Georadar method for detecting underground septic tank

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Abstract. The Ground Penetrating Radar (GPR) method commonly known as Georadar, a non-destructive geophysical method that uses electromagnetic waves. This method is widely used to determine conditions under the surface such as mapping structures and subsurface lithology or buried objects. In this study, the GPR measurement using Geoscanners AKULA A9000 + Antenna GCB3070 is conducted to detect the presence or capacity of a septic tank. The GPR data were initially processed using matGPR based on MATLAB. GPR data on each measuring line is processed first, a series of filters and gaining have been conducted such as Adjust Signal Position, Remove DC, Dewow, Inverse Amplitude Decay, Remove Global Background, Karhunen-Loeve Filter, then time to depth conversion with adjusted parameters. From the result of parameter analysis in processing data, found that the GPR data can be interpreted which show the underground septic tank in the study area with the presence of diffraction signatures.

1. Introduction

Ground Penetrating Radar (GPR) is one of geophysical tool used to detect objects buried underground at a certain depth, using electromagnetic waves. The electromagnetic (EM) waves will be transmitted to the earth and recorded by the antenna when the waves hit the surface. Electromagnetic waves are transmitted, reflected, and scattered by surface structures and create some anomalies as they encounter discontinuities. [1]. That discontinuity may be a boundary or an interface between materials with different dielectrics, or it may be a subsurface entity, such as a delamination or a buried material object. According to the principles of geometrical optics, EM waves dimensions are greater than the wavelength if is reflected by any dielectric singularity. [2].

The penetration depth of this method is relatively low (especially with high-frequency antennas), even though the GPR method can reconstruct in detail the main stratigraphy, soil geometry, including the real dimensions and position of objects [3]. GPR recommends a more penetrating capability such that concrete flaws or deteriorations that can be detected at higher depths. [4]. Even so GPR is very good at near surface geophysical survey, it can be used to identify objects that hidden in a homogeneous medium [2].

Data in GPR is also taken from many spatial locations by dragging antennas along the surface. From the GPR reflected signal will be transformed into radargram with multilayer. Hence the main
parameter in this method is the travel time. Travel times get faster when the antenna moves directly over the buried object and gets slower if the antenna moves away from the object. The resulting travel time plot is a hyperbola. However, if the object asymmetry is not symmetrical, the geometry visible in the radargram is very different from the hyperbola. [2].

Septic tanks are typically used as critical treatment in rural areas, urban areas or municipal areas where soil is not sufficient for the establishment of sewers. [5]. To screen the precise location and condition of the utility’s septic tanks, engineers normally map the underground layer using GPR without the need for excavation. Especially the septic tank is only a few meters from the surface and built using bricks, mortar, or concrete [5]. The efficacy of GPR in the position of underground utilities such as septic tanks and pipes has been shown by many case studies. [3,6–8]. Therefore, this paper aims to detect the presence of septic tanks using GPR.

2. Methodology

2.1. Data Acquisition

There are 3 GPR profiles in this study: Line 1, 2 and 3 that using AKULA A9000 and Antenna GCB3070 (300 Hz) which each line has a length of ± 5 meters. GPQ acquisition used the Radar Reflection Profiling. Survey acquisition design is shown in Figure 1.

![Figure 1. Layout of acquisition ground penetrating radar lines.](image)

2.2. Data Processing

Every data set is processed with adjusted parameters to increase the interpretability of the GPR profiles. GPR data is carried out by various filtering and gaining processes as will be explained below. The flowchart to obtain the final radargram is shown in Fig. 3.

2.2.1 Adjust Signal Position

Adjust the signal to its actual position done for eliminate time delay in data. The process of adjusting the signal position is done to eliminate the signal break also known as time zero (Tz) [7,9]. In different circumstances, the target depth will be exaggerated. If there is evidence of fluctuation in Tz, then it is possible that the antenna or other parts of the system need to be repaired. An unstable Tz will affect the reliability of depth reading [10].

2.2.2 Remove DC

Removing the DC components needs to be done because it can cause distortion in waves. The removal of the DC component is carried out using arithmetic mean calculations from the waveform and removes it. This is often shown within the equation (1) by adding all the numbers in vector x and dividing them by the size of the vector [11].
\[ y(t) = x(t) - x \]  \hspace{1cm} (1)

2.2.3 **Dewow**

Dewow is a basic processing step that uses temporary filtering (high-pass filter) to remove very low frequency components from data. Components of very low data frequency are associated with inductive phenomena or possible limitations of the dynamic range of the instrument. [7]. If dewowing is not carried out, the data will contain low frequency components that distort the entire trace spectrum with a cut-off frequency of 2% of the Nyquist frequency [12].

2.2.4 **Inverse Amplitude Decay**

Inverse Amplitude Decay (IAD) is a data adaptive filter for the entire GPR that calculates the main amplitude decay function. For each trace, the inverse segment is added, and the lateral amplitude difference is retained and the amplitude in the trace is further enhanced. IAD applies a smooth empirical gain function that compensates the amplitude attenuation observed which in radargram [13]. This method calculates the Hilbert Transform of each GPR traces which is real values of a complex signal function \( U^C(t) \) which is described as follows.

\[ U^C(t) = u(t) + iH[U(t)] = A(t) \exp[i\Phi(t)] \]  \hspace{1cm} (2)

2.2.5 **Remove Global Background**

Global Background Removal (GBR) is used to reduce trace range giving the actual range of a part. This filter clears the background and removes horizontal coherent energy with low frequency [9].

2.2.6 **Karhunen – Loeve Filter**

Karhuen – Loeve filter uses the Eigen factor and it better to characterize the signal than the sine function. The number of eigenvectors used to perform signal reconstruction without noise depends on the level of complexity. For example, single-frequency signals only require one function [7].

2.3. **Data Interpretation**

Interpretation is done by paying attention to two parameters: void zone and hyperbolic signature pattern. Septic underground tanks contain mostly air (voids) and water/wastewater. Voids have faded colours that known as echo zones on the radargram. Void zone represented by colors that tend to be brighter or blur ('blank', 'faded', or 'dead'). Meanwhile, the hyperbolic signature of the septic tanks has a specific pattern of shape, size and depth. Hyperbolic in GPR can be classified into three forms: cubic, cylindrical, and disc as shown in Figure 2 [8]. In addition, the interpretation is conducted with the aid of trace analysis to distinguish interaction between two different media based on its amplitude pattern (discontinuity and amplitude variation).

![Figure 2](image.png)

**Figure 2.** Types of hyperbolic signature pattern: (a) Cubic (b) Cylindrical (c) Disc [8].

![Figure 3](image.png)

**Figure 3.** Flowchart of the study
3. Results

The results of the processing from raw data to the karhunen loeve filter are shown in Figure 4 below. Figure 4.b shows that the signal on time zero contained on raw data (see Figure 4.a) has been removed. This deletion needed because tool used in measurement does not directly touch the ground, so there is distance between the tool and the ground. Then, continued with filtering process (see Figure 4.c) which is useful for removing DC component, from the figure 4.e we can see that there is not much different from signal position adjustment result. meanwhile, dewow filter (see figure 4.d) is useful for removing noise with low frequency (wow), hence the figure shows that distortion (noise) from the wave have been reduced and it is easier to read.

![Processing of representative GPR data (Line 1)](image)

Figure 4. Processing of representative GPR data (Line 1) consists of (a) Raw Data, (b) Adjust signal position, (c) Remove DC, (d) Dewow, (e) Mean Filter, (f) Inverse Amplitude Decay, (g) Remove Global Background, and (h) Karhunen Loeve Filter.

Next is mean filter (see figure 4.e), we can see that the display become smoother and ringing under the target has gone. On the next step we can see that the signal is more seen because of the strengthen signal process on inverse amplitude decay filter (see Figure 4.f). Then, form figure 4.g we can see that horizontal banding (noise with similar amplitude from the beginning toned of track) has gone. Horizontal banding can occur due to factors from the tool or operator error during the acquisition. The final step before interpretation is filtering process using Karhunen Loeve (see figure 4.h) which shows noise reduction from the previous step and lateral wave coherence increases.
4. Discussion

![Figure 5](image_url)

**Figure 5.** Radargram and Trace Sampling in (a) Line 1 (b) Line 2 (c) Line 3. Red rectangles show the electromagnetic signal attenuation because of the presence of conductive bodies and consider ‘bright’ spots which indicate presence of septic tank casing.

This study using Ground Penetrating Radar (GPR) data which provide subsurface images to detect the presence of septic tanks below the surface that shown in radargram. The GPR method can be used to detect and describe underground septic tanks in the study area by using filters and time to depth conversion to determine the location and reduce the noise.

Based on the radargrams that have been generated from data processing, it can be seen EM waves that reflected produce some attenuation. First thing to do in the interpretation is to distinguish between the void zone and filled zone by looking at the brightness of the color. The voids appeared as a bright spot between darker spots. This step is needed to determine the area of interest in each radargram by indicate it with red rectangle as shown in Figure 5. Based on the theory, typically in GPR, EM waves formed a hyperbola if the object is symmetry. However, in some cases, the difference in the buried object's shape influences the hyperbolic signature pattern (cubic, cylindrical, or disc). In this work, line 1 and 2 indicate the presence of disc-shaped septic tanks, while line 3 shows cubic-shaped septic tanks.

From line 1 radargram, the septic tank is shown clearly on the right by showing the diffraction of EM waves in contrast rather than the surroundings with disc-shaped hyperbolic pattern (Figure 5.a). To ensure the interpretation, then trace analysis is needed. Trace analysis is to scale the amplitude by the magnitude of amplitude between the medium boundaries. It would make easier to determine the difference of medium and boundary that can be seen clearly, such as sediment layer, septic tank casing, and the boundary between concrete layer. Furthermore, septic tank in line 1 has a small void spot which show the septic tank is not fully loaded. Then from line 2 radargram, the septic tank is presented on the right side with disc-shaped hyperbolic pattern (Figure 5.b). The only difference with the line 1 is there is no void spots in septic tank casing. This shows the septic tank is fully loaded with wastewater. Meanwhile from line 3 has a cubic-shaped hyperbolic pattern that indicates as septic tank (Figure 5.c) because the surroundings data is too distorted. In line 3 radargram, it is less certain whether it is fully loaded or empty.

In line 1 (Figure 5.a), the part with a red box or at a length of 3.5 m to 4.6 m is interpreted as a septic tank casing zone that contains air and/or wastewater, whereas in travel time of 1 ns to 13 ns
interpreted as concrete layer and in travel time 13 ns to the bottom interpreted as sediment layer. Then in the line 2 (Figure 5. b) in areas with red boxes or at travel time of 1 ns to 15 ns with a length around 3.75 m to 5.1 m are interpreted as a septic tank casing with full loads because there is no void space. Meanwhile in line 3 that shown in Figure 5. c which is rather difficult to interpret, but it can be estimated that the septic tank casing area is located in areas with red box or in the travel time range of 1 ns to 15 ns and ranges from scan-axis 3.5 m to 4.5 m.

5. Conclusion
Based on this study, all the processing and interpretation georadar data used in this research are proven effective in detecting underground septic tanks in two dimensions. The presence of a septic tank can be detected with georadar data by various filtering, gaining processes, and interpretation the main parameters from all three lines. The septic tank can be estimated with the length of ± 1 meter with the conditions where septic tank in line 1 is not fully loaded while in line 2 septic tank is fully loaded and in line 3 less certain whether it is fully loaded or not.

Acknowledgements
We would like thanks to PT Andalan Tunas Mandiri who already did the ground penetrating radar survey project. We also like to express deep gratitude to Institut Teknologi Sepuluh Nopember for funding, giving support, and license of MATLAB so this paper can be finished properly.

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