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Identification of Buried Fibre Cable Using Ground Penetrating Radar

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Abstract **-** Today's rapid development makes the surrounding environment congested and busy. Therefore, some impacts on sub-surface utilities are not arranged systemically, creating a false position of existing cables and pipes to detect, especially fibre optic cables. Due to the material and the smallest diameter (0.3mm – 1.5 mm) of fibre optic cables give the advantages when using Ground Penetrating Radar (GPR). This study was done to determine the buried fibre cable in the urban area, and the radargram was used to analyse the characteristics of the fibre cable detected by GPR. An accurate site was chosen for the study by tracing the underground utilities using the GPR grid method. Using the Reflex 2D Quick software, data was post-processed to interpret and filter for a clearer image to estimate the position and depth of the cable. This software is used to extract the resolution of the radargram between the cable, the reflectivity and the velocity of the signal penetrated the target. The results indicate that GPR can be used to determine the fibre cable where the value was close to the existing depth of 0.66m for Type A cable and 1.33m for Type B cable. The values are acceptable in the general field of utility mapping and meet government standards and utility provider specifications for vertical accuracy below 6mm of depth determination. Hence, this study's findings are beneficial, especially to land surveyors and utility providers, in affirming the position and depth of buried fibre cables, particularly in congested urban areas.

Keywords - GPR, Fibre Cable, Urban Area, Utility Mapping, Reflex 2D Quick, Reflectivity

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1. Introduction

Increasing land use for development demands better basic amenities such as utilities (Sagnard et al., 2016), road transport infrastructures (Rasol et al., 2022) and many more. Besides, many previous studies had focused on GPR application for underground Networks (Bachiri et al. 2020). This rapidly increasing building and technology development make Malaysia one of the countries that are no exception for using underground space to channelling utility sources. Therefore, the utility has several effects that are non-systematic to detect sub-surfaces (Hasan, 2012). This gives the advantage of identifying a pipe or cable's exact type and position. Indirectly, the overall detection to determine and identify pipes and cables is closely related to inaccurate utility mapping (Han et al., 2015). This makes detecting cables, especially fibre cables in urban areas, difficult.

In an underground utility, a fibre optic cable is a cable that cannot be easily detected because it is not a metal, and the material cannot drain an electromagnet. This cable has a small diameter and is usually buried at a depth of 1.5m from the ground surface (Bajčeta, 2017). The fibre optic cable is the technology associated with data transmission using light pulses travelling along with a long fibre which is usually made of plastic or glass and is almost helpful for every telecommunications network (Kachmar, 2011). This fibre cable itself is unaffected by electromagnetic interference.

Few tools are used to detect the fibre optic cables, such as Pipe Cable Locator with Sonde (PCL) or Duct road and Ground Penetrating Radar (GPR). This method is helpful for non-metallic detection such as drains, sewer pipes or ducts. Sonde uses the technique as transmitter radiation is an electromagnetic frequency located by the receiver. Sonde or Duct roads were inserted into the pipe casing or jacket and floated or pulled along the pipe. But there are some problems when using PCL with Sonde or Duct road is unsuitable because it has a length limitation. Plus, in another environment, there is no jacket to cover the fibre optic cable, making it complicated for surveyors to determine the fibre optic cable accurately.

The GPR is a suitable technique for locating and identifying the fibre optic cable in terms of accuracy and time (Utsi, 2014). Analysing and interpreting GPR radargram included the physical parameters of material such as resolution, wave propagation velocity and dielectric constant (Bakir et al., 2017). This can be used to detect fibre optic cable in the urban area by analysing radargram image that suits them best.

The primary purpose of this study is to determine the fibre optic cable using GPR and, thus, analyse the radargram image from the reflection. By viewing radargram, images have been analysed to get an accurate position of the fibre optic cable. This is used to determine the best effective criteria for the detection to obtain the fibre optic cable. The GPR data were analysed and compared with the PCL technique and existing data for actual depth accuracy. Hence, it could be the reference for the surveyors in detecting fibre optic cable in the urban area using GPR.

2. Data and Method

In this study, The GPR and PCL were used to determine the buried fibre cable in the urban area. The detection on the site determined the buried fibre cable in the urban area for the first time. This study involved an actual location of data collection in which the GPR must satisfy the scope.

2.1 Study Area

The location was identified as an urban area with a crowded burial of utilities. This located the buried fibre cable, which is the primary purpose of this study. The site is at Jalan Kemus Simpang Empat, Alor Gajah, Melaka, as shown by the red rectangular box in Figure 1.

Figure 1. Location of underground utility in the urban area

2.2 Equipment

The main instrument used for this study is the geophysical tool, GPR. The GPR used is MALÅ Easy Locator Pro Wide Range HDR which can detect deep and shallow targets simultaneously with dual-frequency provided 80MHz-950MHz, as shown in Figure 2. The GPR frequency lies between resolution and depth. According to Karim et al. (2018), as the frequency increases, the depth penetration decreases. This instrument was attached to the controller to display the scanned object. The data collection can be stored and exported to continue working on the post-processing, and it is effortlessly manoeuvring around the most challenging sites.

Figure 2. GPR MALÅ Easy Locator Pro HDR
(Website: https://www.guidelinegeo.com/product/mala-groundexplorer/)

The PCL was used for checking the depth of the fibre optic cable. The PCL model Vivax_Metrotech as shown in Figure 3, is a comprehensive range of locators and transmitters for locating and mapping buried utilities. Dealer calibrated this instrument before being used for data collection.

Figure 3. Pipe Cable Locator with Duct road (Intec, 2021)

This PCL is attached to the Duct road to determine the fibre optic cable. As shown in Figure 4. The Duct road as the transmitter is used for tracing the fibre optic cable inserted into the paths of pipes, ducts or jackets. The Duct road can be fitted to a flexible rod for insertion or pushing through pipe etc.

Figure 4. Duct road

2.3 Data Acquisition

For subsurface data acquisition, all parameters have been set up in MALA as what has been in calibration. Move the GPR toward the location. The GPR has traced the underground utilities based on the grid method, as shown in Figure 5. The ground was marked using a spray, and the scanning process started with a longitudinal line of 5m in length, followed by a traversal line for intervals of 10m. Then, the data was collected as shown in the radargram while GPR was scanning the area target.

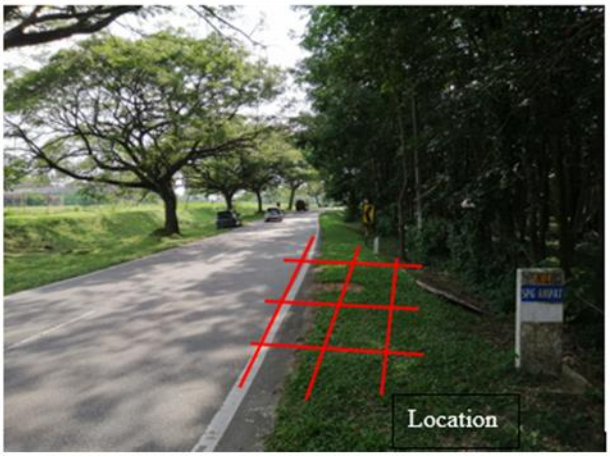


Figure 5. Location of GPR scanning with the Grid method

For data acquisition, PCL and Duct road were inserted. The Duct road was within the jacket and prepared to find the fibre optic cable, as shown in Figure 6. Confirm the Duct road and locater measure at an equivalent frequency and deal properly. The Vivax Metrotech Locator can mechanically show the depth of the Duct road when tracing it and providing the proper signal.

Figure 6. Duct road inserted into the jacket of fibre cable

The method used by PCL must be along the alignment, which is the locator finding the Duct road, as shown in Figure 7. The locator will find the strongest signal on the Duct road when locating the sign. All the safety precaution was applied during the scanning activity to avoid any incident.

Figure 7. Finding tracing wire by the locator

The locator finds the signal by moving backwards and forwards and stops when the locator indicates a peak signal. This method used by PCL must be along the alignment, the locator finding the Duct road. Then, the depth of PCL was sprayed on the ground, as shown in Figure 8. The spray markers were marked on the road's surface for easy-to-see information.

Figure 8. Depth was sprayed after detection by the locator

2.4 Data processing

Before data processing, the data was downloaded from the GPR controller. The data was processed to extract information about the targeted. Interpreting the exact position and depth of the fibre cable after filtering and enhancing the image. The commercial software, Reflex 2D Quick, was used in the processing stage to screen and improve the images, as shown in Figure 9. Two main objectives are to process the data. First, to detect underground fibre optic cable using GPR in the urban areas and to analyse data GPR backscattered image of underground fibre optics.

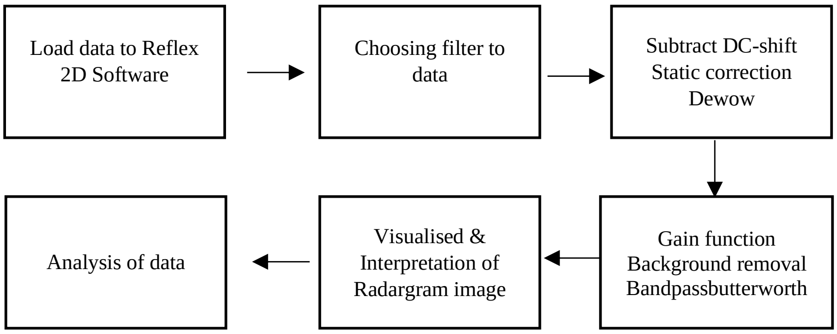


Figure 9. Processing stage to filter and enhance the images

The depth of fibre cable tabulated all data, the power of reflectivity, and the strength of their resolution for metal and non-metal determined by GPR.

3. Result and Discussion

The radargram was obtained from GPR image processing. The radargram image result was interpreted after processed of filtering and image enhancement. Data interpretation was made after processing to extract other information such as the resolution of the radargram, power of reflectivity, the velocity of GPR and depth penetration of GPR.

3.1 Resolution of Radargram

The observation of the radargram image is shown in Figure 10, and the criteria of hyperbolic are in Table 1. The fibre cable has less contrast of radargram image than the type of metal utilities. Thus, the highest resolution contrast finally affected non-metal utilities such as fibre cable as the image's resolution on the radargram.

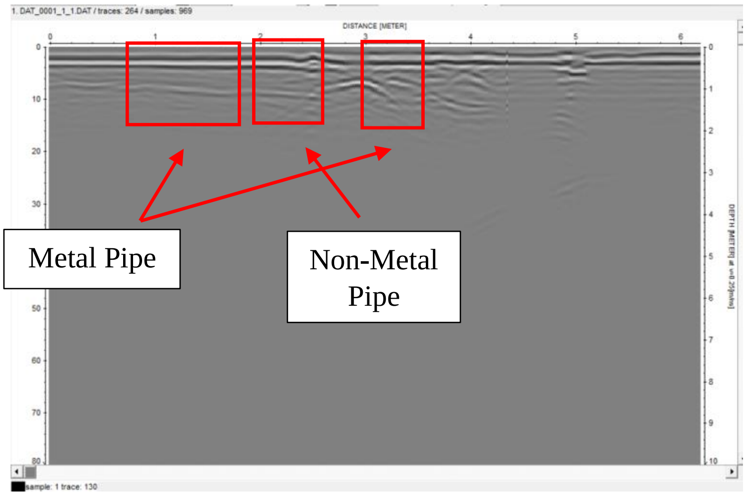
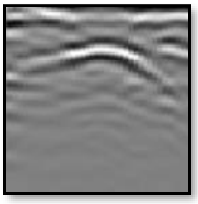
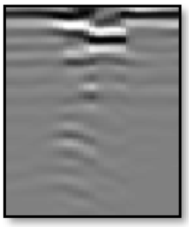


Figure 10. Radargram shows overall buried utilities

As a result, in Table 1, the signal penetration drowns the other utilities. The medium of soil, which is clayey dry, has low reflection dielectric permittivity of medium level that makes signal penetration of EM faster. This shows the target can be seen because the value of dielectric permittivity of clayey dry is around 2.5 (Kamal, 2019).

Table 1. Criteria of underground utility hyperbolic image

Type of Pipe		Hyperbolic image	Criteria
Metal	Water		The radargram shows high contrast & smooth hyperbolic
	Power 1		The radargram shows sharp hyperbolic, high contrast, & smooth hyperbolic image
	Power 2		The radargram shows high contrast & blur of formed the hyperbolic image
Non-metal	Type A Cable		The radargram looks less contrasted & narrow hyperbolic
	Type B Cable		The radargram looks less contrasted, blurred, & narrow hyperbolic

Notes: Type A is Maxis Cables, and Type B is Malaysia Telecom Cable.

3.2 Power of Reflectivity

The value of power reflectivity for buried utilities with high frequency is shown in Table 2. The value of the power of reflectivity was based on the value of amplitude shown in the radargram after the processing. The positive value was extracted from the radargram image to show the reflection of EM.

Table 2. Value of Reflectivity

Type of Pipe		Power of Reflectivity
Metal	Water	10257.2
	Power 1	22478.2
	Power 2	9488.4
Non-metal	Type A Cable	4288.8
	Type B Cable	4172.4

Power reflectivity on fibre cable and telecommunication was the smallest than the other utilities such as water and power. This is because the non-metal utilities have less reflectivity due to the metal utilities and the material's dielectric constant (Shokri, 2015). Based on the table, the power reflectivity for type A and type B cables are similar because they are made from the same optical fibre.

3.3 Velocity Comparison of Buried Fibre Cable

The value of velocity, time travel from the top of the buried utilities, and an estimated depth are shown in Table 3. The radargram evaluated this by fitting the hyperbola to get the best-estimated depth.

Table 3. Velocity and estimated depth for all buried utilities

Buried of utilities		Velocity(m/ns)	Time(ns)	Estimated depth(m)
Metal	Water	0.10	2.809	0.35
	Power	0.15	6.635	0.83
	Power	0.10	5.881	0.74
Non-metal	Type A Cable	0.09	5.278	0.66
	Type B Cable	0.09	10.707	1.33

Based on Table 3, data were extracted from the radargram where the velocity fits the hyperbola to estimate the best depth. The velocity of fibre cable is the smallest compared to other utilities. The data was obtained that the value of the velocity of fibre cable for Type A cable and Type B cable is around 0.09m/ns, which is smaller than the velocity from other utilities. This affects the properties of the medium shown by the wave velocity's relative dielectric permittivity, whereby the lowest relative dielectric permittivity, the highest velocity propagation (Kamal, 2019).

3.4 Comparison Between Actual and Measured Depth

The result of the existing depth and measured depth is shown in Table 4. The current depth of fibre cable was taken from stakeholders, and its clear interpretation of the differences of measure depth with the actual depth. The differences in depth between GPR and PCL were calculated. The error measures how far the depth achieved differs from the actual depth and serves as a control and comparison parameter for the methodologies used in this study.

Table 4. Shows the depth of the existing and measure

Type of fibre cable	**Depth of fibre cable**			**Error (%)**	
	Stakeholder (Actual depth)	GPR	PCL	Diff. between GPR and actual depth	Diff. between PCL and actual depth
Fibre Cable-Type A	0.6m	0.66	0.63	10	5
Fibre Cable-Type B	1.4m	1.33	1.36	7.9	4

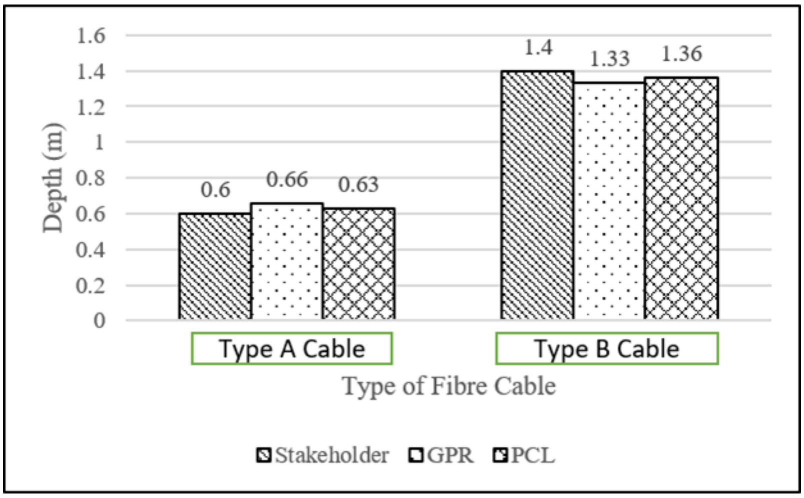


Figure 11. Graph show depth between actual depth and measure depth

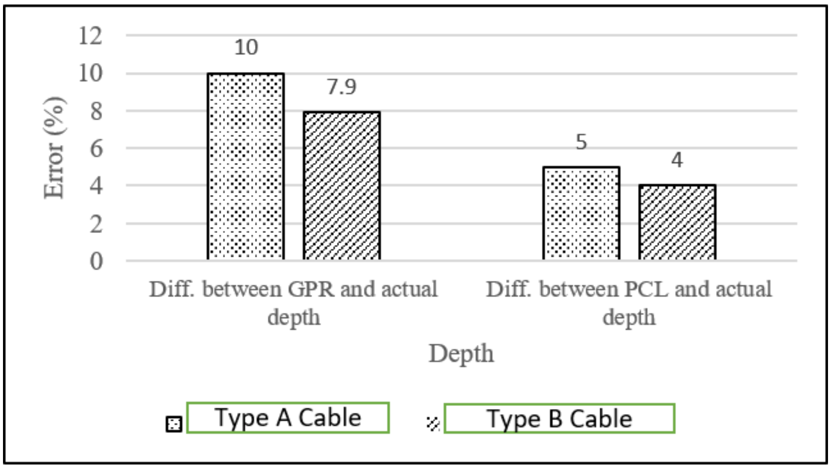


Figure 12. The graph shows the error percentage between the instruments

Figures 11 and 12 show the data distribution of the depth and error estimation of stakeholders, GPR and PCL when determining buried fibre cable. Referring to Figure 11, the depth determined by GPR for maxis cable is 0.66 meters higher than PCL depth, 0.63 meters, during the actual depth Stakeholder depth, 0.6 meters. The depth determined by GPR for telecom cable is 1.33 meters lower than PCL depth, 1.36 meters, during the real depth Stakeholder depth, 1.4 meters. The error percentage between the actual depth and measured depth by GPR shows that the maxis cable achieved a higher value of 10 percent compared to the telecom cable, 7.9 percent. The measured depth by PCL between the actual depth shows 5 percent for Type A cable while Type B cable with 4 percent. This shows the difference percentage error determined by PCL is 1 percent of error between Type A cable and Type B cable.

PCL and GPR obtained the result of depth with their techniques and frequencies (Ismail, 2016). Because the PCL measured the depth of the fibre cable by locating the Duct road compared to GPR by detecting the surface jacket of the fibre cable. As a result, the depth determined by PCL has a smaller error percentage than GPR used for detecting fibre cable. However, the GPR accessibility in determining depth is excellent, with the specified value close to the value measured by PCL with a difference of 3cm. It shows that the GPR can accurately measure depth and locate metallic and non-metallic objects with acceptable value.

3.5 Discussion

Based on the result above, the buried fibre optic can be determined using GPR. This is because to choose fibre cable, it is necessary to use a high frequency of the signal for locating fibre cable. Because fibre cable is a non-metal cable and has a small size diameter. The result of fibre cable was analysed, where the resolution of fibre cable has less contrast compared to metal pipe. Due to the dielectric permittivity of soil and material, the RDP affected the EM velocity in recording radargram rather than reflecting them or allowing them to pass through the object.

The differences in the power reflectivity value are due to the different dielectric constants depending on the material of pipes (Ismail et al., 2016). The strong signal gives advantages to reflecting the signal, and the result is that metal pipe has higher reflectivity than non-metal material such as fibre cable. This study proved the theory said that the lowest relative dielectric permittivity, the highest velocity propagation (Shokri, 2015).

To complete the study, the measurement results of the fibre cable were compared to the actual depth. From the result, the depth measured by PCL approaches the actual depth. This does not mean GPR does not meet the criteria because it depends on the technique used to determine the fibre cable's depth. Because GPR determines the depth of the fibre cable on the surface of the jacket compared to the depth specified by the PCL in which the wire detector is inserted into the jacket. This suggests that despite the technical differences, GPR can determine into fibre cables and is acceptable for utility mapping. The value meets government standards and specifications of utility providers for vertical accuracy below 6mm of depth determination.

This study aids surveyors in providing more confidence when using GPR to detect fibre cables in urban areas. Therefore, this study ensures that the utility depth specified is precise to minimise error when determining the fibre cable in urban areas. Thus, area accidents during the excavation due to inaccurate depth information can be minimised. As a result, this research could contribute to the utility mapping field.

4. Conclusion

In this study, the GPR was used to determine the fibre cable in the urban area where the image was viewed from the radargram after filtering and enhancing the data. This study demonstrates that the non-metal fibre cable has less reflectivity due to the smallest diameter of the cable compared to the metal pipe. The depth determined by GPR is close to the actual depth and the acceptable value. Through this study, the GPR is suitable for determining the smallest diameter of the cable, such as fibre cable in urban areas. Lastly, land surveyors and utility providers can benefit and make them more confident in determining the buried fibre cables in the urban area.

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