

PAPER • OPEN ACCESS

Multi-frequency effect towards High Conductivity Overburden Responses using Vertical Coplanar (VCP) coil configuration for Landslide Instrumentation

To cite this article: Muhammad Syukri Surbakti *et al* 2018 *J. Phys.: Conf. Ser.* **1120** 012069

View the [article online](#) for updates and enhancements.

You may also like

- [Estimation of soil water content using electromagnetic induction sensors under different land uses](#)
Clinton Mensah, Yeukai Katanda, Mano Krishnapillai et al.
- [Modeling Fast Charge Protocols to Prevent Lithium Plating in a Lithium-Ion Battery](#)
Dongcheul Lee, Byungmook Kim and Chee Burm Shin
- [3D Printable Vapochromic Sensing Materials](#)
David M. Stevens, Bonnie L. Gray, Daniel B. Leznoff et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Multi-frequency effect towards High Conductivity Overburden Responses using Vertical Coplanar (VCP) coil configuration for Landslide Instrumentation

Muhammad Syukri Surbakti¹, Bukhari^{1,2}, Nazli Ismail¹, Nasrullah Idris¹, Elin Yusibani¹, Muhammad Isa¹, Saumi Syahreza¹

¹Department of Physics, Faculty of Mathematics and Natural Sciences, University of Syiah Kuala, Banda Aceh, Indonesia, 23111

²Doctorate Program of Mathematics and Applied Science (DMAS), Postgraduate Program, University of Syiah Kuala, Banda Aceh, Indonesia, 23111

Abstract. A novel instrumentation for landslide application has been made and calibrated using Vertical Coplanar (VCP) coil orientation. The early instrumentation and commonly used right now for landslide slopes was gradually equipped with standard and automatic instrumentation: three the piezometric cells, two deep-seated steel wire extensometers, four inclinometric tubes, a rainfall gauge, a snow gauge and an air thermometer. This novel instrumentation works in electromagnetic methods similar with electromagnetic methods in geophysics; otherwise, the system was mechanics and electronics. VCP coil orientation is a coplanar array where both coils are vertical. In VCP, the depth of sounding is about 1.5 times of the coils separation. The overburden thicknesses in the field exploration are often covering the tropical area and presented as weathering layer. The more of overburden thickness then the more of energy of electromagnetic wave will be absorbed, as the result that the electromagnetic wave becomes smaller. The electromagnetic wave that reaches the target of the subsurface is also become smaller in amplitude. The multi-frequency application would be helpful in the data interpretation of the anomaly position and the conductive overburden caused by the domination trends between out-of-phase (OP) and in-phase (IP) components could be determined. In the higher frequencies (3037.5 Hz and 1012.5 Hz), the curve of IP is raised up, with the result that the positive peak values become higher and the negative peak values become lower in levels. The multi-frequency application gives the results that in the higher frequency examinations, the anomaly response is influenced significantly by the conductive overburden. In the lower frequency measurements, the anomaly response is not influenced significantly by overburden response. In the higher frequency measurements, when the electromagnetic wave is passing through the conductive material, the amplitude attenuation and the phase shifting are occurred. Therefore, the OP response becomes inverted in the peaks.

Keywords: landslides, anomaly, overburden, VCP, multi-frequency.

1. Introduction

One method that exists in geophysics is a method that uses an electromagnetic induction system. The advantage of this method is the operation of measuring instruments that are relatively simple and practical [1]. The advantage of the electromagnetic system if applied to the application of landslide is the penetrating power that is shallow in depth, which is in the order of hundreds of meters in the



subsurface, so that it can be regulated not so affected by the material contained below the earth's surface. The advantage of the Vertical Coplanar loop configuration (VCP) compared to the Coplanar Horizontal Coplanar (HCP) method is the shallower penetrating power, which is almost half. The HCP method is also one configuration that results in maximum coupling [2]. These advantages make the VCP method selected as a configuration option in this examination.

The electromagnetic induction system has two coils as transmitter and receiver. If there is a change in distance, change in height, and change in angle between the coils of transmitter and receiver, the receiver will receive a change in response. Change in response can be used as information on movement or small shifts of land which subsequently collected data can be translated into information if landslides occur. This electromagnetic method has a weakness, where the material contained below the earth's surface will also affect the signal received by the receiver. The transmitter will emit a signal called the primary electromagnetic field and if there are conductive objects in the vicinity including below the surface of the earth there will triggered the eddy current on the conductive objects. The eddy current will produced a secondary electromagnetic field. The secondary electromagnetic field will be received by the receiver along with the primary field which reaches the receiver directly. Fortunately, these primary and secondary electromagnetic fields can be separated so that the signal used is only the primary electromagnetic field while the secondary electromagnetic field is removed. However, the primary electromagnetic field in its propagation to the receiver will pass through conductive materials so that this is also undesirable. To overcome this, a pair of frequencies was used.

In this study a pair of frequencies is used, which are referred to as source – reference frequencies (The transmitter will transmit the frequency pair (FP) signals i.e. 112.5 Hz. and 337.5 Hz.; 112.5 Hz. and 1012.5 Hz.; 112.5 Hz. and 3037.5 Hz.; 337.5 Hz. and 1012.5 Hz.; 337.5 Hz. and 3037 Hz., named FP 1, FP 2, FP 2, FP 3, FP 4, and FP 5, respectively). The configuration of the coils from this study is as shown in Figure 1. The effects of the frequencies used as well as the influence of the material on the surface and below the earth's surface, namely overburden and anomalies can be obtained. These data can be used in the design of landslide instruments.

This tool is based on the tools used by GNES instruments that have been used by various applications, some of which are for testing cube anomalies and overburden [3], and metal defect applications [4].

2. Methodology

The VCP method is one of the coil configuration that commonly used in Slingram method. This method uses a transmitter and receiver coil arrangement that is placed vertically at a fixed and plot distance (Figure 2).

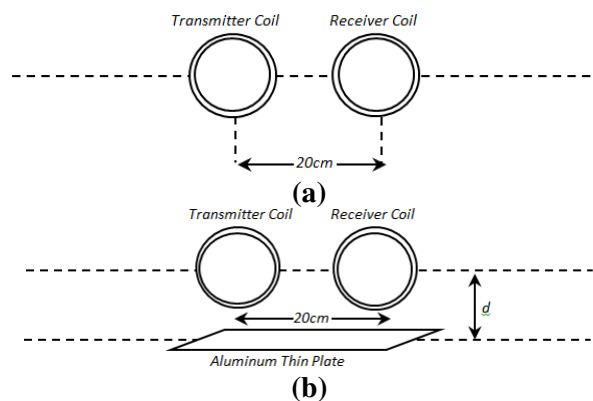


Figure 2. Equipment examination scheme: (a) Without overburden, (b) With overburden.

2.1 The equipment system components for measurement system

The GNES as a basic system for this landslide instrument have three of the components above plus computer controlled system and automatic data acquisition. The GNES is useful for real-time data acquisition with saving data automatically to the computer. The sensors in GNES system are two coils from the transmitter to transmit the primary field and the receiver to receive the secondary and the primary field simultaneously. The signal conditioning the band-pass filter, the notch filter, the precision of mathematical operation circuit, and the absolute value function. There are several outputs in the GNES system i.e. two of analog displays, two of digital displays, and the motor stepper system [3].

Table of The equipment system for measurement.

The Equipment	Total
GNES Equipment	1 unit
Aluminium sheet Type T, (63cmx100cm), thickness = 0.75mm	1 unit
Aluminium sheet Type U, (25cmx10cm), thickness = 0.75mm	1 unit
Aluminium sheet Type V, (40cmx25cm), thickness = 0.75mm	1 unit
Aluminium sheet Type W, (50cmx20cm), thickness = 0.75mm	1 unit

2.2 Physical modeling

The scale factor n is important for interpreting the field data using the physical model data with $n=100$ [5]. In this physical modeling and also in numerical modeling[6], the anomaly target and the overburden were the Aluminum plates. It is assumed that the environment was nonconductive. In the free-air condition which has zero conductivity is become representative for this environment. In the zero conductivity, the secondary field from the medium is not presence. In this condition, there are no phase differences between transmitted electromagnetic fields and that was received by receiver.

3. Results

3.1 Anomaly response

The types of thin plate response are the value of the negative peak between two of the positive peaks. Figure 1 shows the thin plate response without overburden. Otherwise in Figure 2 shows the thin plate response with conductive overburden.

The study conducted by using *half-covering coil* overburden i.e. by covering half of the coils. The dimensions of the overburdens are 50cmx20cm and Aluminum thin plate anomaly of 100cmx63cm. Figure 1 show that the anomaly position could be determined by the indication of the maximum of negative response. The coils distant from the graphic are 20cm (black circles on Figure 1). The graphic nearly symmetry towards Y-axis, therefore, the anomaly has a dip angle of 90° . Figure 1 shows that the positive peak and the negative peaks are symmetry towards the vertical axis. In the standing thin plate measurement, the mutual inductance results for the left and right sides of the plate are the same, as the results that it also has the same of IP and OP responses. In the case of the plate model with overburden, the response is placed on the point where the out-of-phase (OP) inverting is occurred i.e. the component which have $\pi/2$ of phase different with the primary field.

The conductive overburden response will be influenced by the target response; therefore, the response graphic also has change compared with the response graphic of without the conductive overburden. The overburden effects also change the 0% response that should be 20cm (the coils distant) veered to 40cm (the red circles on Figure 4.74).

The multi-frequency measurement gave the determination of anomaly position more accurate with the choices of the contrasts anomaly. Generally, the more of the frequency differences between the source and the reference frequency was the more anomaly contrast present. In the condition that the

overburden is presence besides the low of the reference and the source frequency difference was made the difficulties in interpretation.

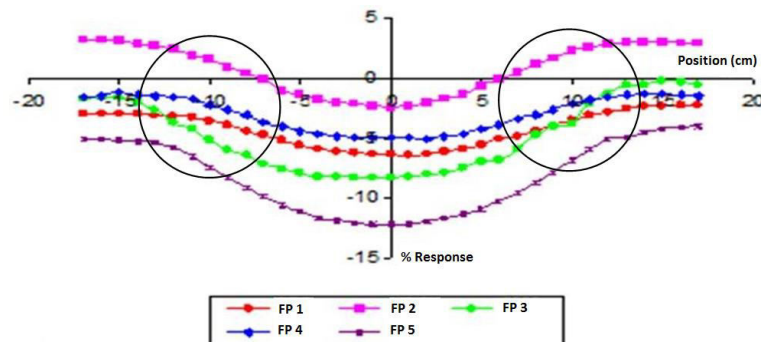


Figure 1. Response of the thin plate without overburden.

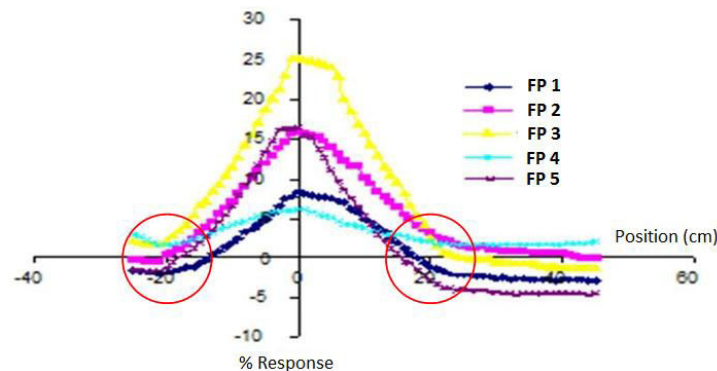


Figure 2. Response figure of the thin plate Type W with conductive overburden

The OP response inverting happens when the high frequency of electromagnetic wave passing through the conductive material because the amplitude attenuation and phase shifting then the OP component has an inverting shape of response. As a result, the total field by the used of the high frequency was smaller than the total field caused by the low frequency application.

The comparative study towards Lowrie and West research found that the response of the thin plate without conductive overburden has the same pattern for the difference of frequency. The differences in response values are caused by the differences of the measurement parameter. The thin plate was used but the Lowrie and West target is a half-plane target. The half-plane characteristic if the minimum of the length in the strike direction of the target is $4x$ and the minimum length in the dip direction is $2x$ (when x is the interval of the transmitter and the receiver coils) [7].

The response parameter of the thin plate depends on several quantities such as the frequency, the transmitter and the receiver interval and the thickness of the plate. Lowrie and West [8] was not using the same conductivity of the overburden as we were used. We could have the similar response by the variation of the thickness of the overburden. The more of a thickness of the overburden then the more energy of electromagnetic wave will be absorbed. As the result, that the amplitude of the electromagnetic wave become smaller. The electromagnetic waves that reach the target of below of the surface also become smaller in amplitude. If the primary field amplitude is small then the secondary field amplitude of the target also becomes smaller. The total response of the conductive overburden and the anomaly target will be dominated by the overburden response. Therefore, the thin plate anomaly will be covered by the overburden.

In the next examination, the thin plate of Aluminum with all of the transmitter and the receiver coils are covered by the overburden will used. The overburden and the thin plate anomaly dimensions are 40 cm x 25 cm and 100 cm x 63 cm respectively. The reference frequencies of 112.5 Hz and 337.5 Hz were paired with 337.5 Hz, 1012.5 Hz and 3037.5 Hz named source frequencies.

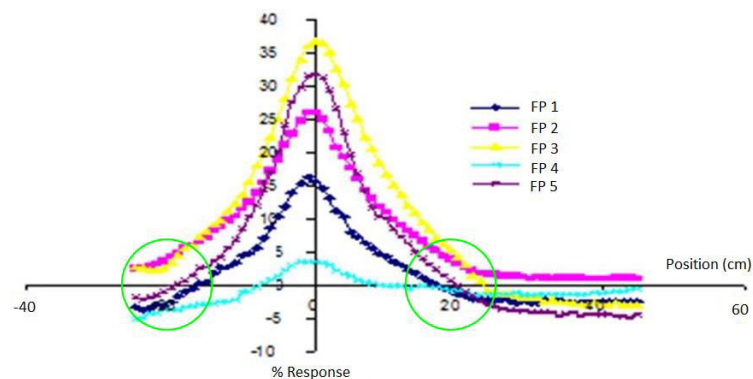


Figure 3. Response figure of Aluminum thin plate Type V with conductive overburden.

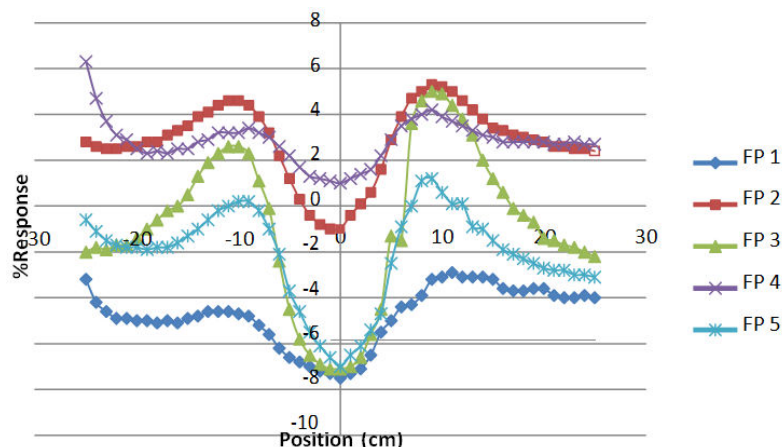


Figure 4. Response figure of Aluminum thin plate Type T with overburden thickness Type U.

Figure 3 show that the anomaly is placed on the maximum amplitude of the OP component caused by conductive overburden when all-cover coil measurements. The overburden effect is changing the 0% response; therefore, the coils intervals which must be 20cm in length veer become 40cm (the green circle on Figure 3). The multi-frequency application will be useful in the interpretation of the anomaly position and the conductive overburden because the inverting of OP component is also tend to become bigger when the frequency differences of the reference and the source become bigger. The contrasts of anomaly from the lowest to the highest were FP 1, FP 2, FP 3, FP 4, and FP 5.

In the last examination, the thin plate of Aluminum with the transmitter and the receiver coils are not covered by the overburden at all. In this measurement was used the uncovering coil overburden i.e. by laying of the conductive overburden which not covering the transmitter and the receiver coils at all. The dimensions of the overburden and the anomaly are 10cmx25cm and 100cmx63cm, respectively.

As in Figure 4, the series of the anomaly contrasts in Figure 4.76 are FP 4, FP 1, FP 2, FP 5 and FP 3. The series shows that the anomaly contrasts are higher when the difference of the reference and the

source frequency are bigger. The anomaly position is the mid position of the transmitter and the receiver coils which informed by the maximum of negative response indication.

Multi-frequency application will more help in the anomaly and the conductive overburden predictions because the veer of the OP and IP components could be predicted and the total responses could be averaged.

4. Conclusion

Multi-frequency application will more help in the anomaly and the conductive overburden predictions because the veer of the OP and IP components could be predicted and the total responses could be averaged and could be filtered for this landslide instrumentation. The series of the anomaly contrast in Figure 1 and 3 are FP 4, FP 1, FP 2, FP 5 and FP 3. The contrasts of anomalies from the lowest to the highest in Figure 2 are FP 1, FP 2, FP 3, FP 4, and FP 5. The series shows that the anomaly contrasts are bigger when the difference of the reference and the source frequency are bigger. The anomaly position is the mid position of the transmitter and the receiver coils which informed by the maximum of negative response indication. If there is a change in distance, change in height, and changes in angle between the transmitter and receiver, the receiver will receive a change in response. Changes in response can be used as information on movement or small shifts of land which subsequently collected data can be translated into information if landslides occur.

5. References

- [1] Grant F S and West G F 1965 Interpretation theory in applied geophysics
- [2] McNeill J 1980 Electromagnetic terrain conductivity measurement at low induction numbers
- [3] Surbakti M S, Jafri M Z M, San L H and Tahrin N M 2011 Overburden Effect Examination Of Cubical Anomaly Using Geometry Normalized Electromagnetic System (GNES) Equipment. In: *Proceedings of International Conference on Environment Science and Engineering (ICESE 2011)*,
- [4] Zakaria Z, Surbakti M S, Syahreza S, Jafri M Z M and Tan K C 2017 Development of Geometry Normalized Electromagnetic System (GNES) instrument for metal defect detection. In: *High-Performance Computing in Geoscience and Remote Sensing VII: International Society for Optics and Photonics*) p 104300J
- [5] Surbakti M S and Waluyo S 2004 Pembuatan, pengkalibrasian dan pengujian model fisis alat sistem elektromagnetik ternormalisasi geometrik= Development, calibration and physical modeling examination of a geometry *Sains dan Sibernatika* **17**
- [6] Farquharson C G, Duckworth K and Oldenburg D W 2006 Comparison of integral equation and physical scale modeling of the electromagnetic responses of models with large conductivity contrasts *Geophysics* **71** G169-G77
- [7] Frischknecht F 1988 Electromagnetic physical scale modeling *Electromagnetic methods in applied geophysics-theory* 365-441
- [8] Lowrie W and West G 1965 The effect of a conducting overburden on electromagnetic prospecting measurements *Geophysics* **30** 624-32