen in the Dst index [9].

Study results of Yumoto, et. al. show that in this method the alleged polarization anomalies as earthquake precursors was value increase. From graph in Figure can be known some increase in magnetic polarization ratio H_H/H_{HT} value. Earthquake occurrence also plotted as case study at interval time, so known relationship between anomalies with earthquake event [3].

From graph in Figure can be known some increase of ratio H_H/H_{HT} value. Anomaly with significant increase was found at January 10th, January 29th, February 23th, March 14, April 7th, April 22th, August 8th, August 29th, Sept 24th and 26th, October 9th and 13th, Nopember 7th and 21th. Earthquake at February 2nd (M 5.3) with distance 190 km was occured after anomaly at January 29th or 5 days before event earthquake at February 26th (M 5.4) with distance 210 km occured after anomaly at February 23th or 3 days before events. Then earthquake at April 8th and 16th were occured after anomaly at March 14th, or 21 days before events. Earthquake at July 21th occured after anomaly at June. After that, also occured significant unstable anomaly at August until early October, that was anomaly before earthquake at October 24th. Then the last anomaly was occured at Nopember 7th, 6 days before earthquake at November 13th.

Significant increase of polarization value that the probably caused by earthquake epicenter was shallow and near with observation station, so thus causing a very large effect. From plotting magnitud and ratio at graph, known that some distance occurs between anomaly on earthquake event were different. So, couldn't determine certainty long gains and interval time anomaly to earthquake event. The increase of polarization value to earthquake event occurred in ground, thus causing greater effect [10].

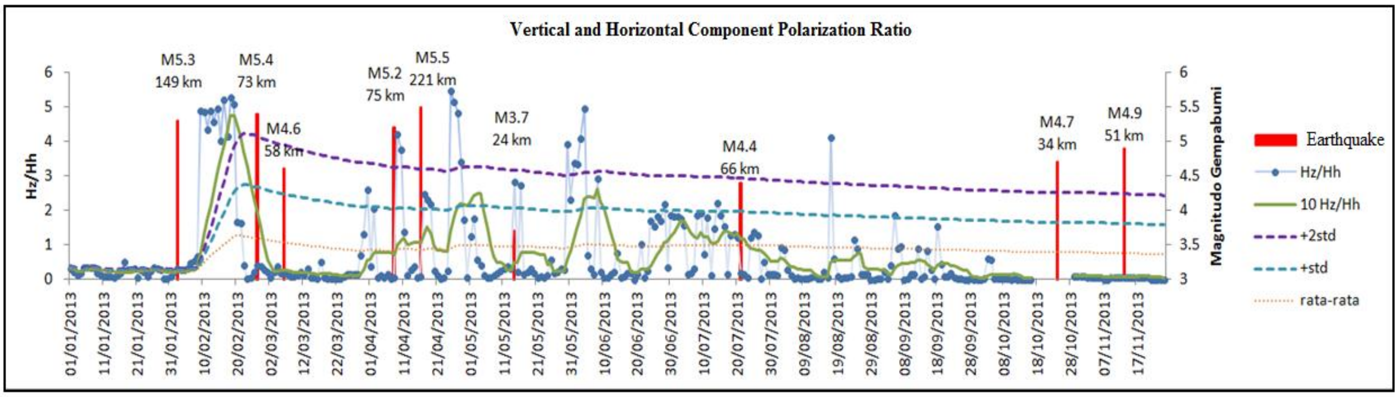

Fig. 4. **Results of electromagnetic data processing about ratio of vertical and horizontal polarization components**

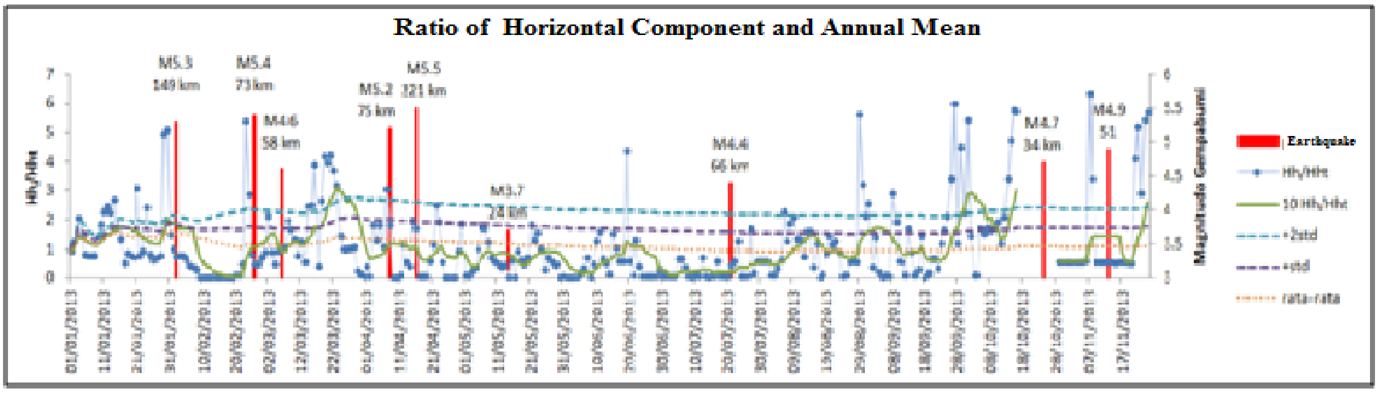

Fig. 5. **Results of electromagnetic data processing about ratio of horizontal component and annual mean**

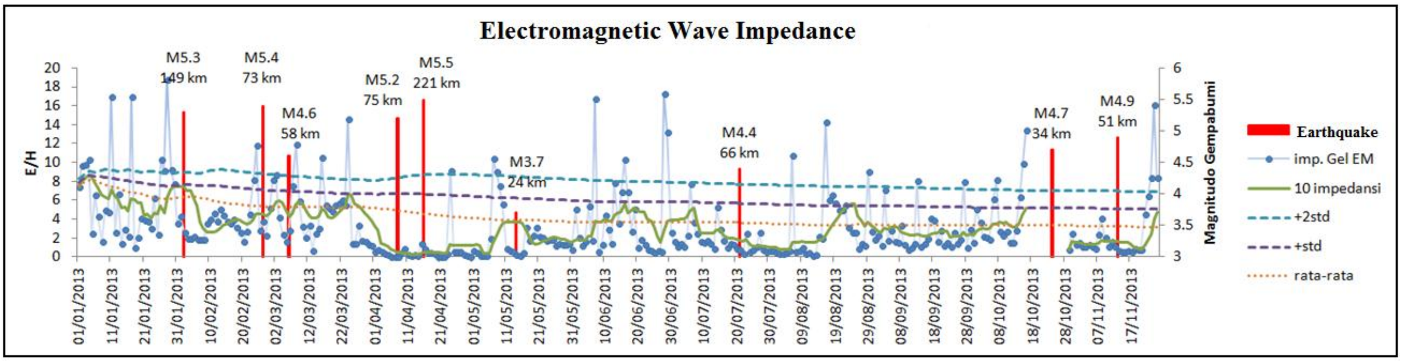

Fig. 6. **Results of electromagnetic data processing about electromagnetic wave impedance**

B. Analyze of Electromagnetic Wave Impedance

Figure 6 shows graph of electromagnetic waves impedance variation at January to November 2013. Impedance values obtained from comparative calculation of magnetic field divided magnetic field that perpendicular to the direction (E_X/H_Y). Has been discussed above that impedance or ratio between electric field (E) and magnetic (H) depend on resistivity of medium or rock. So, impedance as function of period provide information about resistivity of medium as depth function [9].

Previus results studies [8] show that anomaly of resistivity thought to be earthquake precursors was the value decrease. Existence of some decrease in impedance values was show in graph at Figure 6. Then the earthquake occurrence data also plotted at same graph as a case study at that time, so relationship between the impedance anomaly with earthquake events can be known directly. Some anomalies of impedance that occured at interval January – November was shown in figure 6. Anomaly of electromagnetic wave impedance parameters during January to November 2013 took place on February 2, February 23 - 24, March 1 - 2, May 7, June 13 and 28, August 17, October 14-15, and November 22-23. There are some events that happened after impedance anomaly, with different variational distance between anomaly to earthquake. But there are anomalies that occur without followed by earthquakes [8].

Earthquake at February 2 (M 5.3) with a distance of 149 km coincided with anomalies on February 2. Further anomalies at February 23 - 24 followed by earthquake at February 26, or 2 days later. Four days after anomaly on March 1 – 2, occured earthquake with magnitude 4.6 at 58 km length from magnetic station. Earthquake on April 8 and 16, there was no sign of electromagnetic impedance anomaly. Furthermore, earthquake at 14 May (M 3.7) with distance of 24 km occurred after the anomaly on the of May 7th. Anomaly on June 13 and 28 followed by earthquake on 21 July (M 4.4) at distance of 66 km. Anomaly on August 17 was not followed by earthquake events. But further anomalies on October 14 - 15 followed by earthquake on October 24 October (M 4.7) with distance of 34 km. There is an increase again on 22-23 november, but unfollowed by earthquakes, earthquake incident occurred prior to the anomaly, which is on the 13th november.

The results of the analysis of electromagnetic parameters using magnetic data (H_Z/D_D and D_D/H_{HT}) and impedance (E_X/H_Y) obtained precursor anomaly approximately 7-50 days before the earthquake occurred (Table 2), so that these parameters are included in short-term precursors that may be exacerbated elektrokinetis and microcrack process before the buildup of energy regardless as earthquakes. The closer the epicenter of the earthquake led to the emergence of a span of the longer detectable electromagnetic anomalies [9].

Table 2. Time interval about anomalies that as earthquake precursors

Parameters	**Interval anomaly before earthquake (2013)**						
	Febr 2nd	**Febr 26th**	**March 6th**	**April 8th**	**April 16th**	**Oct 24th**	**Nov 13th**
Magnetic							
H_Z/H_H	-	7 days	8 days	7 days	6 days	54 days	-
H_H/H_{HT}	5 days	3 days	-	3 days	20 days	11 days	6 days
Electromagnetic Impedance							
Ex/Hy	1 days	2 days	4 days	-	-	10 days	-

VII. CONCLUSION

Magnetic anomalies were detected 7 - 54 days before earthquake events. Electromagnetic wave impedance anomalies appear 1 - 10 days before earthquake events. Electromagnetic anomalies as earthquake precursors are classified as short-term precursors.

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