ARPN Journal of Engineering and Applied Sciences

EVALUATION OF GEOELECTRICAL NOISE IN URBAN AREA: A CASE STUDY IN HANOI, VIETNAM

Tran Vinh Thang, Do Trung Kien and Nguyen Duc Vinh
Faculty of Physics, VNU-University of Science, Hanoi, Nguyen Trai, Hanoi, Vietnam
E-Mail: thang7685@gmail.com

ABSTRACT

Geoelectrical survey usually is performed in the field scale at low frequencies in order to reduce electromagnetic coupling effects. However, electric noise often obscures interesting signals due to the inherently weak received signals even it is in the range of these low frequencies. Especially in urban area, where the culture or human generated noises are major causes that makes the signal to be deeply buried in noise. Evaluation of electric and electromagnetic noise in Earth surface is necessary task to choose a suitable frequency for acquiring the high quality geophysical data. This paper presents the equipment and method for evaluating geoelectrical noise in campus of Hanoi University of Science, which located in central of Hanoi, Vietnam. By using the conventional electrodes as used in geoelectrical surveys, an ultra-high resolution digitizer and time-frequency analysis by Sigview software, the voltage noise can be detected at amplitude as low as -150dB of ±2.5V full scale. The background geoelectrical noise measured in HUS's campus is about -100dBfs, some interference frequency also to be evaluated.

Keywords: geoelectrical surveys, noise measurement, analog to digital converter, low frequency noise, Fast Fourier transform.

1. INTRODUCTION

Electrical methods in field usually referred to as geoelectrical method that is one of the oldest and most commonly used geophysical exploration methods, certainly for environmental and engineering investigations [Binley, 2015]. Geoelectrical measurements basically consist in injecting a direct current between two current electrodes and recording the responded voltage deference between two other electrodes and working in extremely low frequency range from mHz up to 30 Hz. It base on standard electrode patterns such as the Wenner, Schlumberger, dipole-dipole, or pole-pole configurations [Loke *et al*., 2013].

However, in the field experiments, measuring of electric signals are often noise adding, because there are many noise sources in the ground that are of similar magnitude and/or frequency as responded potential and the chargeability effect in IP measurement [Dahlin and Leroux, 2013; Milsom and Eriksen, 2011], even at extremely low frequency near DC as high natural noise presented in the long-term or 4D geoelectrical resistivity monitoring surveys [Rain *et al*., 2004, Super, 2011].

Due to technological growth man-made electromagnetic noise is nowadays superimposed on natural noise almost everywhere on Earth. Especially in urban areas, where the distortion of geoelectrical data are mainly caused by several human generated noise sources such as power lines, traffic vehicles, telecommunication systems [Bianchi and Meloni, 2007; Szarka, 1988]. Rapidly expanding cities space requires more geological structure investigations before infrastructure constructions work. So, geoelectrical method is still a good choice for this work because of its cost effective, but noise is always a challenge.

In the field measurements, especially as large-scale geophysics with the extreme low responded signal, if the amplitude of noise components is too large, the interesting signal may not be detected, because of preamplifier reached saturation state and/or signal to be buried in noise. Therefore, automatic evaluating background electric noise before taking measurements is very important and necessary task to obtain a high quality data.

Normally, noise measurement instrument is performed by directly connecting device under test (DUT) to a digital spectrum analyzer [LaFontaine, 2011]. Average of measured signal before analyzing is a simple effective technique for reducing statistical noise and increasing the signal to noise ratio - SNR. This method is usually used in measurement system. In the case of low level noise, it employs preamplifier to boost the small voltage levels before to be analyzed by the analyzer. However, the internal noise of amplifier is added to the analyzed signal.

Geoelectrical noise measurements in Earth surface have been carried out for geophysical and other applications both at low frequency [Neuenschwander, 1942] and in kilo-Hertz frequency range to use in through-the Earth communications [Munoz *et al*., 2011; Santarelli *et al*., 2014]. It measures the voltage difference between two grounded electrodes that combine with the surface to play the role as the DUT. Metal stakes are commonly used as the electrodes similar in geoelectrical surveys. Non-polarized electrodes may be used as in IP surveys to reduce electrode polarization effects if necessary.

This paper presents a method and instrument for measuring and evaluating the geoelectrical noise of Earth surface in the campus Hanoi University of Science located in the near the central of Hanoi, Vietnam, where is a big urban area with many culture noise sources. The heart of instrument is a 31bit analog to digital converter (ADC). By using this converter with ultra-high resolution, pre-amplifier becomes unnecessary as the A/D's they can discern much smaller changes in input voltage. This design yields more stability and greater accuracy in measuring the weak signals, which are not detectible with conventional 16-bit or 24-bit ADC.

2. MATERIALS AND METHODS

2.1 Measurement system

The measurement system is employed by using 31 bits analog to digital converter ADS1282 evaluation module combined with digital signal processing (DSP) board [Texas Instruments Inc.] as shown in Figure-1. A high precision voltage source REF5050 with temperature coefficient of 5ppm/C is used for ADC reference. Very low equivalent noise input of 1.3nV/√Hz further ensures maximum signal-to-noise ratio and dynamic range. Built-in preamplifier circuit of evaluation module with the gain equals to one has been modified for obtaining the best performance when working in field experiments. Eight 13 volt SA13C bi-directional TVS diodes are parallel connected with the inputs to protect the electronic board by overvoltage and transient signals. External input resistor R1 is cut out for getting a high impedance differential input of about 30 MΩ. Block diagram of the system is shown in Figure-2.

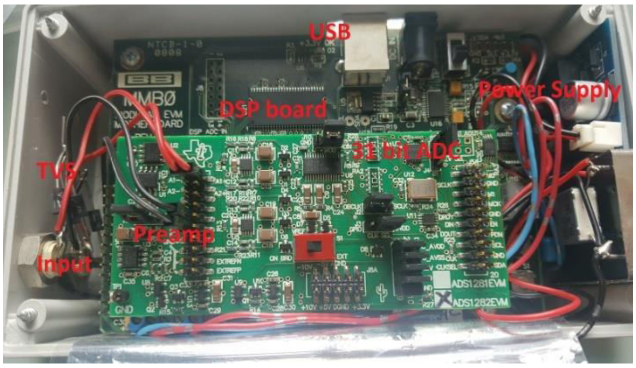

Figure-1. Ultra high resolution 31 bits data acquisition board.

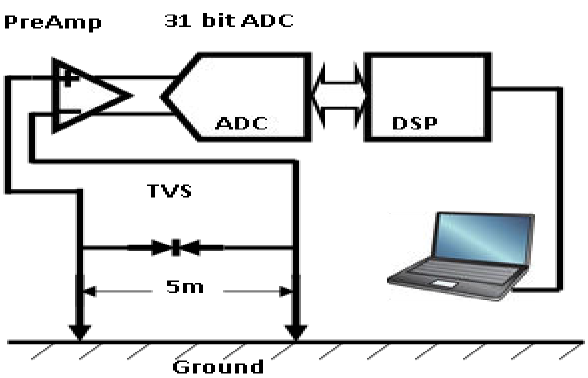

Figure-2. Block diagram of the data acquisition system.

The ADCPro software [Texas Instruments Inc.] controls all parts of module including: gain of preamplifier, sampling rate, USB connection, acquiring and storing data to the memory. Once all the measurement points have been collected, data are transferred to the laptop computer via USB interface and to be saved in a data file. Sample rate is chosen by software at 250 samples to second (sps) for the best resolution and temporal capture interval is 1200 seconds enough to evaluate slowly change of signals down to 1 mHz. The full scale of ADC is ± 2.5 V enough for picking up a widely input range of signal. With this, the resolution of this 31 bits ADC is approximate 2.33 nV/ bit without amplification.

Data stored in file presents the voltage noise in time series, which are transformed to frequency domain using Fast Fourier Transform (FFT) algorithm with the same window function by Sigview software to estimate the magnitude of noise in a specific frequency band [Sigview.com]. To evaluate the noise by time, the measured data are presented by time - frequency domain.

2.2 Field experiment arrangement

Noise measurements have been captured in HUS's campus located in central of Hanoi (Figure-3). In the measurements, two copper bars were used for the electrodes. Although the low noise amplifier presents high input impedance of 30 MΩ, so the impedance of the electrode contacts can be neglected. The span between the electrodes is fixed to 5 meters similar to configuration that used in geoelectrical methods. The connection wires are coaxial copper cable to reduce electromagnetic noise that be induced in the transmission lines.

Figure-3. Field measurement arrangement at HUS' campus.

The system is warmed up before acquiring data. After one hour, the measurement is performed with the inputs to be shorted circuit to evaluate the background noise of ADC. Then acquires the data with the circuit shorted at the electrodes to evaluate the electric and EM noise, which induced in the electric cable. Finally, voltage difference between two electrodes is recorded continuously in approximate 17 hours over night, when the most of human activities is idle. During each period of approximate 20 minutes, the voltage noises of the ADC, cable and Earth surface are collected with a same sample rate and data length then stored to an independent file, this takes a few seconds, which does not affects to time series data.

VOL. 14, NO. 9, MAY 2019 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

3. RESULTS AND DISSCUSSIONS

Figure-4 shows the background noise of this system presented in histogram distribution of approximate 600000 samples. Only the Gaussian noise is here, its mean value can be considered as DC offset or systematic error, which is about 2.7μV and to be subtracted by software before performing FFT analysis. The root mean square - RMS of 0.6μV is small enough to make this system is suitable for ultra-low level signal measurement purposes.

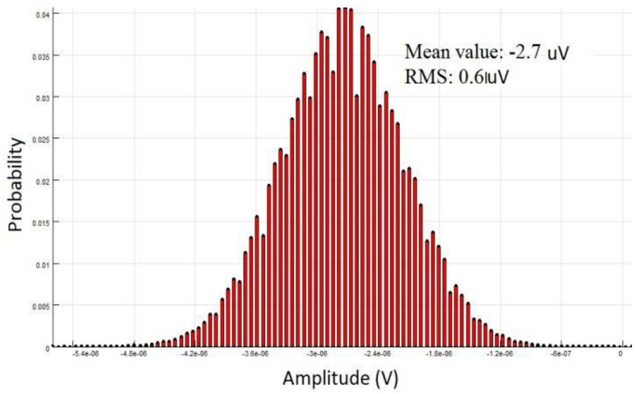

Figure-4. Histogram distribution of background noise.

Figure-5 shows the comparison of ADC's noise floor, coaxial cable and a typical geoelectrical noise measured in HUS's campus presenting in frequency domain with the same length of 300k samples. From this spectrum, the background noise floor of ADC is around -150dB of ± 2.5 V full scale (FS), while the earth ground noise have a 50 dB higher and about -100 dBFS.

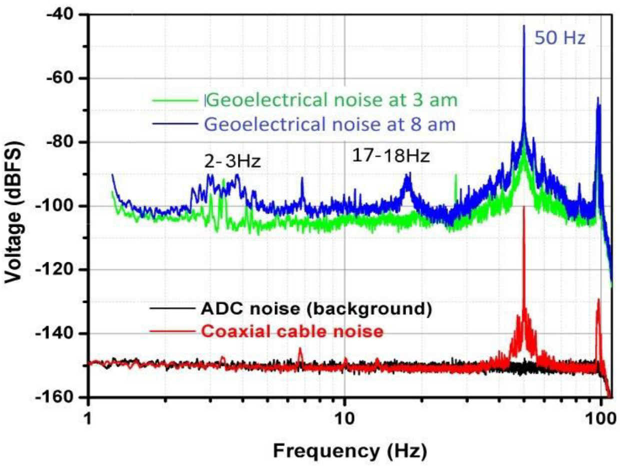

Figure 5. Comparison of ADC noise, cable noise and typical geoelectrical noise of Earth surface at low frequency range.

Due to the measurement is performed in urban area, so the power lines noise have a strong magnitude, which illustrates by a peak locate at around the frequency of 50Hz in all spectrums, except in the ADC noise spectrum, because of its small amplitude.

Time domain expression of geoelectrical noise measured during approximate 17 hours overnight is shown in Figure-6. The peak to peak noise in the time from 8 pm to 6 am of next day is lower than others.

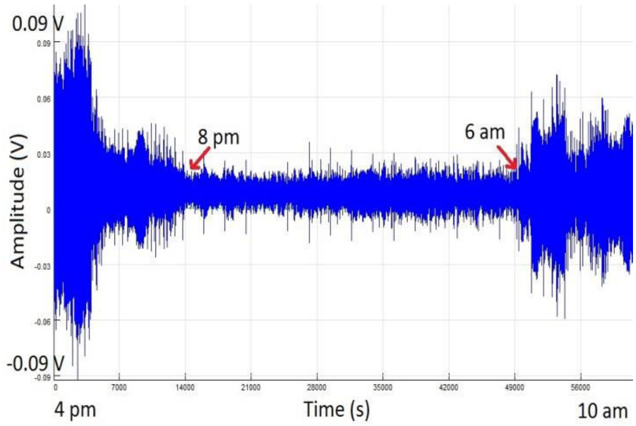

Figure-6. Time domain description of geoelectrical noise

To deeper understand about the noise components, time series data of geoelectrical noise is processed by time - frequency analysis of the interesting frequency in the range from 0.02 Hz to 30 Hz. According to the time - frequency domain description as shown in Figure-7, there are two narrow frequency bands, one band is around 2 Hz that can be generated by digital transmitters of the radio-telecommunication networks and to be observed in different regions of the world [Pham *et al*., 1999]. This frequency range may consist of the long transient electric signals that looking like Seismic Electric Signals (SES) [Varotsos, 1984].

Another frequency band around 17 Hz is due to traffic vehicles generated noise such as trains or cars. Its magnitude varied according to traffic density such as increased in rush hour (around 8 am and 18 pm) and reduced at night, when the traffic activities are low.

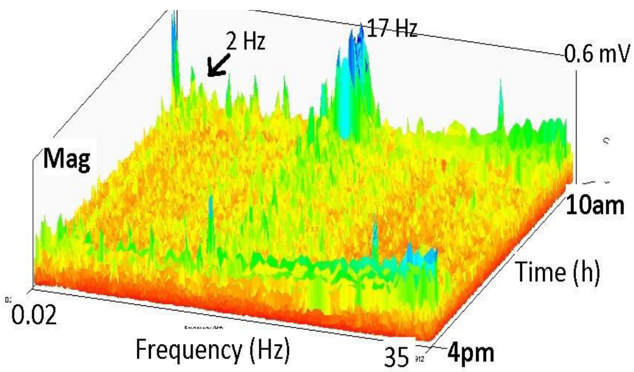

Figure-7. Geoelectrical noise pattern measured at HUS' campus in Time - Frequency domain.

More clearly, Figures 8a, b, c show the time-dependent of specific peak at 2 Hz, 50 Hz and 17 Hz, respectively. The 2 Hz and 50 Hz peak seem elated each other. Both of their amplitudes are reduced at night when the human activities such as acting on communication system are most idle. The 50 Hz noise generated by

ARPN Journal of Engineering and Applied Sciences

lighting system at night is smaller than other electric equipment's, which is illustrated by Figure-8b.

Railway system around Hanoi plays a major role to the noise at 17 Hz, which repeats at nearly the same time interval according to activity schedule of train. Other traffic vehicles such as cars, motorbikes are contributing a smaller part depending on their speed, except in the rush hours as shown in Figure-8c.

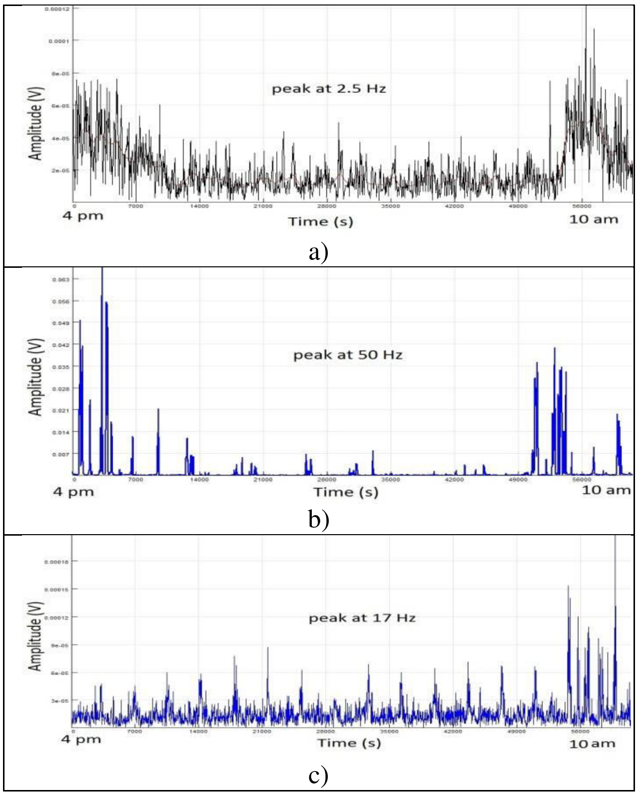

Figure-8. Time dependent of 2, 50 and 17 Hz noise.

Figure-9 shows the voltage drift measured in HUS' campus. It is difficult to identify the source of noise with the extremely low frequency as near DC. Natural, unidirectional currents flow in the ground and produce voltage anomalies that can amount to several hundreds of millivolts [Rain *et al*., 2004]. Besides self-potential of Earth surface, other sources of background noise are telluric currents that are caused by variations in Earth's magnetic field, which in turn are caused by interactions of the solar wind with the ionosphere. This is a complicated process and need a long term monitoring and logging data before to be concluded.

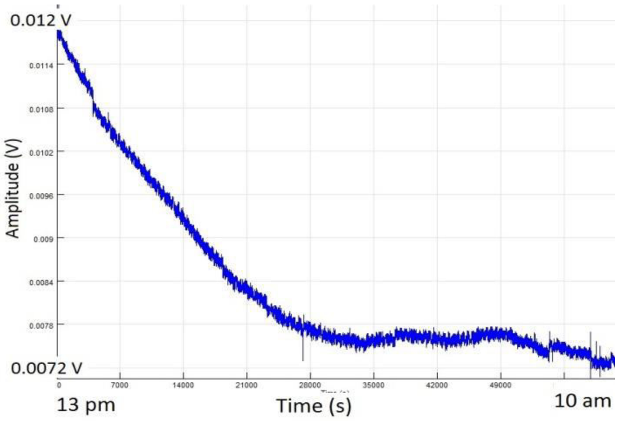

Figure-9. DC background noise measured at HUS's campus.

4. CONCLUSIONS

The measurements of electrical noise using two conventional electrodes are performed in Earth surface in urban area, as well as the instrument developed to capture them. By using an ultra-high resolution digitizer, the noise levels can be detected at amplitude as low as -150dB of ±2.5V full scale with ~ 2.3 nV/ bit resolution. According to the obtained results, the background noise measured in HUS's campus is about -100dBFS. There are two low frequency bands around 2 Hz and 17 Hz varied by time in HUS's campus that may affects to geoelectrical survey in Hanoi, Vietnam. It can be concluded that is very important to measure and characterize the time-dependent noise with grounded electrodes to choose a stimulus frequency suitable for geoelectrical surveys where low background noises are presented. Besides, the human activities can be evaluated indirectly through the geoelectrical noise spectrum when the time-dependent of specific noise is investigated.

ACKNOWLEDGEMENT

This research is funded by the Vietnam National University, Hanoi (VNU) under project number QG.16.02

REFERENCES

[1] Bianchi C. and Meloni A. 2007. Natural and man-made terrestrial electromagnetic noise: An outlook, Ann. Geophys. 50, 435.

[2] Binley A. 2015. Tools and techniques: DC electrical methods, in Treatise on Geophysics. 11: 233-259, 2nd edn, ed. Schubert, G., Elsevier.

[3] Dahlin T., Leroux V. 2012. Improvement in time-domain induced polarization data quality with multi-electrode systems by separating current and potential cables, Near Surface Geophysics. 10, pp. 545-565.

[4] La Fontaine D., Application Note 1560. 2011. Making Accurate Voltage Noise and Current Noise

Measurements on Operational Amplifiers Down to 0.1Hz. Intersil Corp.

[5] Milsom J. and Eriksen A. 2011. Field Geophysics, 4th Edition, John Wiley & Sons.

[6] Munoz A., Bataller V., Ayuso N., Molina P., Mediano A., Cuch J. A. and Villarroel J. L. 2011. Noise Characterization in Through-The-Earth Communications with Electrodes, Progress In Electromagnetics Research Symposium Proceedings, Marrakesh, Morocco, Mar. 20-23, 1521.

[7] Neuenschwander E. F. and D. F. Metcalf 1942. A study of electrical earth noise. Geophysics. 7(1): 69-77.

[8] Loke M.H., Chambers J.E., Rucker D.F., Kuras O., Wilkinson P.B. 2013. Recent developments in the direct-current geoelectrical imaging method, Journal of Applied Geophysics. 95, pp. 135-156.

[9] Pham V. N., Boyer D., Le Moue J. L., Chouliaras G., Stavrakakis G.N. 1999. Electromagnetic signals generated in the solid Earth by digital transmission of radio-waves as a plausible source for some so-called 'seismic electric signals', Physics of the Earth and Planetary Interiors. 114, pp. 141-163.

[10] Rein A., Hoffmann R., Dietrich P. 2004. Influence of natural time-dependent variations of electrical conductivity on DC resistivity measurements, Journal of Hydrology. 285, pp. 215-232.

[11] Santarelli L., Palangio P., Lauretis M, D. 2014. Electromagnetic background noise at L'Aquila Geomagnetic Observatory, Annals of Geophysics. 57, 2, G0211.

[12] Supper R. 2011. The GEOMON 4D electrical monitoring system: current state and future developments, Berichte Geol. B.-A., 93,- International Workshop on Geoelectric Monitoring, November 30th - December 2nd, Vienna.

[13] Szarka L. 1988. Geophysical aspects of man-made electromagnetic noise in the Earth-A review, Surveys in Geophysics. 9, 287-318.

[14] Texas Instruments Inc. 2010. ADS1282 EVM user's guide.

[15] Texas Instruments Inc., 2012. ADCpro User's Guide.

[16] https://sigview.com/

[17] Varotsos P., Alexopoulos K. 1984. Physical properties of the variations of the electric field of the earth preceding earthquakes, I. Tectonophysics. 110, pp. 73-98.

[18] Bataller V., Muñoz A., Molina Gaudó P., Mediano A., Cuchí J. A. and Villarroel J. L. 2010. Earth Impedance Model for Through-the-Earth Communication Applications with Electrodes, Radio Science. Vol. 45, RS6015, pp. 1-18.