Noise Reduction for Transient Electromagnetic with High Cultural Noise: Case Study in Cisarua, Bandung Barat Regency

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Abstract. Transient Electromagnetic data acquisition was conducted in Cisarua, Bandung Barat Regency. Data are acquired using grounded dipole transmitter 500 meter spaced, with 13 A of current injected. TEM period are 40 s with 102 measurement period in total. Magnetic impedance sensor as receiver measured vertical magnetic field, located 400 meter from transmitter center point. The measurement area was located in a residential area and very close to man-made electromagnetic noise sources including power lines, radio and cellular transmitters. Periodic noise recorded along with transient signal was very strong, where the amplitude of 50 Hz noise is higher than the transient signal even at early time. This poses a challenge where a technique that capable of reducing noise and reconstructing the transient data are needed, so the data can further be processed in inversion program to create subsurface model. First technique used was statistical selection which is simple but proven effective in reducing noise in this condition without distorting the data. Data processing then continued by applying digital notch filter. After the transient signal are obtained, smoothness constrained least-square inversion are used to get the subsurface resistivity model, which shows 2 low resistivity zone. The shallower zone was supported by Electrical Resistivity Tomography data, and interpreted as shallow unconfined aquifer. The deeper zone was taught to be old volcanic products saturated with water associated with fault in the eastern area.

Keyword: Transient Electromagnetic, Cultural Noise, Noise Reduction, Electrical Resistivity Tomography

1. Introduction

Transient Electromagnetic (TEM) is a geophysical method that uses electromagnetic waves to detect sub-surface conductivity / resistivity contrast. The method is using direct current from transmitter, which will be turned off abruptly while the receiver records secondary magnetic field (Tesla) that decays over time. In order to provide good results, high quality data that has undergone noise reduction process are required, without adding distortion in the process. The noise contained in the transient electromagnetic data consists of natural and cultural noise (Munkholm and Auken, 1996). Natural noise can originate both from the interaction between the earth's magnetic field and the sun's plasma as well as lightning. Cultural noise generally comes from power line, which is a periodic noise with a frequency of 50-60 Hz. The research area is located in the residential area so the periodic noise level is very high, where the amplitude is higher than the TEM signal strength in the early time (Figure 1). The acquisition parameters used are grounded dipole transmitter 500 meters spaced, 13 A current
injected, 400-meter receiver offset and the period is 40 second. The transmitting system and receiver system are manufactured by the GeoProb Co. Ltd, Japan. The same instrumentation system is also used for baseline survey for CCS in Gundih Area which record high S/N data (Srigutomo et al., 2015) due to higher injected current and larger transmitter length, and also significantly lower cultural noise level.

2. Statistical Stacking
The first stage done in the data process is stacking both transients in each period. In addition to reducing noise, this stage is also useful to eliminate DC leveling effects. Data selection is applied, since the success rate of this technique in reducing noise depends on the phase of the periodic noise in both transient data. When the noise phase is near identical, the noise level will not change much, and the data should be removed from the data set (Figure 2.a). Best data is obtained when the noise is near 180 degree out of phase (Figure 2.b).

Determining accepted and rejected data can be done in several ways. In addition to computing the noise phase of both data, standard deviation or absolute mean of stacking result can be used and is
simpler. We calculated standard deviation and absolute mean to 102 available TEM periods, the values obtained were then sorted and the results are shown in Figure 3.

![Figure 3](image1.png)

**Figure 3.** Statistic that can be used to determine accepted and rejected data: (a) Standard Deviation (b) Absolute Mean

Data with high periodic noise tend to have higher standard deviation and also absolute mean if they oscillate near zero value. Therefore, the selection process can be done by determining cut off threshold (red line in Figure 3). Since only one criterion is needed for the selection process, absolute mean is chosen because it gives equally good results and is more efficient in terms of computation. Only 19 out of 102 data are selected either on the standard deviation or the absolute mean criteria. Determining best cut off value is important to prevent bad data being accepted or making the total selected data being too small. The selected data are then stacked and we can see the results compared to all stacked data in Figure 4.

![Figure 4](image2.png)

**Figure 4.** (a) All Transient data Stacked compared to (b) Statistical Selection Result

3. Digital Notch Filtering

Digital Notch filtering was applied to suppress remaining main periodic noise (50 Hz) after statistical selection process and the noise at other frequencies including 150, 250 and 350 Hz. Applying digital notch filter needs to be done carefully, as it potentially causes distortion to the data. The degree of
attenuation at selected noise frequency depends on the filter bandwidth, therefore it can potentially eliminate data at frequencies around the noise frequency. The result of the digital notch filter process can be seen in Figure 5.a. The result of statistical selection and digital notch filter in suppressing noise compared with stacking result of all data can also be seen in power spectrum density in Figure 5.b.

![Figure 5. (a) TEM data after notch filter applied (b) Power Spectrum Density comparison: stacking all transient data (red), statistical selection result (blue), after digital notch filter (black). Y-axis is in logarithmic scale](image)

### 4. Inversion

Before entering the inversion process, the transient data must be resampled. The transient data after filtering process are still very noisy, thus we decided to visually estimate the transient signal. To provide an overview of the transient signal curves that are still buried in noise, we created synthetic model with parameter adjusted to real data. Forward modelling to create synthetic model is using long grounded wire formulated by Ward and Hohmann (1988). Periodic noise with the amplitude adjusted to remaining periodic noise, which is already 1/100 of the periodic noise in the raw field data is also added in the synthetic model (Figure 6.a). The resampling results of the field data are shown in Figure 6.b. Since the transient signal in field data is not as clear as in synthetic data, two variation of resampled data are made (Resampling A and B) and the differences in the resulting model are then compared.

![Figure 6. (a) Synthetic Transient (Forward Modelling Result) with periodic noise added (b) TEM Resampled Data as data input in inversion program](image)
The subsurface resistivity models are computed using smoothness constrained least-square inversion. The results of both resampled data are shown in Figure 7. In the resampling B, the resistivity value is slightly higher in the deeper area (above 80 meters) and slightly lower in shallower area but still shows similar anomaly.

![Figure 7. Inversion Result (a) TEM Resampling A (b) TEM Resampling B](image)

TEM inversion results are also compared to two Electrical Resistivity Tomography (ERT) inversion result. The first ERT line is located 320-meter north of the TEM station (west-east line orientation) and the second ERT 250-meter west of the TEM station (north-south line orientation). The resistivity value of the two ERT inversion results is averaged over the same depth to obtain 1D data that is easier to compare with the TEM result (Figure 8). ERT 1 in 2D section are published in Laesanpura et al. (2017) as well as geological discussion of the area.

![Figure 8. Inversion Result of TEM data compared to ERT in 1D](image)

5. Conclusion
Although transient signal that are clean of noise is not obtained, the techniques discussed in this paper proved to be able to estimate the TEM data in high periodic noise (very low signal to noise ratio). The TEM inversion results is able to map two low resistivity zone. The first zone is supported by ERT results and interpreted as unconfined shallow aquifer. The second zone shows existence of aquifer at deeper depth taught to be old volcanic products saturated with water associated with fault in the eastern area.
In terms of acquisition parameters used, usage of larger transmitter length and higher transmitter current will produce stronger signal. Discussion regarding the field parameters in synthetic data can be seen in Yogi and Warsa (2017). However, these two factors is limited to the field and equipment, where the transmitter length is limited to field terrain and transmitter cable length, and the current is limited to surface resistance of the electrodes and the power source used. Therefore, adding measurement period is another technique for improving the quality of the data, since the method discussed rely on the number of selected transients. Total measurement periods can be increased in various ways, including the addition of measurement duration per station, the use of more receiver sensor in one station, and use of shorter periods. For example, by reducing the measurement period from 40 s to 8 s we will obtain 5 times the amount of data with the same acquisition period. While longer transient time equal to deeper skin depth, the practical limitation of EM system investigation is also determined by the ambient or inherent noise level (Spies, 1989). Field Acquisition documentation can be seen in Figure 9.

Figure 9. (a) Transmitter Station (b) Receiver Station (c) Three phase generator as transmitter power source

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