Detection of Subsurface Pipes by Using Ground Penetrating Radar (GPR) in Selected Area at University of Baghdad

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Abstract

In this study (250 and 500)MHz antennas frequencies were used to perform eleven profile approximately perpendicular to the expected pipes at two areas to get the best subsurface picture. In the first area there are five profiles were chosen for interpretation, the pipe was found nearly at a depth of about 1.50m. in a location (4.14m.- 5.43m.) from the beginning of the profile using 250 MHz antenna, while it was found at a depth of 1.50m in a location 4.11m.- 4.76m. using 500 MHz. The second area (stadium) there are six profiles were chosen for interpretation , the pipe was found nearly at a depth of 1.30 m in a location 17.69m- 23.85m. from beginning of the profile using 250 MHz, antenna. while the pipe depth was about 1.30m. and its location was found to be between 18.6m.–21.45m. for 500 MHz .The results showed that the pipes were located at different depths and that they incised the study areas in slanted manner, and the results that have been reached in this research are differ with the engineering maps of the University of Baghdad with a slight difference of (2) meters.

Key Words: Ground Penetrating Radar, Subsurface Pipes and Geophysical Methods.

التحري عن الانابيب تحت السطحيةِ استخدامِ تقنية رادار الاختراق الارضي في موقع مختار في جامعة بغداد

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الخلاصة

استخدم في هذه الدراسةِ هوائيان ذات تردد (250 MHz و 500 MHz) وتضمنت اجراء قياسات على امتداد احد عشر مساراً عمودياً على الاتجاه المتوقع للانابيب الموجودة في موقعين ضمن موقع الدراسة . في الموقع الاول اختيرت خمسة مسارات لاغراض التحليل ووجد ان الانبوب يقع على عمق (1,50m) عند مسافة(4,14 m م – 5,43) من نقطة البدائية باستخدام هوائي ذي تردد 250 MHz ، وعلى عمق (1,50m) عند مسافة (4,11m م – 4,76) من نقطة البداية باستخدام هوائي ذي تردد 500 MHz . اما في الموقع الثاني فقد اختيرت ستة مسارات لاغراض التحليل ووجد ان الانبوب يقع على عمق(1,30 m) عند المسافة 17,69 م – 23,85 م من نقطة البداية باستخدام هوائي بتردد 250 MHz ، وعلى عمق (1,30 m) عند مسافة (18,6m – 21,45) من نقطة الانطلاق باستخدام هوائي بتردد 500 MHz . لقد بينت النتائج ان الانابيب تقع على اعماق مختلفة وانها تقطع منطقتي الدراسة بصورة مائلة. تم مقارنة مواقع الانابيب المستحصلة من الدراسة مع مواقعها المثبتة في الخرائط الاساس فوجد ان هناك اختلاف في الموقع المحدد بواسطة الرادار الارضي عن الموقع المثبت في الخرائط الهندسية للجامعة بحدود (2م).

الكلمات المفتاحية: رادار الاختراق الارضي ، انابيب تحت سطحية و الطرق الجيوفيزيائية.

Introduction

The primary economic loss comes from the cost of raw water, its treatment, and transportation. Leakage inevitably also results in secondary economic loss in the form of damage to the distribution network itself (e.g. erosion of pipe bedding and major pipe breaks) and to the foundations of roads and other man-made structures. Leaky pipes also create a public health risk, as every leak is a potential entry point for contaminants if pressure should drop in the system. Economic cost and scarcity of public water sources mandate that a systemic leakage control program be developed. In such a program, there are two components: water audits and pipe detection surveys. The GPR geophysical method is a rapid, high-resolution tool for non-invasive subsurface investigation. The ability of geophysical methods to detect pipes and cables depends on the material from which it was made, its size, depth, and proximity to other sources of "noise" that may mask the signal from the detection equipment. GPR produces electromagnetic radiation that propagates through the ground then returns to the surface.

GPR can, in principle, identify buried water pipes either by detecting underground voids created by the leaking water as it erodes the material around the pipe, or by detecting anomalous change in the properties of the material around pipes due to water saturation. GPR unlike acoustic methods could have a higher potential of avoiding difficulties encountered with commonly used acoustic pipes detection methods as it applies to plastic pipes (Hunaidi and Giamou, 1998).

The aim of the study is the detection of buried pipes by using nondestructive technique.

Materials and methods

Location of Study Area

The area of study lies within University of Baghdad, which is located in the southern part of province of Baghdad, to the east of the Tigris River. The work was carried out in two areas. It includes two locations inside Baghdad University; the first location lies in the college of science, Department of Physics, and is located by latitude 33° 16´29.33" N to 33°16´28.72"N and longitude 44°.22´49.01"E to 44° 22´ 49.25" E. The second location lies in the football stadium which is determined by latitude 33°16´ 25" N to 33°16´25.09" N and longitude 44°22´34.12" E to 44°22´44.21" E, as shown in figure (1) and figure (2).

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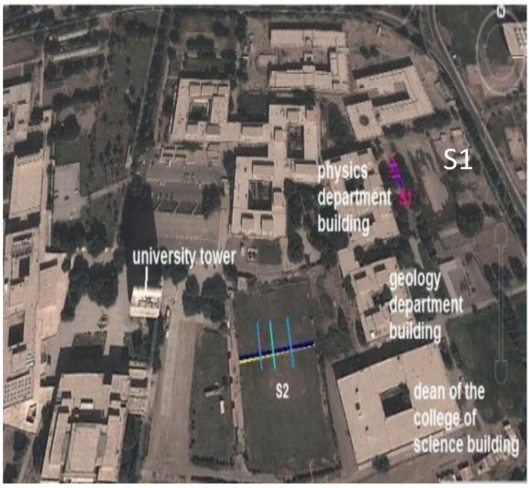


Fig. (1) Photo Shows the Locations of Area S1 and Area S2 Inside the Campus of the University of Baghdad.

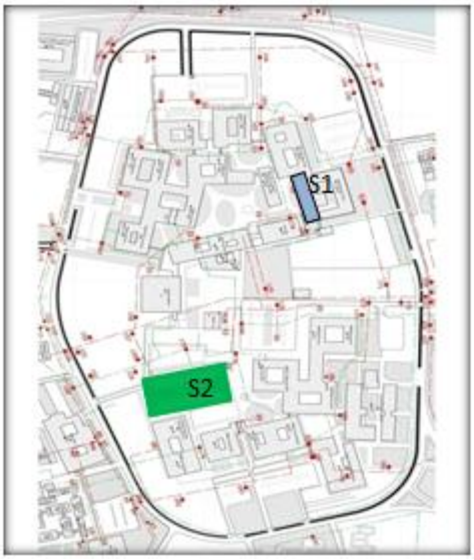


Fig. (2) The Map Locations of the First Study Area (S1) and Second Study Area (S2).

Theory of Ground Penetrating Radar

The foundations of GPR lie in electromagnetic (EM) theory, the history of this field spans more than two centuries (Annan, 2001 and Harry, 2009). A typical GPR system has some main components: transmitter and receiver that are directly connected to an antenna and a control unit as well as the recording and display unit figure (3), for most GPR applications; an electromagnetic field is excited by causing electrical currents to flow on metal structures called antennas (Basson, 2000 and Weaver, 2006). The transmitter antenna is designed to radiate the electric signal with fidelity and generate the pulse that enters into the ground. While the receiver antenna is designed to pick-up, the reflected pulses and transform it to electric signals (Kun, *et al.*, 2009) ;(Uduwawala, *et al.*, 2005). The receiving antenna is usually identical to the transmitting antenna (Annan, 2001).

Maxwell's equations mathematically describe the physics of EM fields, while constitutive relationships quantify material properties. Combining the two provides the foundations for quantitatively describing GPR signals in mathematical terms; EM fields and relationships are expressed as follows:

$$\overline{\nabla} \times \overline{E} = -\frac{\partial \overline{B}}{\partial t}$$

$$\overline{\nabla} \times \overline{H} = \overline{J} + \frac{\partial \overline{D}}{\partial t}$$

$$\overline{\nabla} \cdot \overline{D} = q$$

$$\overline{\nabla} \cdot \overline{B} = 0$$

Where:

$\overline{E}$ = th ngth vector.

q= the electric charge density.

$\overline{B}$ = the magnetic flux density vector.

$\overline{J}$ = the electric current density vector.

$\overline{D}$ = the electric displacement vector.

t = time.

$\vec{H}$ = the magnetic field intensity.

∇ Laplace factor

For GPR, the electrical and magnetic properties are of importance. Constitutive equations, description of how electrons, atoms, and molecules respond in mass to the application of an EM field.

$$\overline{J} = \tilde{\sigma}\overline{E}$$

$$\overline{D} = \tilde{\varepsilon}\overline{E}$$

$$\overline{B} = \tilde{\mu}\overline{H}$$

Electrical conductivity $\tilde{\sigma}$
Dielectric permittivity $\tilde{\varepsilon}$
Magnetic permeability $\tilde{\mu}$

Electrical conductivity characterizes free charge movement (creating electric current) when an electric field is present. Resistance to charge flow leads to energy dissipation. Dielectric permittivity characterizes displacement of charge constrained in a material structure to the presence of an electric field. Magnetic permeability describes how intrinsic atomic and molecular magnetic moments respond to a magnetic field. For simple materials, distorting intrinsic magnetic moments store energy in the material, (Santamarina, *et al.*, 2001).

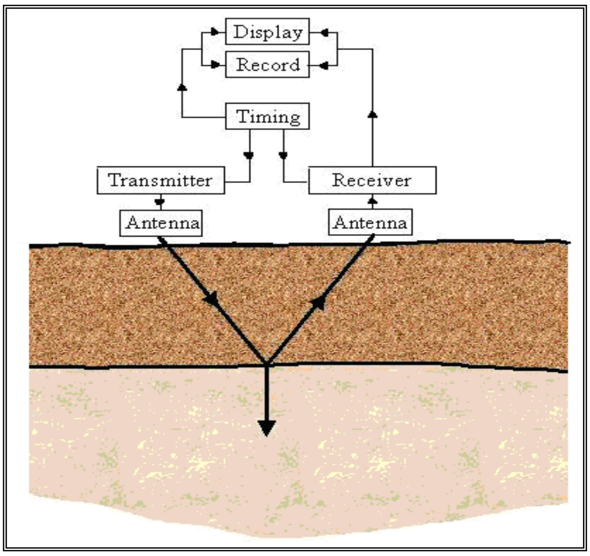


Fig. (3) GPR System (Basson, 2000)

The most common display of GPR data is one showing signal versus amplitude and this form is called a trace. This trace consists of the transmitted energy pulse followed by pulses that are received from reflecting objects or layers. When the antenna is moved along a survey line, a series of traces are collected at separated points along the line. These traces are stacked-up side by side to form a display profile called radar section (Radar-gram) or B-scan (Daniels, 2000). The recorded signals are displayed on a graphic recorder determined by the operator, figure (4). The received signals are displayed as a function of their two-way travel time, i.e. the time taken from instant of transmission to time of detection by the receiver (Reynolds, 1997).

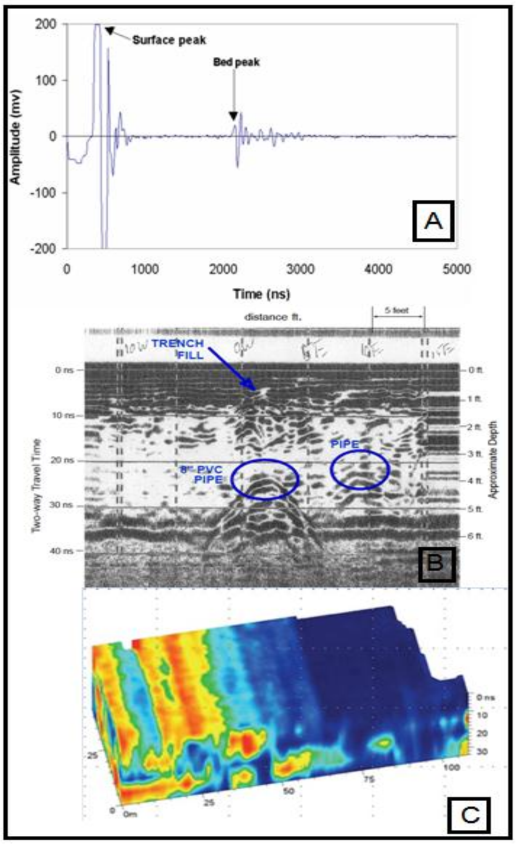


Fig. (4) The Display Modes of GPR Systems; A, Trace Mode; B, Radar Gram Mode; C, 3-D Diagrams (Harry, 2009).

Field work

Ground pentrating radar survey carried out by using the instruments from MALA company, type (RAMAC) with shielded-type antennas. Many profiles were taken perpendicular to the expected pipe location depending on the engineering maps of the University of Baghdad at two selected areas. Figure (5) shows the field work in the stadium area.

Fig. (5) The Field Work in the Stadium of Baghdad University.

The interpretation is done by applying DC , band pass , automatic gain and background removal filters. Three test profiles were performed in the first area using 250MHz and 9 testing profiles by using 500 MHz antennas to reach the perfect picture. The interpretation is done by taking five profiles (3 profiles by 250MHz and 2 profiles by 500 MHz) perpendicular to the pipe direction with spacing between adjacent profiles 3 meters, as shown in figure (6).

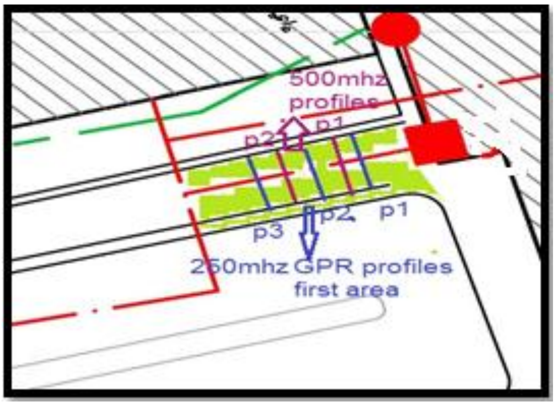


Fig. (6) The Location of the 250 and 500MHz Profiles in the First Area.

Five test profiles were performed in the second area (stadium) (3profiles by 500 MHz and 2 profiles by 250MHz) perpendicular to the pipe direction. The interpretation in the stadium is done by taking six profiles (3 profiles by 250 MHz and 3 profiles by 500 MHz) as shown in Figure (7).

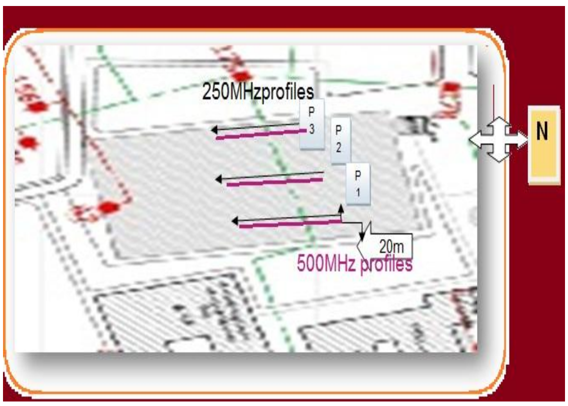


Fig. (7) The Locations of the GPR Profiles in the Second Area.

Results and Discussions

1- First Area (The Garden of Physics Dept.)

Five profiles were applied in this area, three by using 250 MHz antenna and two by using 500 MHz antenna. Figures from (8 to 12) show the radar grams for these profiles. Tables (1) shows the measurement information and table (2) shows the depth and location which found from these profiles.

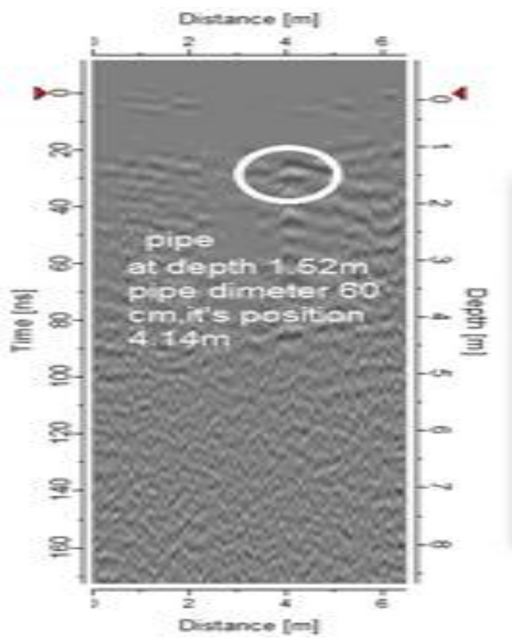
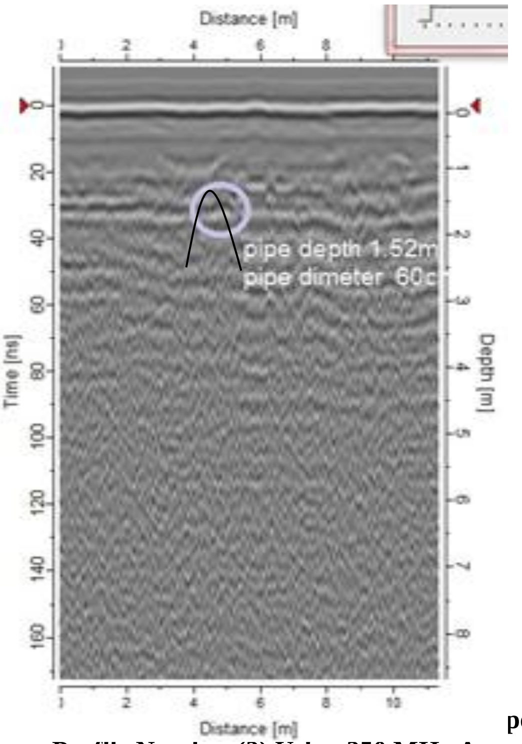


Fig. (8) Reflection of the Buried Pipe in Profile Number (1) by 250 MHz Antenna.



pe in Profile Number (2) Using 250 MHz Antenna.

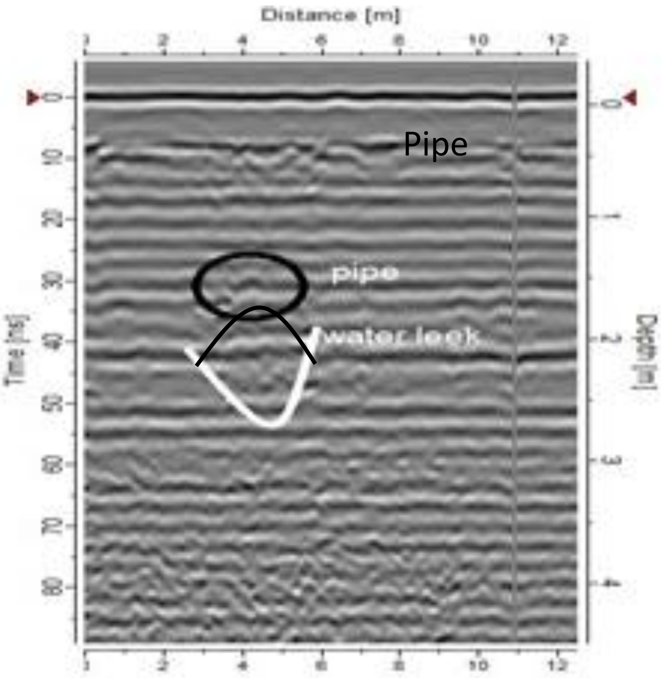


Fig. (11) The Reflection of the Buried Pipe in Profile Number (4) by 500 MHz Antenna

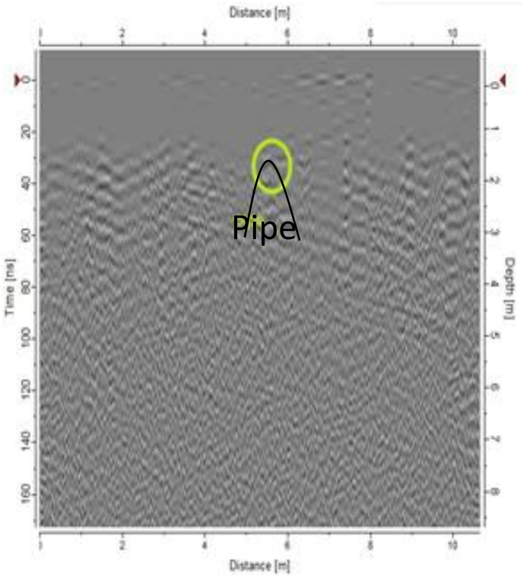


Fig. (10) The Reflection of the Buried Pipe in Profile Number (3) by 250 MHz Antenna

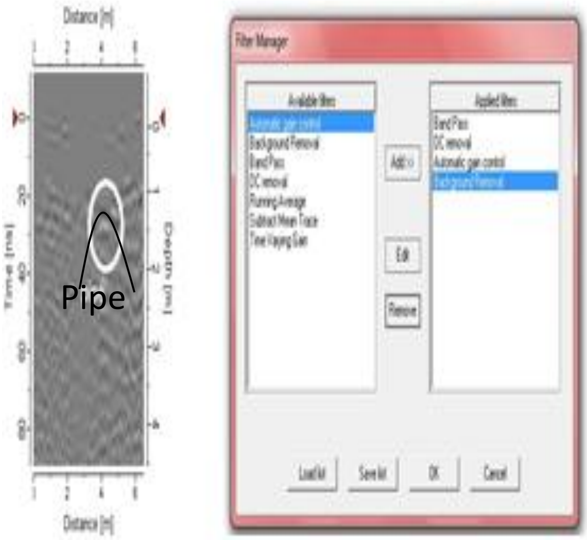


Fig. (12) Reflection of the Buried Pipe in Profile Number (5) 500 MHz Antenna

Table (1) The Measurements and Information for these Profiles.

	Profile No.1	Profile No.2	Profile No.3	Profile No.4	Profile No.5
Antenna name	250 MHz	250 MHz	250 MHz	500 MHz	500 MHz
Sampling freq.	2607	2607	2607	6513	6513
No. of sampling	512	512	512	400	400
No. of Stacks	4	4	4	4	4
No. of traces	166	289	524	262	166
Time window	196ns	196ns	196ns	101ns	101ns
Trace interval	0.039m.	0.029m.	0.020m.	0.048m.	0.039m.
An. separation	0.360m.	0.360m.	0.360m.	0.180m.	0.180m.
Filters used	-DC filter -Band Pass -Automatic gain -Subtract mean	-DC filter -Band Pass filter -Automatic gain filter	-DC filter -Band Pass filter -Automatic Gain filter -Background removal	-DC filter -Band Pass filter -Automatic gain filter -Running average	-DC filter -Band Pass -Automatic gain filter -Background removal

Table (2) Shows the Depth and Location Which Found from these Profiles

Profile No.	Depth of pipe	Location from Zero point
1	1.5 m.	4.14m.
2	1.5m.	4.76m.
3	1.5m.	5.43m.
4	1.5m.	4.13-4.73m.
5	1.53m.	4.11-4.63m.

1- Second Area (Stadium)

Six profiles were applied in this area, three by using 250 MHz antenna and three by using 500 MHz antenna. Figures from (13 to 18) shows the radar-gram for these profiles. Tables (3) shows the measurements information and table (4) shows the depths and locations which have been found from these profiles.

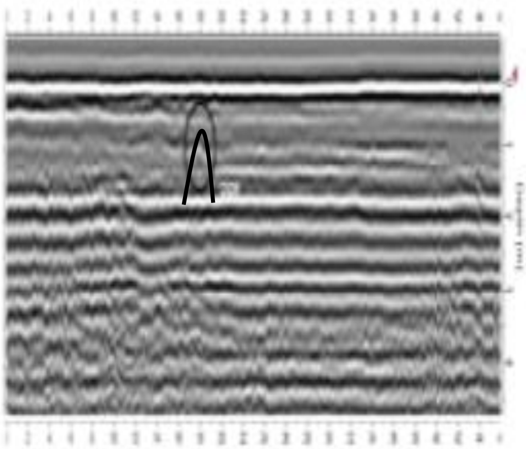


Fig. (13) The location of Subsurface Pipe in Profile Number (1).

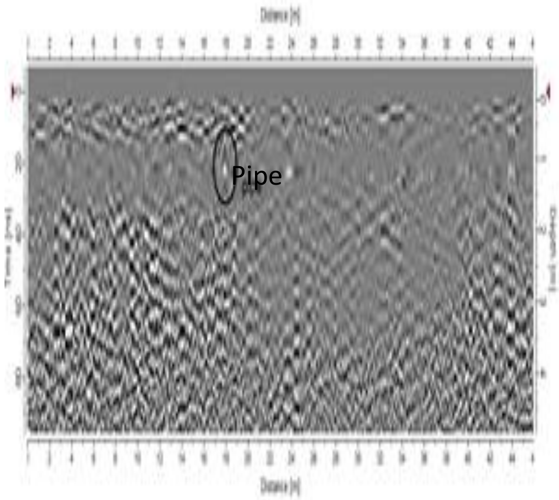


Fig. (14) The location of Subsurface Pipe in Profile Number (2).

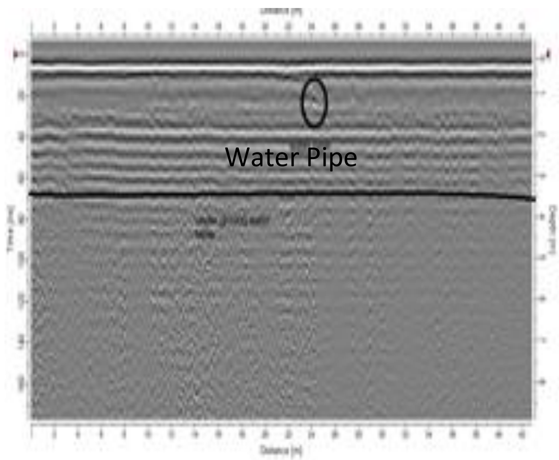


Fig. (15) The location of Subsurface Pipe in Profile Number (3).

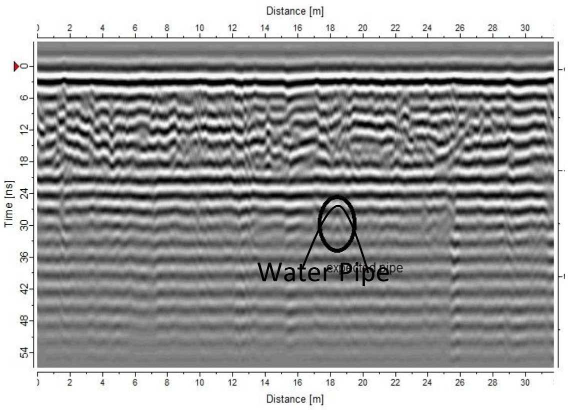


Fig. (16) The location of Subsurface Pipe in Profile Number (4).

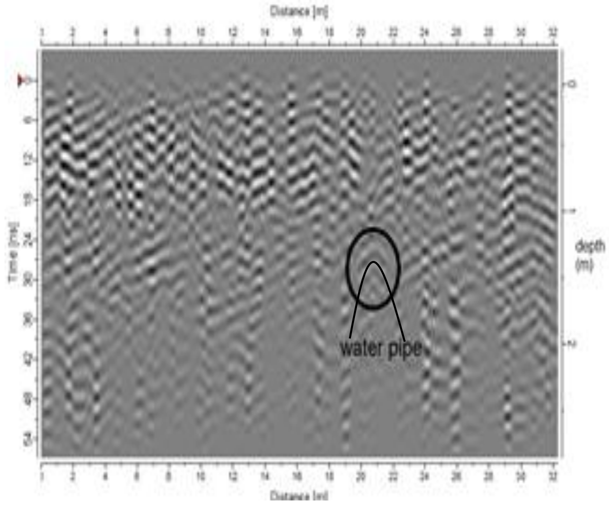


Fig. (17) The location of Subsurface Pipe in Profile Number (5).

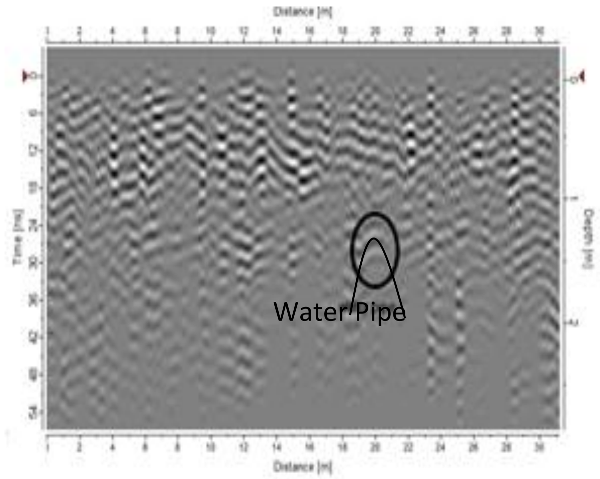


Fig. (18) The location of Subsurface Pipe in Profile Number (6).

Table (3) Shows the Measurement Information for these Profiles

	Profile No.1	Profile No.2	Profile No.3	Profile No.4	Profile No.5	Profile No.6
Antenna name	250 MHz	250 MHz	250 MHz	500 MHz	500 MHz	500 MHz
Sampling freq.	2607	2607	2607	6513	6513	6513
No. of sampling	512	512	512	400	400	400
No. of Stacks	8	8	8	8	8	8
No. of traces	962	962	897	665	677	64
Time window	196ns	196ns	196ns	61ns	61ns	61ns
Trace interval	0.048m.	0.048m.	0.048m.	0.048m.	0.048m.	0.048m.
An. separation	0.360m.	0.360m.	0.360m.	0.110m.	0.110m.	0.110m.
Filters used	-DC filter -Band Pass -Automatic gain	-DC filter -Band Pass -Automatic gain filter Background removal	-DC filter -Band Pass filter -Automatic Gain filter	-DC filter -Band Pass filter -Automatic gain filter	-DC filter -Band Pass -Automatic gain filter -Background removal	-DC filter -Band Pass -Automatic gain filter -Background removal Running average

Table (4) Shows the Depths and Locations which are Found from these Profiles.

Profile No.	Depth of pipe	Location from Zero point
1	1.35 m.	17.65m.
2	1.30m.	18.95m.
3	1.31m.	23.85m.
4	1.35m.	18.65m.
5	1.33m.	20.15m.
6	1.30m.	21.45m.

Conclusions

The GPR technique was used in this study for detecting the subsurface pipes at shallow depths within two sites in Baghdad University, Al-Jadriya region. The conclusions of this study can be briefed as following:

From testing by GPR in both areas and by changing the values of sampling frequency the best image gotten are when the sampling frequency is 2607 by using the

The use of antennas with frequency (250 and 500)MHz was successful in the detection of pipes and locate them as these antennas with wavelength (59 , 118 cm.) suitable for the identification of targets of small dimensions and sizes as well as penetrability of soil that does not exceed 2 m. in the soil specifications in Iraq, which has high electrical conductivity of the high content of salts and high relative humidity.

250MHz antenna and when the sampling frequency is 6513 by using the 500 MHz antenna.

1. From the velocity analyses, the radar wave velocity was approximately 0.077m/ns in the stadium and for the garden was 0.079m/ns. This indicates that the medium surrounding the pipes is similar in both locations.
2. From the hyperbola fitting process, the depth of the pipe is found to be about 1.30cm for the stadium area, and 1.50 cm for the garden area.
3. The ability of GPR to image quickly is a powerful aspect of this method and the application of this method gives a flexible, easy and rapid work.
4. All GPR data require some sort of processing before interpretation to be appropriate and successful so the techniques should be used judicially, particularly the more advanced ones.
5. The GPR penetration depth will in many cases be insufficient because of attenuation related to the presence clays and high water content.

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