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The effectiveness of Ground Penetrating Radar in detecting buried objects

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Abstract: Reliable information such as the position of buried utilities underneath the ground is an important ingredient in any undertaking. The most difficult part of obtaining information about buried objects or utility lines is that very little is visible. Existing drawings, plans or information can sometimes be obtained from relevant parties but many times they are inaccurate, faulty or incomplete. A suitable technique such as GPR, ultrasonic, and IR Imaging has to be used to obtain the information from underground.
In this paper we are going to discuss the effectiveness of the Ground Penetrating Radar (GPR) to detect an underground objects such as concrete, voids, cavities, pipes, bones, etc. These objects were buried at a known depth and location. Data that collected can be interpreted after applying simple processing or data enhancement such as band-pass filter and AGC. Depth conversion was also done to convert the time to depth section. The result shows all the objects can be detected however an experience operator manages is needed to predict the depth and the width of each object.

Abstrak: Maklumat yang tepat berkaitan dengan kedudukan dan kedalaman objek-objek tertanam adalah penting sebelum sesuatu kerja pengorekan dilakukan. Maklumat ini sukar diperolehi. Kebiasaannya peta-peta atau rekod-rekod penanaman objek merupakan sumber rujukan awal, walau bagaimana pun rekod-rekod ini kadangkala ketinggalan zaman dan sukar diperolehi. Oleh itu teknik-teknik pengesanan seperti GPR, ultrasonic, dan Pengimejahan IR mestilah dilakukan terlebih dahulu.
Dalam kertas kerja ini, kami akan membincangkan keberkesanan teknik Radar Penembusan Bumi (Ground Penetrating Radar, GPR) bagi mengesan objek yang ditanam seperti kepingan kinkrit, lohong (tong plastik), batang paip dan juga tulang lembu. Bahan bahan ini ditanam terlebih dahulu dan rekod penanamannya seperti lokasi dan kedalaman direkodkan. Data yang diambil boleh ditafsirkan sebaik sahaja pemprosessan mudah seperti penurasan dan peningkatan signal dilakukan. Penukaran masa kedalaman juga dilakukan bagi mendapatkan maklumat kedalaman. Hasil kajian mendapati semua objek yang ditanam dapat dikesan, walau bagaimana pun kecekapan dan pengalaman diperlukan bagi mendapatkan kedalaman dan kelabaran yang tepat untuk setiap objek.

INTRODUCTION

Ground penetrating Radar (GPR) is the general term applied to techniques which employ high frequency radio waves to map structures and objects beneath the ground. Historically the usage of GPR technique only focuses on the mapping of underground structures; however in recent years this technique has been used in all sort of applications, even in the non-destructive testing of non-metallic structures (Annan, 1999).

The GPR technique uses the basic reflection seismic concept, in which instead of using the seismic waves, it uses a radiating antenna to generate electromagnetic waves, which are transmitted into the subsurface. Depending on the changes in the electrical properties of the medium that it travels in, it will be reflected, transmitted or diffracted before returning to the surface. A receiving antenna will detect the returned energy and used it to reconstruct a signal in time domain. Figure 1 shows a series of reflected energy in seismic reflection format. By applying an amplitude window to the reflected energy, the signal received will be displayed in the computer screen as shown in Figure 1 (right).

The returned GPR reflection pattern can be classified into two basic types, which are point source diffraction hyperbola, and high contrast continuous plane reflection patterns. The reflections signals indicate the arrival time of a signal propagating through the medium to the target/ object and reflected back to the surface. This travelled time is known as Two-Way-Time (TWT).

The depth of the reflector can be calculated using a simple equation (Eq. 1)

$$d = \frac{vt}{2} \qquad \text{Eq. 1}$$

where d = depth; t = two way reflected time; and v = velocity

The velocity used in calculating the depth is neither fixed nor constant, and is dependent directly on the electrical properties (dielectric constant, e) of the medium crossed. A rough estimation of the (v) value for low conductivity materials is given as

$$v = \frac{c}{\sqrt{\varepsilon}} \qquad \text{Eq. 2}$$

where c = velocity of electromagnetic wave in vacuum; and ε = dielectric constant

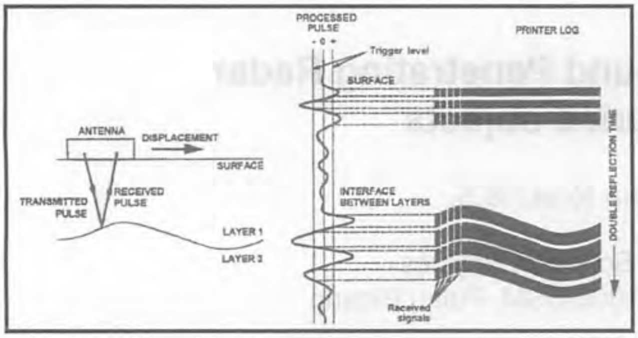

Figure 1. The reflected energy (signal) received displayed in the computer screen.

Table 1. List of the (ε) value for various materials.

Object / materials	(ε) value
Air	1
Fresh Water	80
Sea Water	80
Dry Sand	3-5
Saturated Sand	20-30
Clay	3-40
Granite	4-6
Limestone	4-8

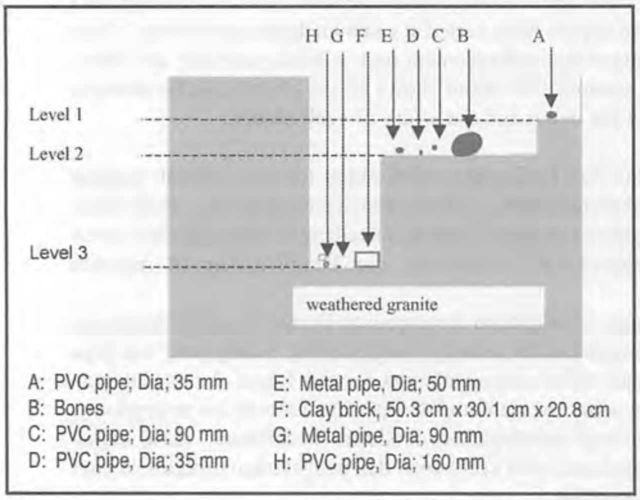

Figure 2. The cross section of the trench with relevant objects buried at different levels.

Table 2. List of the objects buried with respective depth.

	Object	Level & Depth (m)
A	35mm PVC pipe	L1; 0.6
B	Bone	L2; 1.3
C	90mm PVC pipe	L2; 1.3
D	35mm, PVC pipe	L2; 1.3
E	50mm steel pipe	L2; 1.3
F	Clay bricks	L3; 2.5
G	90mm steel pipe	L3; 2.5
H	160mm PVC pipe	L3; 2.5

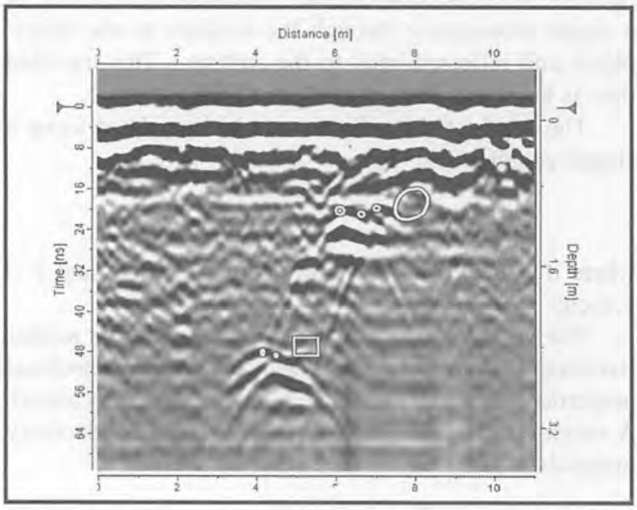

Figure 3. This example shows the results from GPR test site in USM containing various objects of different materials and at different depths.

Table 3. Comparison between the depth buried and the depth from the section for selective objects.

Object	Actual depth, m	Depth from section, m	Differences, m (Accuracy, %)
35mm PVC pipe	0.6	0.4	.2 (67%)
Bone	1.3	1.1-1.0	.2 (84.6%)
90mm PVC pipe	1.3	1.1	.2 (84.6%)
35mm, PVC pipe	1.3	1.2	.1 (92.3%)
50mm steel pipe	1.3	1.2	.1 (92.3%)
Clay bricks	2.5	2.2	.3 (88%)
90mm steel pipe	2.5	2.4	.1 (96%)
160mm PVC pipe	2.5	2.3	.2 (92%)

This equation (Eq. 2) shows the importance of knowing (ε) in order to estimate the velocity of EM wave travelled through the medium. Table 1 listed the (ε) value for various materials.

The main purpose of this work is to evaluate the effectiveness of GPR in locating a known objects buried at different depth.

THE SITE

A trench with three levels of depth was dug at an USM test field. The site is a weathered granite layer. On each level, different materials such as steel and PVC pipes of various size, a bone, clay bricks and drums were placed and marked before the trench was covered back using the excavated materials (Table 2). The cross section of the trench with relevant object buried at different level is shown in Figure 2.

Several lines of GPR survey were run through the target area to detect the location of those buried objects using the RAMAC/GPR system and 250 MHz antennas. The result of this survey is given in the Figure 3.

DISCUSSION AND CONCLUSIONS

Since the survey lines were run perpendicular to the length of the objects, they can be consider as a point source and the hyperbola diffraction pattern should be expected on the GPR sections. At least seven hyperbolas of different sizes can be seen on the section. Different responses are observed from the different buried materials and the reflection from the sidewall. The depth of those objects can be determined with an accuracy of 90% (Table 3).

The differences in the value measured from the section and the buried depth may be is due to the way the depth measurement is done. For the buried depth, it was measured down to the terrace level, where as the depth from the section was measured up to the peak of the hyperbola only (i.e. the top portion of the objects).

As a conclusion, this GPR technique is very useful to engineering, archaeology, and any shallow investigation works. It can be used to detect object underneath the ground to avoid accident while doing construction or other work.

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REFERENCE

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