

Implementation of EML and GPR Technology for Underground Utilities Detection

Syed Idrus Syed Salim¹, Asrul Zakaria², Nor Azme Nordin³ & Sulzakimin Mohamed⁴
^{1,2,3}Politeknik Sultan Haji Ahmad Shah, Malaysia & ⁴Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia

ARTICLE INFO

Article history:

Received Dec 30, 2021
Revised Jun 28, 2022
Accepted July 25, 2022

Keywords:

Underground Utilities
Detection,
EML,
GPR

Conflict of Interest:

None

Funding:

None

ABSTRACT

Underground utility mapping is important for extracting underground utility information such as electrical and telephone cables, gas pipes, drainage pipes and water pipes. Electromagnetic Location Surveys (EML) and Ground Penetrating Radar (GPR) have been widely used for mapping underground utilities at certain depths and refined utility characteristics. If it involves certain soils such as involving soils that are harder than usual, there is a possibility that the waves transmitted by the GPR are slower as compared to softer soils. Even the moisture rate on the soil also affects the GPR image. This study was conducted to find out how these two equipments are used with reference to the accuracy of hyperbolic images in GPR Radargram. The methodology carried out is by utility installation detection work and marking of detection information using EML and GPR by taking several images using the same frequency in the same area which is located in Perumahan Makmur Penor Utara Jaya (PUJ) using GPR model equipment (Leica DS2000), GPS (Topcon Hyper V) and EML (RD8100). Thus, the analysis found that appropriate conditions was when electrical cables can be detected more easily by using the clamping method which used the "peak" mode at frequencies of 8KHz - 33 KHz for EML devices and for GPR. The use of high frequencies (1GHz or more) is more suitable at making detection work for smaller utilities, in line with the formula $0.1 \cdot \lambda$, where λ is the wavelength. Therefore, the results of this study are very important for quality improvement during data collection work as well as an increase in the production of high-quality underground utility maps.

Corresponding Author: Syed Idrus Syed Salim, Department of Civil Engineering, Politeknik Sultan Haji Ahmad Shah, Malaysia & Tel. (+60 13-980 0918). E-mail: idruss@polisas.edu.my.



© Syed Idrus Syed Salim, Asrul Zakaria, Nor Azme Nordin, Sulzakimin Mohamed

This is an open-access article under the CC BY-SA 4.0 international license.

1. Introduction

Public utility systems like telecommunication, electricity distribution, natural gas, cable television, fiber optics, traffic lights, streetlights, water mains, wastewater pipes are run underground. The rapid and continuous development of the country has increased the need to provide and supply underground infrastructure information such as accurate utility positioning for public facility maintenance planning. Moreover, data from GPR can also be used in analysing the type of metal or non-metal utility by looking at the hyperbolic image on the radargram. Furthermore, the importance includes:

- To extract information on utility features found underground such as electrical and telephone cables, gas pipes, drainage pipes and water pipes.
- The rapid and continuous development of the country has increased the need to provide and supply underground infrastructure information such as accurate utility positioning for public facility maintenance planning.
- Information on the exact position of underground utilities can generally be simultaneously measured and obtained during the installation of such utilities. This situation requires detection work using

equipment such as Pipe and Cable Locator (PCL) and Ground Penetrating Radar (GPR) used to identify the position and type of the utility.

1.1 Problem Statement

In most of the cases, utility systems like telecommunication, electricity distribution, natural gas, cable television, fiber optics, traffic lights, street lights, water mains, wastewater pipes run under the main public roads. So it requires governments to denote and approve the underground location of these systems. This is done to ensure public security and safety so that existing underground lines don't get hit. Furthermore, the damages of physical underground structure are becoming apparent when detection is done without the use of electromagnetic energy or wave. Hence, EML & GPR detection work that uses the transmission of electromagnetic energy along with radio frequencies to investigate underground structures or man-made structures, without damaging the physical modifications of the structure (Lai, Dérobert and Annan, 2018 and Glaser *et al*, 2012).

Ground penetration radar on GPR has the advantage of detecting almost anything below the ground surface compared to EML which only detects utilities composed of metals only (Mahdi, 2018; Glaser *et al*, 2012, and Cheng & Jack, 2005). Being able to determine the precise location of underground services lessens the risk of any interruption of utilities, injury, delay or major repairs. Moreover, limiting risk allows for better planning and proper budgeting.

Underground detection electromagnetic radar can penetrate as well as detect utilities up to 3 meters below the ground surface. Therefore, could provide an indication of the location and depth of the utility that has been planted. Even so, the depth of radar penetration can actually be extended but it will interfere with the resolution of the image. Generally, this process focuses on spatial data collection, utility information management, and actual mapping of utility networks.

1.2 Research Objectives

- 1) To study EML equipment in detecting utilities such as electrical cables, water pipes, sewage routes, optical cables compared to detectors using GPR equipment.
- 2) To identify the weaknesses and strengths of this GPR and EML equipment.

1.3 Research Scope

The study area covers the utility installation route area in Kuantan, Pahang which involves 6 lanes in the housing area namely Lorong PUJ 17, to Lorong PUJ 22 and the main route which is Jalan Perumahan PUJ 16 and Jalan Perumahan PUJ 28.

In this study, the equipment used is GPR model GPR (Leica DS2000), GPS (Topcon Hyper V) and EML (RD8100) as well as using REFLEXW software, uNext 1.3.3, MapInfo Pro, ZWCAD 2021, RD Manager, Global Mapper, Magnet Field and two (2) types of utilities involved are metal and non-metal utilities.



Figure 1. Lane PUJ 17 to Lane PUJ 22 and main accessible lane of Jalan Perumahan PUJ 16 and Jalan Perumahan PUJ 28

2. Literature Review

Underground utility mapping is a process of identifying the position and mapping of utilities located underground. Samples of utilities found underground are as electrical cable networks, gas pipes, water pipes, wastewater pipes, telecommunication lines, tunnels and oil pipelines (Jamil *et al*, 2012; Daniels, 2004, and Hung *et al*, 2002).

Underground utility mapping refers to the detection of the condition and shape of underground pipes and cables that are planted without the need to make excavations that can damage the utility and the surrounding surface. The position and condition of underground utilities can be obtained with modern or conventional study equipment. Therefore, generally underground utility mapping is a combination between two major fields of science known as geophysics and geomatics (KPUP, 2007).

The rapid and continuous development of the country has increased the need to provide and supply underground infrastructure information such as the exact location of utilities for the purpose of planning and maintenance of public facilities. Information on the exact position of underground utilities can generally be measured and obtained during utility installation. However, in most cases, the position of the underground utility was not measured during installation despite the placement of its route according to a pre-determined plan during the initial stages of the proposal of the construction (Cassidy, Eddies & Dods, 2011 and Glaser *et al*, 2012). This situation requires detection work with pipe and cable locator equipment and Ground Penetrating Radar (GPR) is used to identify the position of the utility (KPUP, 2013).

Survey work carried out by Surveyors usually involves the installation of underground utilities installed in the path of the utility facility in the following circumstances:

- i) Placement of underground utility routes without tunnels but sharing common routes (*common trenching*)
- ii) Placement of underground utility routes in the construction of integrated utility tunnels (*common utility tunnel*)
- iii) Placement of underground utility routes installed separately below the road surface or in the road reserve.
- iv) Utilities installed through directional drilling (*horizontal directional drilling*)

3. Method

Planning is the first and most important element in a project. It is a process of compiling an action plan which aims to achieve the goals and objectives of a study in an orderly manner and completed within a specified time (Annan, 2009 and Yarovoy & Harry, 2009). One of the first steps in making a plan is to visit the work area first and look around the area to be measured. Surveys and site visits must be carried out before commencing an underground utility measurement work for the purpose of:

- i) Identifying the sources of utilities that are exposed on the earth's surface such as manholes, tnb feeder pillars, tnb substations, fire hydrants, lampposts/electric poles, water valves and other utilities on the earth's surface.
- ii) Identifying entry and exit routes to the work site to ensure job safety is complied with and it is easy to enter.
- iii) Identifying the basic support equipment that needs to be brought based on the exposed utility sources for example suitable manhole openers and water pumps if necessary.
- iv) Identifying the appropriate EML techniques to be used based on the exposed utility sources such as clamping techniques on electrical cables in the electrical box and direct connection techniques on water valve to detect water pipes
- v) Necessary Safety awareness equipment such as red cones and safety gloves.
- vi) Survey also to identify soil type and soil moisture at the survey site and found that the soil type in the field identified is the type of 'Soil Loamy Dry' where the value of 'Dielectric Contant' is in the range between 4 - 10 and the soil condition is residential road.
- vii) The connection of each main hole utility found to get an initial picture of the utility path to be measured.

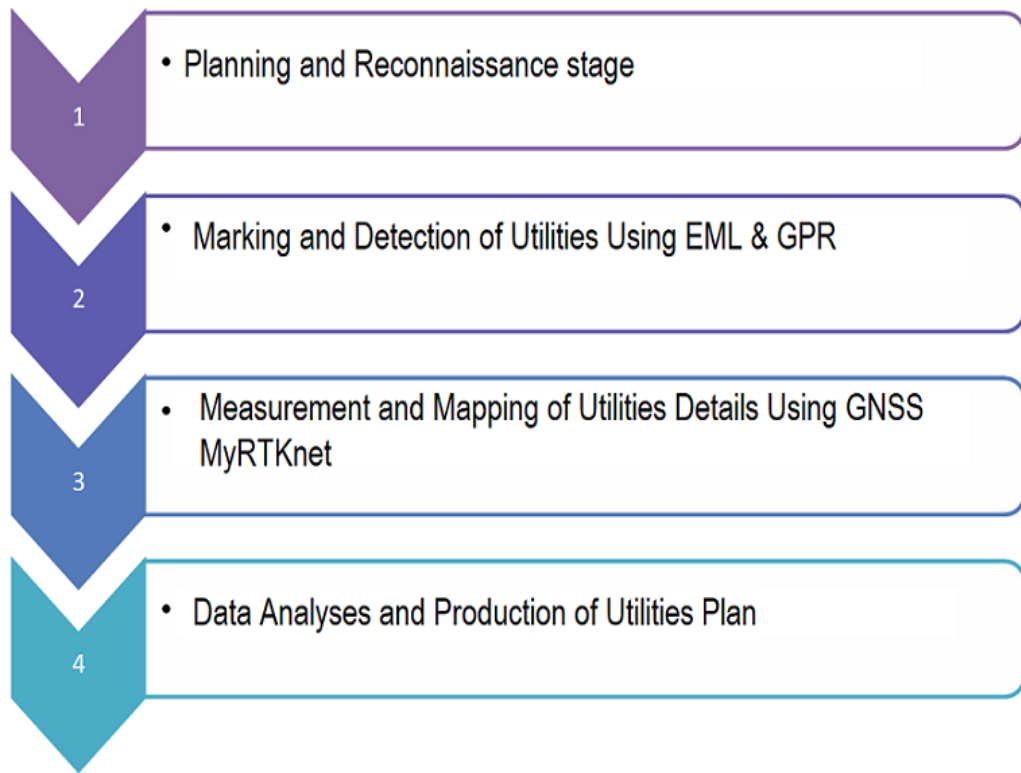


Figure 2. *Research Methodology*



Figure 3. *Data Collection*

4. Results and Discussion

4.1 Using EML

- i. Electrical cables can be detected more easily by using the clamping method by using the "peak" mode at a frequency of 8KHz - 33 KHz.
- ii. Water pipes are quite difficult to detect even using the direct connection method on the water valve that arises as a result of the effect of distortion/coupling signal frequency. As a solution, GPR is used to detect the position of the utility.

- iii. Telecommunication cables cannot be detected using EML because the telecom boxes in the field are made of non-conductive fiber optic material and cannot be used as a source for connection with EML devices to search for other telecom cables.
- iv. The utility sewerage route also could not be traced by using EML because the material is made of non-conductive clay, however if this sewerage manhole can be opened, the use of Sonde may be recommended for the utility route effect.
- v. Understand the nature of milliamps or the amount of electric current provided by an EML transmitter against EML receivers in identifying utility paths that are conductive in nature.

4.2 Using GPR

- i. Electric cable utilities that are small in size and have a large number of electrical cable routes and located close to each other, will produce hyperbole that is dense and difficult to identify (interpretation), therefore GPR devices with higher frequency are needed to carry out this measurement and to produce a sharper hyperbolic image
- ii. The loss and ambiguity of the resulting hyperbolic image for some slice scanning for sewerage line after the data conversion process caused the 3D process unable to capture the measured utility image, hence the analysis of 3D data for the utility involved could not be carried out.
- iii. The use of GPR tools in utility detection work is very necessary because it can solve the problem of distortion/coupling that is often encountered in the use of EML tools.

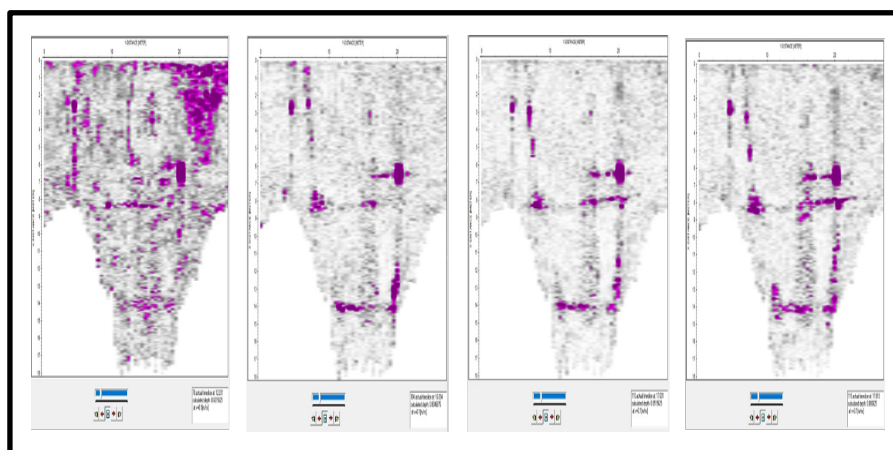


Figure 4. 3D Time Slices Images

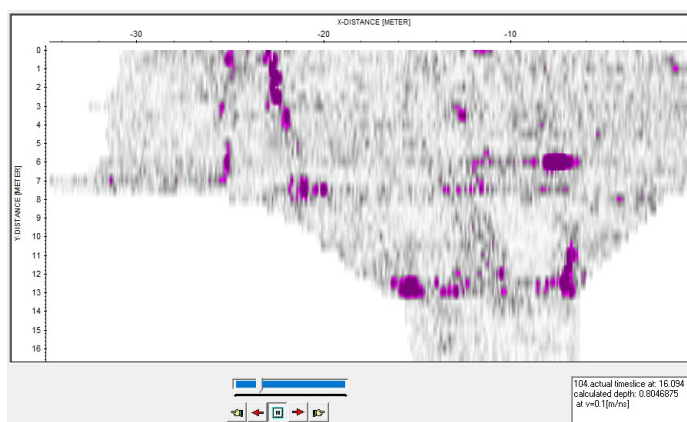


Figure 5. The measured Water Pipe Utilities and Drains that cross the tarmac began to appear in 3D Time Slices images at a depth of 0.8m.

5. Conclusion

As a conclusion, several EML techniques need to be used in order to determine the suitable frequency usage to reduce distortion interference during utility installation detection. Other than that, ground stake should be placed at an appropriate distance and in the correct position to enable the detection work using the Direct Connection method to get better results. Moreover, the use of both GPR and EML tools is essential in carrying

out detection work. This is because, each usage and method of the two tools has its respective disadvantages and advantages. Therefore, these two types of tools need each other and can complement each other in carrying out a more holistic detection measurement.

Acknowledgements

While preparing this research project, I was in contact with many individuals, researchers, academicians and practitioners. The entire individuals have contributed to help me understand and practice the knowledge towards successful study in the geomatics field. I would like to express my sincere appreciation to my head of department Pn Rosmiza binti Wira that had initiated the idea, sharing knowledge and in helping me in research of the project. My sincere appreciation should also be extended to Mr. Adam Bin Idriss Licensed Land Surveyor, Mr Ameer Shafuan bin Mohd Kifli Precise Subsurface and Mr Faiz bin Hj Alias Jurukur Mahabob and Co for equipment and knowledge sharing. Finally, I must express my dearest friend, Mr Fuad, Mr Nizar, Mr Faez, (proofread) and who are involved either directly or indirectly for their understanding, support, encouragement, and motivation in my journey for master studies. This accomplishment would not have been possible without them.

References

- Annan, A. (2009). *Methodology for Radar Transillumination Experiments*. Geol Survey.
- Cassidy, N. J., Eddies, R., & Dods, S. (2011). Void detection beneath reinforced concrete sections: The practical application of ground-penetrating radar and ultrasonic techniques. *Journal of Applied Geophysics*, 74(4), 263-276.
- Cheng, L. and Jack, F. T. (2005). *Ground Penetrating Radar Soil Suitability Map of the United State*. National Soil Survey Center.
- Daniels, D. J. (2004). *Ground Penetrating Radar Second Edition*. The Institution of Electrical Engineers, London United Kindom.
- Glaser, D. R., Werkema, D. D., Versteeg, R. J., Henderson, R. D., & Rucker, D. F. (2012). Temporal GPR imaging of an ethanol release within a laboratory-scaled sand tank. *Journal of Applied Geophysics*, 86, 133-145.
- Yarovoy, A., & Harry, M. J. (2009). Landmine and unexploded ordnance detection and classification with ground penetrating radar. *Ground Penetrating Radar Theory and Applications*, 445-478.
- Jamil, H., Nomanbhoy, Z., & Mohd Yusoff, M. Y. (2012). Underground utility mapping and its challenges in Malaysia. *TS05 J—Mining and underground Engineering Surveying II*, 5636. Retrieved from https://www.fig.net/resources/proceedings/fig_proceedings/fig2012/papers/ts05j/TS05J_jamil_nomanbhoy_e_t_al_5636.pdf on 15 May 2022.
- Jeong, H. S., Arboleda, C. A., Abraham, D. M., Halpin, D. W., & Bernold, L. E. (2003). Imaging and locating buried utilities.
- KPUP, Perkeliling Ketua Pengarah Ukur dan Pemetaan Malaysia, Bil. 1 Tahun 2013-Garis Panduan Pengukuran Jajaran Laluan Utiliti Baru.
- KPUP, Pekeliling Ketua Pengarah Ukur dan Pemetaan Malaysia Bil. 1 Tahun 2007 - Garis Panduan Ukuran Pepasangan Utiliti.
- Liu, Z., & Kleiner, Y. (2013). State of the art review of inspection technologies for condition assessment of water pipes. *Measurement*, 46(1), 1-15.
- Mahdi, A. S., & Mohammed, A. A. (2015). Study the Possibility of using Ground-Penetrating Radar to Detect Walls and Archaeological Finds underground. *Iraqi Journal of Science*, 56(4B), 3256-3267.
- Lai, W. W. L., Dérobert, X., & Annan, P. (2018). A review of Ground Penetrating Radar application in civil engineering: A 30-year journey from Locating and Testing to Imaging and Diagnosis. *Ndt & E International*, 96, 58-78.