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To cite this article: Bukhari Bukhari *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **273** 012022

Multi-frequency effect towards High Conductivity Overburden Responses using Horizontal Coplanar (HCP) coil configuration for Landslide Hazard Instrumentation

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Abstract. The instrumentation for the sensing of natural disaster phenomena as like as landslide instrumentation has acquired great importance for the instrumentation community. The novel instrumentation for landslide application has been made and calibrated using Horizontal Coplanar (HCP) coil orientation. The early instrumentation for landslide slopes was gradually equipped with standard and automatic instrumentation consisting of three the piezometric cells, two deep-seated steel wire extensometers, four in clinometric tubes, a rainfall gauge, a snow gauge and an air thermometer. This novel instrumentation works in electromagnetic methods similar with electromagnetic methods in geophysics. HCP coil orientation is a coplanar array where both coils are horizontal. In HCP, the depth of sounding is about 1.5 times of the coils separation which have maximum coupled configuration (HCP, VCP, and Vertical Coaxial configuration). The overburden response had inverted the percent value of maximum negative response then there were three maximum response amplitude peaks. Measurement and data processing were performed using a computer through Delphi program. The diagonal cross sections of the overburden as the centre were the maximum value of inverted response of anomaly positions. In aluminium thin plate overburden, the diagonal cross section point as the overburden centre was the maximum value of inverting value of the highest minimum response amplitude. The measurement graphic in the computer screen with several types of overburdens would be displayed. As the result, that the overburden widths for overburden were determined by subtracted of two turning points positions. The overburden positions were accurate for Type P overburden. The master curve had a high anomaly contrasts with two of positive anomaly peaks. Otherwise, the anomaly positions were between two of the negative anomaly peaks.

1. Introduction

One method that exists in geophysical instrumentation is a method that uses an electromagnetic induction system. The advantage of this method is the operation of measuring instruments that is relatively simple and practical [1]. The advantage 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. The shallow penetrating power can be regulated not too affected by the material contained below the earth's surface. The Horizontal Coplanar loop configuration (HCP) is relatively lower in noise compared to the Vertical Coplanar (VCP) method. It caused by the atmospheric noises are usually in vertical polarization. The HCP method is also one configuration that results in maximum coupling (McNeill, 1980). The VCP method was 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 changes in angle between the coils of transmitter and receiver, the receiver receives a change in response [1]. An examination for VCP configuration also has been conducted which had a lower level in the depth penetration and more noise contribution [2]. Changes in response can be used as information on movement or small shifts of land if landslides occur. This electromagnetic method has a weakness, where the material contained below the earth's surface also affect the response. The transmitter emits a signal called the primary electromagnetic field and if there are conductive objects in the subsurface there are eddy currents on the conductive objects. The eddy currents then trigger a secondary electromagnetic field. The secondary electromagnetic field simultaneously with the primary field reach 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 passess through conductive materials so that this is also undesirable. To overcome this, a pair of frequencies is used.

In this study, several pairs of frequencies is used, which are referred to the three source frequencies (S) and the two of reference frequencies (R). The frequency pairs are 112.5 Hz.(R) & 337.5 Hz. (S), 112.5 Hz. (R) & 1012.5 Hz. (S), 112.5 Hz. (R) & 3037.5 Hz. (S), 337.5 Hz. (R) & 1012.5 Hz. (S), and 337.5 Hz. (R) & 3037.5 Hz. (S). 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 early warning system 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[1], and metal defect applications [3].

2. Methodology

The HCP method is a variation of the most commonly used Slingram method [4]. This method uses a transmitter and receiver coil arrangement that is placed horizontally at a fixed (co-axial) (dashed line on Figure 1.a) and a plot distance with overburden level and co-axial (dashed line in Figure 1.b).

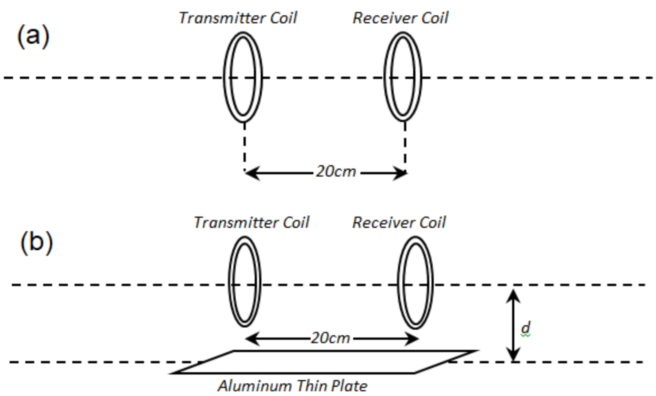

Figure 1. Equipment examination scheme: (a) Without overburden, (b) With overburden.

2.1 The equipment system components for measurement system

The GNES has three components above plus computer-controlled system and automatic data acquisition. The GNES is useful for real time data acquisition that saves the 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 circuits are the band-pass filter, the notch filter, the precision of mathematical operation, 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 [1].

Table 1. The equipment system for measurement.

The Equipment	Total
GNES Equipment	1 unit
Aluminium sheet Type P (20cm x 20cm), thickness = 0.75mm	1 unit
Aluminium sheet Type Q (36cm x 36cm), thickness = 0.75mm	1 unit
Aluminium sheet Type X, (36cmx6cm), thickness = 0.75mm	1 unit
Aluminium sheet Type Z, (120cmx36cm), 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. In this physical modelling (*n*=100), the anomaly target and the overburden were a cubical Aluminum and an Aluminum plates respectively. It is assumed that the environment was non-conductive. In the free-air condition which has zero conductivity is representative for this environment. In the zero conductivity, the secondary field from the medium is not presence. In this condition, there is no phase difference between transmitted and received electromagnetic fields.

3. Results and Discussion

3.1 Anomaly response

The HCP coil orientation is a coplanar array where both coils are horizontal. In HCP, the depth of sounding is about 1.5 times of the coils separation which have maximum coupled configuration (HCP, VCP, and Vertical Coaxial configuration). An examination of anomaly response by physical model using thin plate of aluminum with 120cmx36cm of dimension (Type Z), 0.075 cm of thick, dip = 0^o, and depth = 2 cm was conducted. The results are described in Figure 2.

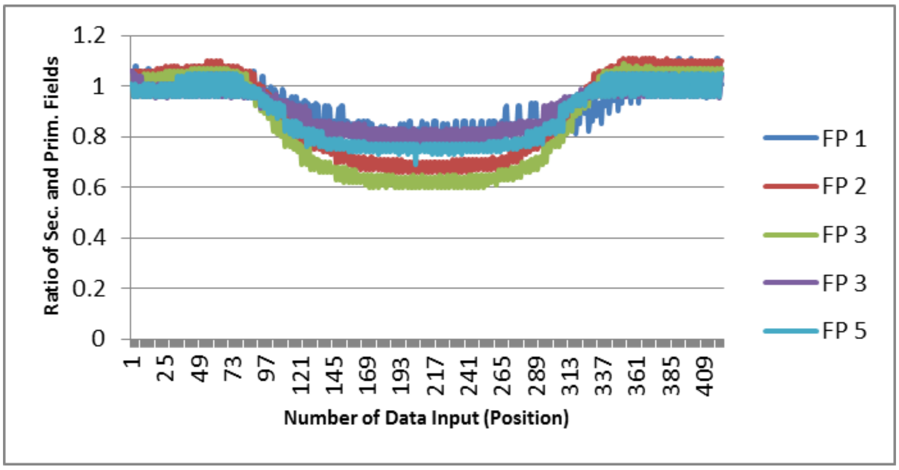

Figure 2. Response of Aluminum thin plate anomaly Type Z.

An online observation through the monitor of computer is can be performed. The secondary and primary fields have the same in quantity when the transmitter or the receiver coils precisely at above the anomaly ($V_S/V_R = 1$). The ratio of secondary and primary field when the anomaly positions placed below the coils is marked by intersections of the graphic with y-axis on y = 1. The anomaly position (AP) is the maximum of secondary field at AP point in the middle of the points of $V_S/V_R = 1$ or a midpoint between the intersections as found Sinha [5].

The anomaly position (AP) of the five pairs of frequency is 70 cm (the number of input data). The transmitter and the receiver coils position when $V_S/V_R = 1$ are 30 cm and 110 cm, respectively. The anomaly contrasts series from the lowest to the highest are in the frequency pairs of FP 1, FP 4, FP 5, FP 2 and FP 3 for the ratio of secondary to primary fields of 0.81833, 0.80583, 0.75417, 0.68667 and 0.6275, respectively

3.2 Overburden response

The overburden response had inverted the percent value of maximum negative response then there were three maximum response amplitude peaks. Measurement and data processing were performed using a computer through Delphi program. The diagonal cross sections of the overburden as the centre were the maximum value of inverted response of anomaly positions.

The diagonal cross section point as the overburden centre was the maximum value of inverting value of the highest minimum response amplitude. The measurement graphic in the computer screen with overburden Type P is displayed in Figure 3. We had the centre position for overburden Type P was 68cm. We had the overburden width for overburden Type P by subtracted two of the turning points positions we found 20 cm. We had the overburden position accurately for Type P. The master curve had a high anomaly contrast. There were two positive anomaly peaks. The anomaly position was between two of negative anomaly peaks (Figure 3).

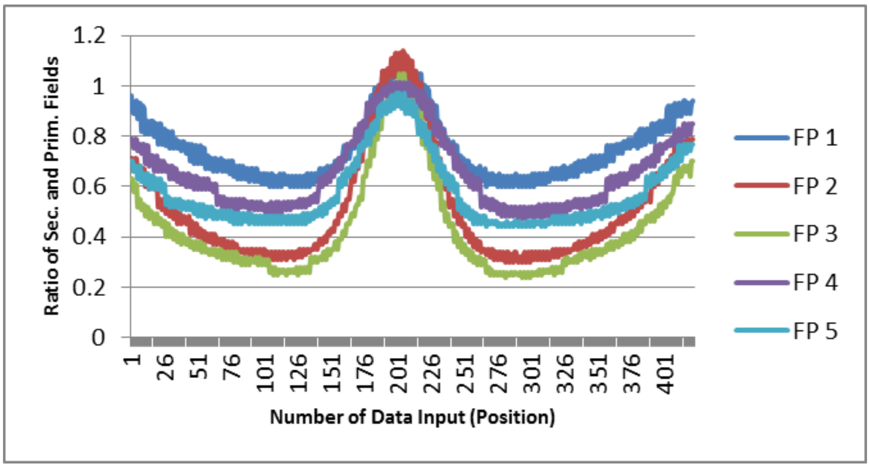

Figure 3. Overburden Type P response by multi-frequency.

The cross sections points of the overburden for five of frequency pairs are 68cm. The ratios of secondary and primary fields on the cross section for Figure 3 start from the higher contrasts to lower contrast are 1.10083 (FP 2), 1.07583 (FP 1), 0.9975 (FP 3), 0.99167 (FP 4) and 0.94583 (FP 5). The turning point of the five frequency pairs are 47 cm and 87 cm. The values of V_S/V_R and diagonal cross section points are given by Table 2.

Table 2. Interpretation of Aluminium thin plate overburden (Figure 3)

Frequency Pairs (FP)	Diagonal Cross Sections Points (cm)	The V_S/V_R Values of The Left Side of Overburden	The Ratio of Secondary to Primary Fields (V_S/V_R) (position)	The V_S/V_R Values of The Right Side of Overburden
FP 1	67	0.653	1.07583	0.66
FP 2	67	0.3767	1.10083	0.37
FP 3	67	0.94	0.9975	0.93
FP 4	67	0.6	0.99167	0.613
FP 5	67	0.5067	0.94583	0.47
Average	67	0.61528	1.07583	0.6086

3.3 Anomaly with overburden

The overburden thickness in the field exploration is often covers the tropical area such as in Malaysia and Indonesia presented as weathering layer. The more of thickness then the more of energy of electromagnetic wave can be absorbed, as the result that the electromagnetic waves become smaller. The electromagnetic wave that reaches the target of below of the surface is also smaller in amplitude. Generally, there are no direct connections between the sizes of the anomaly when the overburdens were present. The response of the overburden is usually dominant.

3.3.1 Aluminium Type X anomaly with Type P overburden

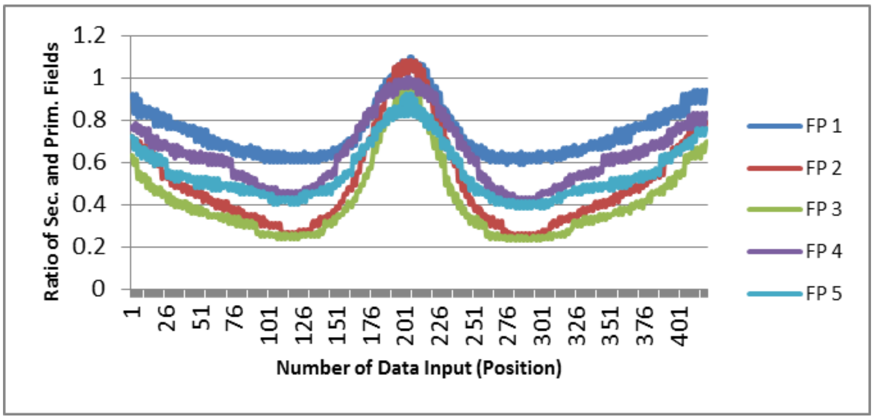

Figure 4. Response of Aluminium Type X with Type P overburden.

The cross sections points of the overburden for five of frequency pairs are 67 cm. The ratios of secondary and primary fields from higher to lower contrasts are 1.0525 (FP 1), 1.04917 (FP 2), 0.97583 (FP 4), 0.925 (FP 3) and 0.87333 (FP 5) as shown in Figure 4. The turning point of the five frequency pairs are 47 cm and 67 cm. The values of V_S/V_R and the diagonal cross section points are given by Table 3.

Table 3. Interpretation of graphic of Figure 4.

Frequency Pairs (FP)	Diagonal Cross Sections Points (cm)	The V_S/V_R Values of The Left Side of Overburden	The Ratio of Secondary to Primary Fields (V_S/V_R) (position)	The V_S/V_R Values of The Right Side of Overburden
FP 1	67	0.5133	1.0525	0.5133
FP 2	67	0.2267	1.04917	0.2467
FP 3	67	0.53	0.925	0.5533
FP 4	67	0.4367	0.97583	0.42
FP 5	67	0.513	0.87333	0.4767
Average	67	0.44394	0.975167	0.442

3.3.2 Aluminium Type Q anomaly with Type P overburden

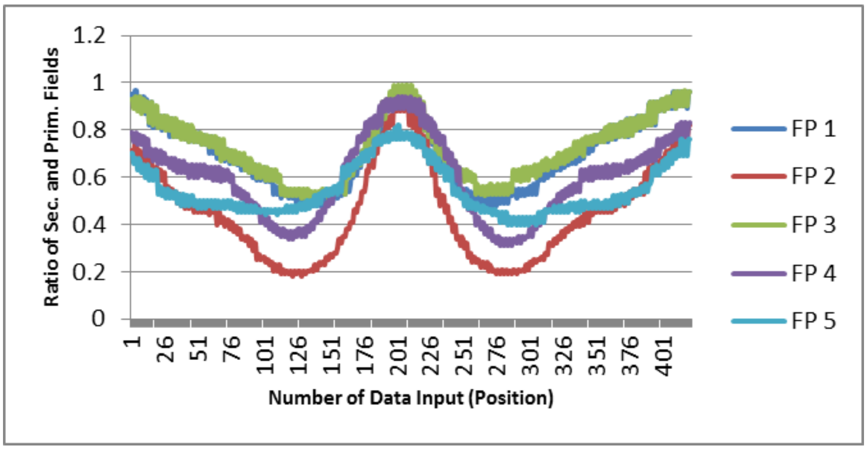

Figure 5. Response of Aluminium Type Q with Type P overburden.

The cross sections points of the overburden for five of frequency pairs are 68 cm (Figure 5). The ratios of secondary and primary fields from higher to lower contrasts are 0.9575 (FP 3), 0.9425 (FP 1), 0.91833 (FP 4), 0.88917 (FP 2) and 0.78583 (FP 5) as shown in Figure 5. The turning point of the five frequency pairs are 47cm and 67cm. The values of V_S/V_R and the diagonal cross section points are given by Table 4.

Table 4. Interpretation of graphic of Figure 4.

Frequency Pairs (FP)	Diagonal Cross Sections Points (cm)	The V_S/V_R Values of The Left Side of Overburden	The Ratio of Secondary to Primary Fields (V_S/V_R) (position)	The V_S/V_R Values of The Right Side of Overburden
FP 1	68	0.5133	0.9425	0.5133
FP 2	68	0.2367	0.88917	0.2333
FP 3	68	0.54	0.9575	0.55
FP 4	68	0.4467	0.91833	0.4
FP 5	68	0.5233	0.78583	0.47
Average	68	0.452	0.898667	0.43332

3.3.3 Aluminium Type Z anomaly with Type P overburden

The cross sections points of the overburden for five of frequency pairs are 68 cm. The ratios of secondary and primary fields on a position points from the higher contrasts to lower contrasts are 0.93167 (FP 1), 0.91667 (FP 4), 0.86583 (FP 2), 0.77333 (FP 5) and 0.711167 (FP 5) as shown in Figure 6.

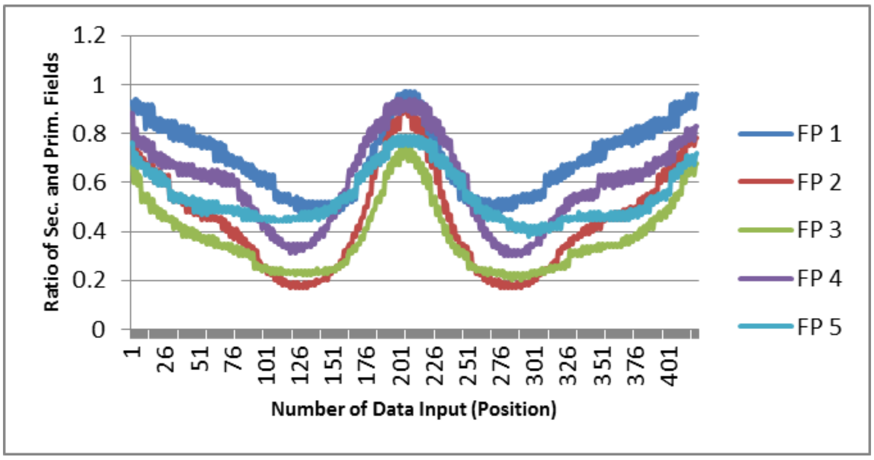

Figure 6. Response of Aluminum Type Z with Type P overburden.

The turning point of the five frequency pairs are 48cm and 88cm. The values of V_S/V_R and the diagonal cross section points are given by Table 5.

Table 5. Interpretation of graphic of Figure 5.

Frequency Pairs (FP)	Diagonal Cross Sections Points	The V_S/V_R Values of The Left Side of Overburden	The Ratio of Secondary to Primary Fields (V_S/V_R) (position)	The V_S/V_R Values of The Right Side of Overburden
FP 1	68	0.5	0.93167	0.51
FP 2	68	0.22	0.86583	0.22
FP 3	68	0.2433	0.71167	0.24
FP 4	68	0.4067	0.91667	0.4
FP 5	68	0.4867	0.77333	0.4833
Average	68	0.37134	0.839833	0.37066

4. Conclusion

Multi-frequency application contribute 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 filtered for this landslide instrumentation. The ratio of secondary and primary field when the anomaly positions placed below the coils is marked by intersections of the graphic with y-axis on y = 1. The anomaly position (AP) is the maximum of secondary field at AP point in the middle of the points of $V_S/V_R = 1$ or a midpoint between the intersections. The diagonal cross sections of the overburden as the centre were the maximum value of inverted response of anomaly positions. The overburden response can inverted the value of maximum negative response then there were three maximum response amplitude peaks. The series shows that the anomaly contrasts are bigger when the different 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 receives a response change. 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

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