

Surface Clutter Reduction for Ground Penetrating Radar

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Abstract

Ground Penetrating Radar (GPR) utilizes electromagnetic waves transmitted to the ground and serve as a non-destructive technique. In the detection process, electromagnetic waves touch the surface clutter and to underground to detect the buried object. Ground reflected signal, called surface clutter, is received along with object reflected signal unexpected. Surface clutter is one of the problem in GPR survey that may caused the difficulty in detecting object. Clutter reduction can improve detection results. Averaging method is one of the methods to improve the detection result. In this experiment, GPR system is modelled using Vector Network Analyzer (VNA) and the averaging method is applied on object object detection which is recognized more clearly. The result obtained after the surface clutter reduction process at 3cm depth is the disruption of the hyperbolic shape from the object due to its position adjacent to the surface clutter. Whereas at 10cm depth, the hyperbolic signal from the object is not disturbed due to its position far from the surface clutter.

Keywords: GPR, surface clutter, VNA, averaging method

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1. Introduction

Lots of activities require information about conditions below the ground surface such as military, civil engineering, and geophysics. In this era, engineers developed a Ground Penetrating Radar (GPR) to complete those activities with a non-destructive method for ground surface. Several functions of GPR are including pipes and detect land mines, concrete thickness measurement, detect void, and evaluate the corrosion [1, 12, 15]. GPR utilizes the principle of scattering of electromagnetic waves to determine the location of a buried object by emits those waves to the ground and receives the echo signals [3]. These echoes are processed and served as detections in form of A-scan or B-scan. A-scan detection is in one dimensional meanwhile, B-scan is in two dimensional [4]. The GPR is modelled by VNA in the experiment. The obtained signal from VNA is a

hyperbolic pattern, which is a superposition of coupling signal, surface clutter signal, and the object signal.

In signal processing, the clutter made the detection performance of GPR limited [5]. Besides, another problem is the backscattering signal from the object, which makes the object that is close to the surface difficult to be detected [6]. One of method for reducing the clutter is average method [13]. This method is a simple method that can increase the accuracy estimation [7, 8]. According to research [12], the average method divided into three, namely realization, angular, and frequency averaging. In realization averaging, the average ensemble obtained from heterogeneous soil surface samples with the same statics. In angular averaging defined as a change in the angle of incidence and angle of scattering. In frequency averaging, it used to simulate the scattering of buried objects

placed under a heterogeneous soil surface.

This study focuses on processing GPR data obtained from the VNA experiment. The experiments are conducted by detecting signal from the buried cans at 3 cm and 10 cm underground which are further called A and scenario B, respectively. In order to avoid problem in detection, clutter reduction was carried out using the averaging method. In this study, the obtained A-scan data is collected into B-scan to determine the presence of clutter, then the range clutter is taken for each A-scan and calculated into Eq. 5. In the final stage of this study, the results of the B-scan in hyperbolic pattern from the object are clearer when the clutter is reduced.

2. Surface Clutter Reduction Method

GPR divided into transmitter block and receiver block. In the transmitter block, there are transmitter antenna and pulse generators. On another side, a receiver block consists of a receiver antenna and a central unit for displaying the final data after post signal processing. Figure 1 explains the working principle of GPR, where the transmitter block, which is pulse generator will produce an electrical pulse with the form of pulse repetition frequency (*prf*), energy, and a certain duration. This pulse transmitted by the transmitter antenna to detect buried objects under the ground surface. In most practical situations, to apply the constant speed technique used to estimate the depth of an object, an estimate can be made based on constants from the ground that correspond to the speed calculated using Eq. (1). The depth of a object (*h*) can be shown in Eq. (2). The reflected result from the electromagnetic wave symbolized by S_1 , S_2 and S_3 which are represented the reflected signal between two antennas, reflected from ground surface and reflected from the object, respectively [12].

$$v = \frac{c}{\sqrt{\epsilon}} \quad (1)$$

where *c* is speed of light and ϵ is relative permittivity.

$$h = \frac{1}{2}vt \quad (2)$$

where *v* is constant velocity and *t* is transit time. Referring to the Figure 1, the receive signal (S_r) can be written as

$$S_r(t) = S_1(t) + S_2(t) + S_3(t) \quad (3)$$

where S_1 is coupling antenna signal directly from antenna to antenna, S_2 is the reflected signal from

the surface and S_3 is the reflected signal from the surface and the buried object.

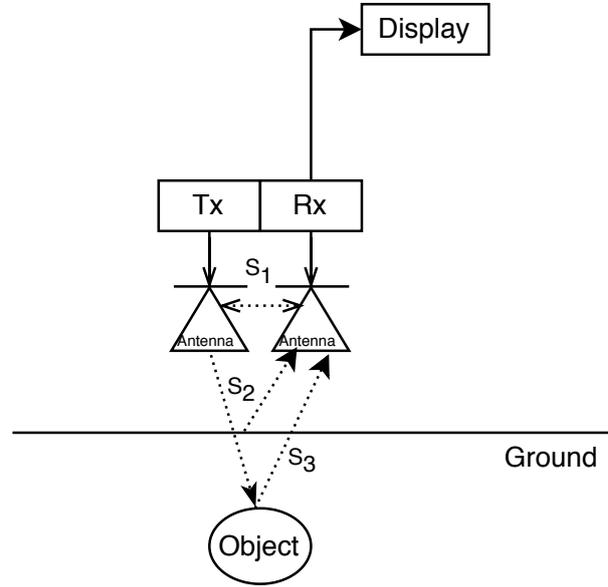


Fig. 1. Illustration of GPR work

This pulse experience attenuation and other signal defects during the propagation on the ground to detect the buried object. The pulse touches the ground surface first, then proceeds to hit the object and reflected into the receiver antenna (Rx). If the ground is homogeneous, the reflected signal clutter is small. If the pulse hits a heterogeneous ground, the reflected signal clutter is bigger than homogeneous. The received signal processed using the software in the central unit and rendered as an image which divided into A-scan, B-scan and C-scan [1, 14].

A-scan signal is the presentation of one dimensional data obtained from stationary measurements and signal collection at the desired position. In Figure 2 there are two axes, namely horizontal axes (*x*) as the surface of the plane and vertical axes (*t*) as the alternating time of electromagnetic waves. The signal transmitted from antennas to the ground surface has time for the signal to reach the bottom of the surface ground to find the whereabouts of buried objects. Each antennas shift has a different receiving time and waveform due to the shape of the layer of the ground detected and how close the signal transmission to the object detected. The main value of A-scan is monitoring data quality control.

$$S_A = S_r(t, x) \quad (4)$$

where S_r is the point from which data was taken, *t* is alternating time of electromagnetic waves, and *x* is the surface ground as in (3).

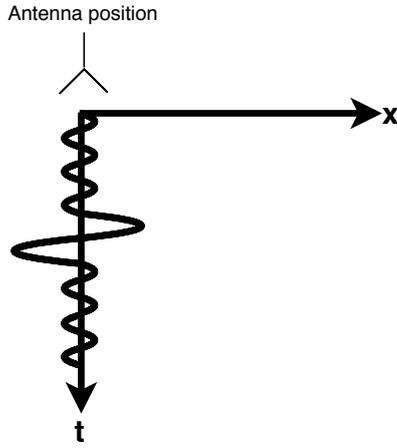


Fig. 2. Presentation of A-scan

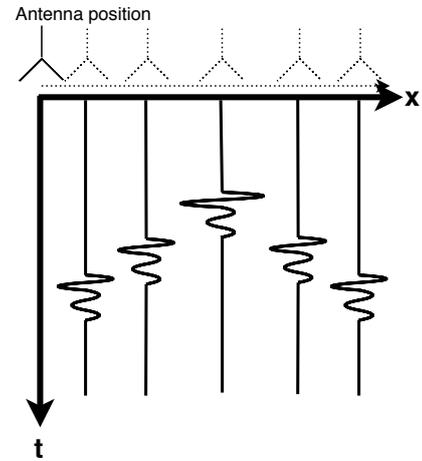


Fig. 3. B-scan signal

On A-scan processing, the form of the received time wave is obtained from the convolution of some time which functions to represent the impulse response of the radar component of the system in addition to noise, then it is accepted in the form of time waves. The impulse response object composed of the convolution from the desired object with other reflections. Some methods that applied in A-scan are zero offset removal, noise reduction, clutter reduction, time-varying gain, frequency filtering, and wavelet optimization or deconvolution techniques [1]. The method in this letter reduces the surface clutter by the averaging method given by Eq. (5).

$$S_A = \frac{1}{n} \sum_{a=1}^n S_2 \quad (5)$$

where n is number of clutter and S_2 is surface clutter.

This method works well for a limited number of objects and is physically separated. The sum of the average values includes contributions from all objects. The greater the number, the less difference is produced. The situation that occurs at the planar interface in the area of interest, has the effect of removing part of the wavelength [1].

B-scan signal is a presentation of two dimensional data obtained from the collection of A-scan on the horizontal axis. Another term for two-dimensional data is radar profile or radargram [11]. The horizontal axis in Figure 3 is the surface position and the vertical axis is the alternating time of electromagnetic waves. The B-scan used to assure the depth of the object under the ground [1].

Data collection for detecting buried objects using GPR modeled by VNA shown in Figure 4. VNA sends electromagnetic waves to the object

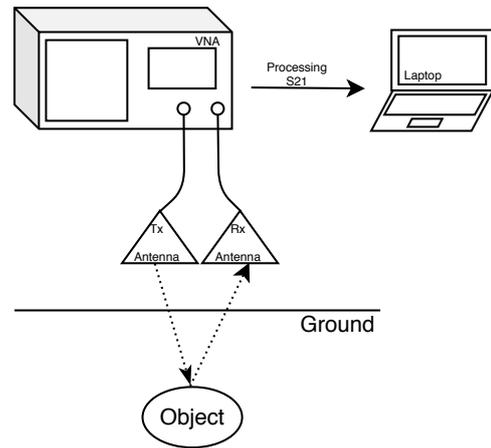


Fig. 4. Modelling using VNA

through the transmitter antenna (Tx) and received by receiver antenna (Rx), which displayed on the VNA monitor. In this experiment, the scattering parameter used is S_{21} , where port 1 and port 2 respectively used for the transmitter antenna and the receiver antenna. Collected data by VNA arranged in polar form with real imaginary mode ($R + Im$) and stored as a CSV file format [10]. The formula used to represent VNA when retrieving S_{21} data shown in Eq. (6).

$$H(f) = \frac{S_r(f)}{S_t(f)} \quad (6)$$

where $H(f)$ is represent S_{21} , $S_t(f)$ is transmitted signal, and $S_r(f)$ is received signal. The S_{21} data received from the GPR signal can be recruited using the IFFT relationship written as Eq. (7).

$$S_r(t) = F^{-1}[S_{21}(f)S_i(f)] \quad (7)$$

where S_i is the fourier transform of the monocycle signal as a waveform test. The monocycle signal

is written as Eq. (8).

$$S_i(t) = \frac{1}{\sigma\sqrt{2\pi}}(t - \tau)\exp\frac{(t - \tau)^2}{2\sigma^2} \quad (8)$$

where t is scaling parameter that sets the pulse width and s is shift parameter for pulse location.

3. Design of Experiment

Data collected in the sandbox that placed outside the room. The experiment setup is shown in Figure 5. The sandbox is constructed from wood and has no impact on the measurement result. Meanwhile, the sand is heterogeneous. The size of sandbox used is $1 \times 1 \times 1$ m and t_p is 50 cm. The used antenna type is Vivaldi with a range frequency of 1-10 GHz, where the distance between the antennas (d) is 8 cm. The distance between the antenna to the ground surface is 12 cm. The range frequency of VNA is 0.3-8000 MHz.

In this experiment, the object used is a cylindrical and conductive can. It has dimensions of 5 cm and 13 cm in diameter and height, respectively. This experiment has two scenarios, which are scenario A where the object buried 3 cm under the surface and scenario B where the object buried 10 cm under the surface.

The A-scan data obtained by scanning one point to get the signal and then scanning it in another point to get the B-scan data. Data processing undergoes several processes, namely A-scan and B-scan. The process is carried out sequentially.

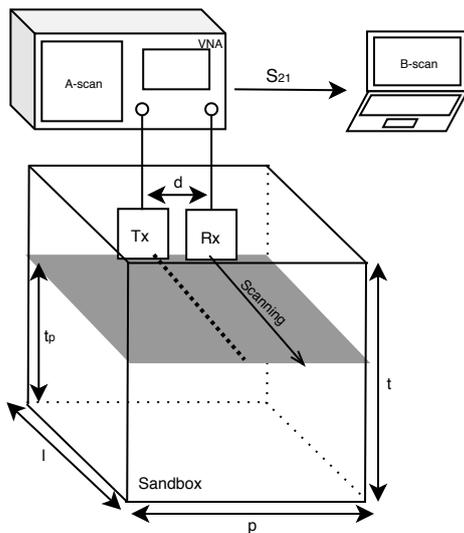


Fig. 5. Experiment design

4. Result and Discussion

The reduction of surface clutter can be if seen from the quality of the reflected signal B-scan quantitatively and qualitatively. Qualitatively, reducing surface clutter can affect the level of clarity of reflected objects in the form of hyperbolic pattern where the surface clutter reduced B-scan show clearer results than original B-scan. The quantitatively is to view the accuracy of the object's position.

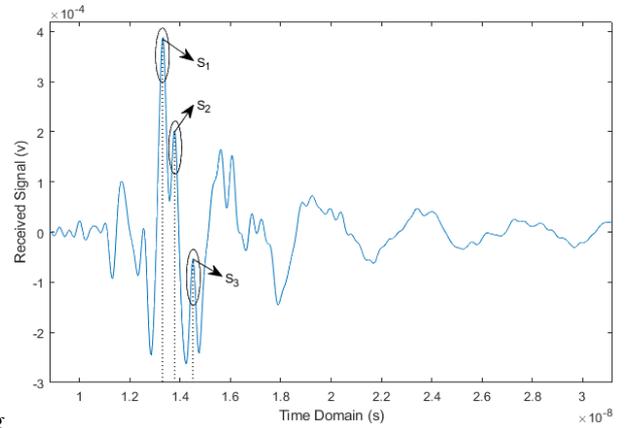


Fig. 6. A-scan of scenario A

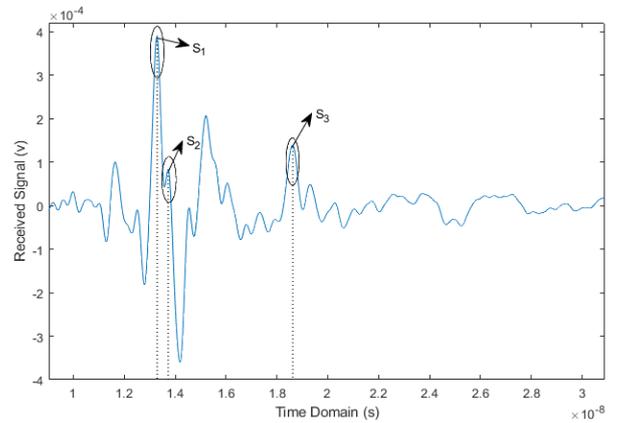


Fig. 7. A-scan of scenario B

A-scan conditions in A and B scenario, display the value of the signal received when detecting object buried in different depths. The result of taking a single point data show in sequence. Changing the sequence into time-domain needs to be done to ensure that the signal received from the objects reflection during the experiment is similar to the actual objects position. Figure 8, shows the result of the A-scan signal with S_1 , S_2 , and S_3 peaks at 1.333×10^{-8} second, 1.379×10^{-8} second, and 1.4451×10^{-8} second, respectively. The distance between the antennas and the surface

ground is calculated by using $\Delta S_1 S_2$ is 0.46×10^{-9} second and the $\Delta S_2 S_3$ is 0.72×10^{-9} second times speed of light (c) divided by two. On the other hand, in Figure 7 shows the result of the B-scan signal with S_1 , S_2 , and S_3 peaks at 1.329×10^{-8} second, 1.376×10^{-8} second, and 1.861×10^{-8} second. The distance between the antennas and the surface ground is calculated by using $\Delta S_1 S_2$ of 0.47×10^{-9} second and the $\Delta S_2 S_3$ of 4.85×10^{-9} second times speed of light (c) divided by two.

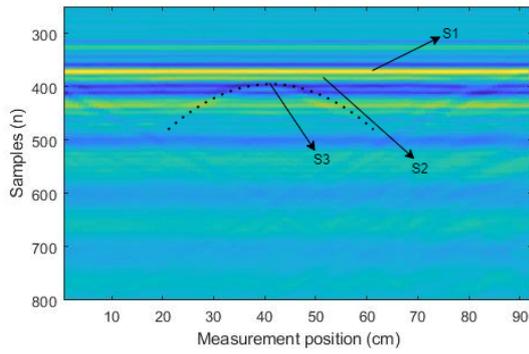


Fig. 8. B-scan of scenario A

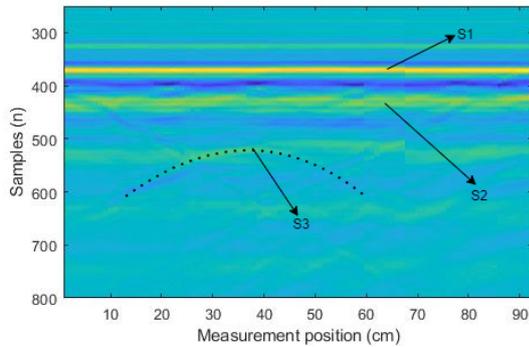


Fig. 9. B-scan of scenario B

Quantitatively, the depth of scenario A is calculated using Eq. (2) with the velocity value of $84.75 \times 10^6 m/s$ and alternating time of $2.36 \times 10^{-9} s$. The real depth of the antenna to the object is 10 cm, however the estimated value for depth is 10.0005 cm. It means the accuracy of scenario A is 99.95%. On the other hand, in scenario B, the velocity value used of $144.07 \times 10^6 m/s$ and an alternating time of $10.64 \times 10^{-9} s$. The real distance between the antenna and the object is 17 cm, however the estimated distance of 17.00272 cm. It means the accuracy of scenario A is 99.728%. The difference in velocity produced by two scenarios is caused by heterogeneous ground.

The experiments show that the position of the object affects the interpretation and distance of

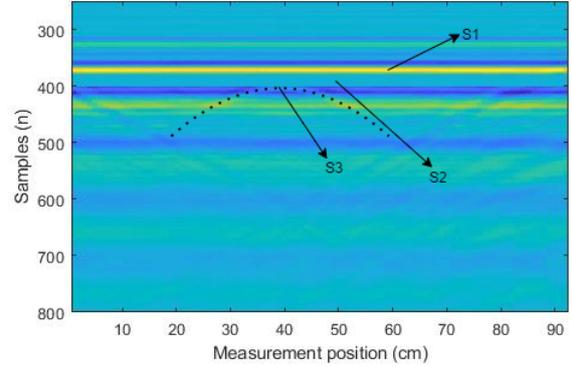


Fig. 10. scenario A without surface clutter

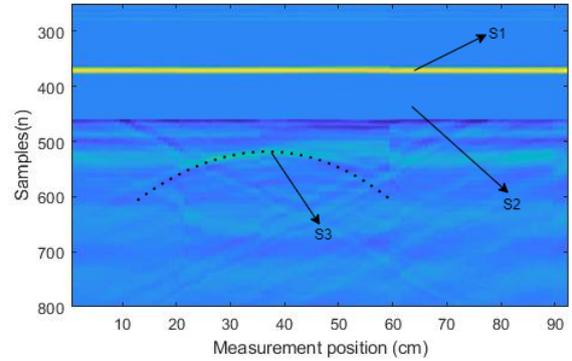


Fig. 11. scenario B without surface clutter

the reflected signal generated from the object and the surface reflection signal. In scenario A, the difference between object reflection and surface reflection is difficult to distinguish because the object's distance is too close, but the interpretation of the signal is clearer, as shown in Figure 8. The dotted lines on the B-scan result indicate that at the peak of the hyperbolic shape, indicating a detected object. While in scenario B, the interpretation of the signal is more subtle than scenario A, but the distance between the surface reflection signal and the object reflection signal is further apart that makes it easier to distinguish, details can be seen in Figure 9.

The process of reducing surface clutter is provided on the results of scenarios A and B by using Eq. (5). In scenario A, the reduction of surface clutter is more difficult because the distance between the surface reflection clutter and the object reflection is also reduced in the process as shown in Figure 10. While, in scenario B, surface clutter is easier to reduce because of the distance between the object's reflection and the surface reflection is wider so that the results of the hyperbolic pattern from the object's reflection are not disturbed as

shown in Figure 11.

5. Conclusion

This study focuses on the effect of object depth on reduce the clutter. Further depth variation is necessary to be studied to obtain more comprehensive results. At 3cm depth, the process of reducing surface clutter is more difficult due to the close distance between the surface clutter and the object and not all surface clutter is reduced because it affects the hyperbolic signal of the object. In contrast, the process of reducing surface clutter at 10cm depth is easier because the long distance between the surface clutter and the object.

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