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Study the Possibility of using Ground-Penetrating Radar to Detect Walls and Archaeological Finds underground

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Abstract
Ground penetrating radar (GPR) is one of the geophysical methods that utilize electromagnetic waves in the detection of subjects below the surface to record relative position and shape of archaeological features in 2D and 3D. GPR method was applied in detecting buried archaeological structure in study area in a location within the University of Baghdad. GPR with 3D interpretation managed to locate buried objects at the depth of (1m) . GPR Survey has been carried (12) vertical lines and (5) horizontal lines using frequency antenna (500) MHZ .

Keyword: Ground-Penetrating Radar GPR, Wall, Archaeological, Ramak and Easy 3D.

دراسة إمكانية استخدام الرادار المخترق للأرض للكشف عن الجدران والاكتشافات الأثرية تحت الأرض

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الخلاصة
رادار الاختراق الأرضي (GPR) هي واحدة من الطرق الجيوفيزيائية غير المدمرة التي يستخدم الموجات الكهرومغناطيسية في الكشف عن الآثار تحت سطح الأرض لتسجيل موقف وشكل معالم اثرية بالصيغتين الثنائية 2D و الثلاثية D3. تم تطبيق الطريقة في الكشف عن الجدار والاجسام الأثرية المدفونة في منطقة الدراسة في موقع داخل جامعة بغداد. تم استخدام رادار الاختراق الارضي مع بصيغة 3D وقد تمكنت من تحديد مواقع الأشياء المدفونة على عمق (1) متر. المسح الراداري أنجز على (12) مسار عمودي و(5) مسارات افقية باستخدم هوائي بتردد (500) ميكاهرتز.

Introduction

Ground Penetrating Radar is a device that transmits short pulses of electromagnetic energy with pulse duration (1-20) ns with high frequency range (10-2500) MHz to the ground by a transmitting antenna [1]. The energy propagation speed through the ground depends upon dielectric constant of the medium [1, 2]. When the radar waves encounter an interface between two different materials (layers) with different refraction indices, some of the transmitted wave energy is reflected back to the surface. A receiver picks up these reflections as analogue signals. The input analogue signals are digitized and quantified using an analogue-to-digital converter in order to be ready for processing in the computer to create an image called the radargram Figure-1, -2, -3. [1-3]

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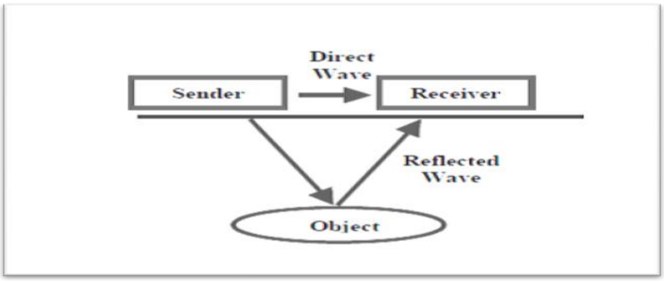

Figure 1- The different paths of reflection of radar waves

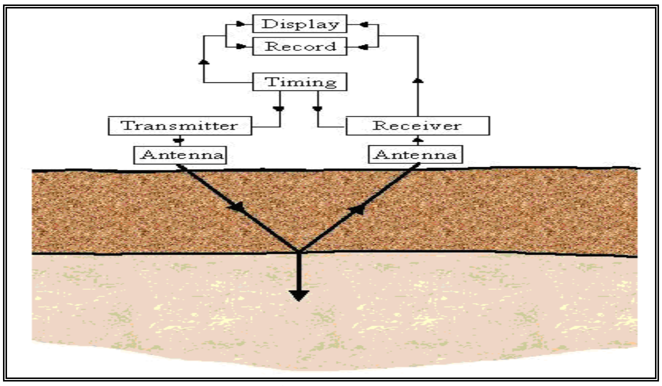

Figure 2- The behavior of the radar wave's transmission and receiving [4]

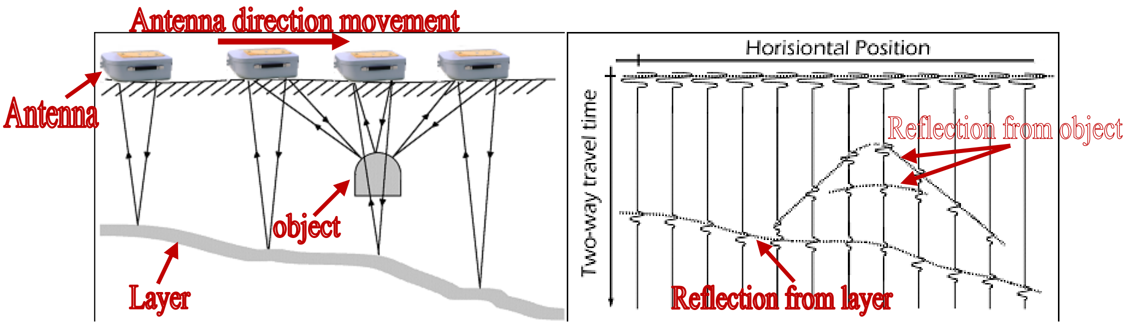

Figure 3- Space the principle of GPR detection. It shows clearly that the radar wave is reflected by the buried object (on the left). The results recording are show on the right. [3].

The difference in media of the underground changes the phase angle and the amplitude of the radar waves which appears as sharp edges on the radar gram, **[1]**. Upon receiving the reflected signals from the ground, an analog-to-digital converter is used to digitize these signals with time and store them as radar images or radargram, **[5]**. Knowing the type of the media in which the electromagnetic wave is moving is necessary to predict the depth of penetration because it is related to the dielectric constant of the media using the following relation:

$$v_m = \frac{c}{\sqrt{\varepsilon_r}} \qquad (1)$$

Where c is the speed of the light in a space ε_r is a dielectric constant of the medium, v_m is a radar wave speed. The depth of the body can be determined using the following relation;

$$d_r = \frac{v_m t_r}{2} \qquad (2)$$

Where d_r is the depth of the body, v_m is a radar wave speed; t_r is the travelling time of the radar wave, [1, 5]. The depth of penetration of the radar wave is also dependent upon both the frequency of the wave and the electrical properties of the media. The higher frequencies used, the lower depth is achieved. However, using high frequencies is usually accompanies with high resolution of the radargram and vise versa, [6]. The best penetration is achieved in high resistivity media. Low resistivity media on the other hand attenuate the signals which results in low or shallow penetration, [5, 7]. For the available frequencies (10 – 2500) MHz the penetration of the GPR signals is about (less than 1meter up to tens of meters). The most effective parameter on the depth of the GPR signals is the resistivity of the media. Even with low frequencies the signals may reach less than one meter if the medium was a low resistivity one [1, 8], because only the electric component of the electromagnetic wave reacts with the medium of penetration. Hence, the electrical properties of the medium are the most important in determining the attenuation effect of the medium on the EM wave Figure- 4[1, 5, 9].

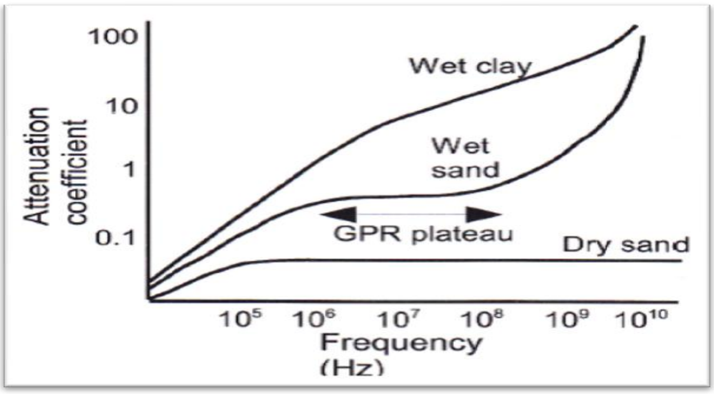

Figure 4 - The attenuation coefficient of the radar wave as a function to the frequency into the wet and dry media [5].

The depth of penetration of the radar wave can be determined in different media by using the relation:

$$D = \frac{35}{\sigma} \text{ (meter).} \qquad (3)$$

D is a penetration depth (meter); σ is an electric conductivity of the mediums [5], See Table-1.

Table 1- Electromagnetic wave speed, electrical conductivity, attenuation coefficient of the signal and the typical relative permittivity to the different media, [5,9].

Material	Typical Relative Permittivity	Electrical Conductivity, mS/m	Velocity, m/ns	Attenuation, dB/m
Air	1	0	0,30	0
Distilled Water	80	0,01	0,033	0,002
Fresh Water	80	0,5	0,033	0,1
Sea Water	80	3000	0,01	1000
Dry Sand	3 – 5	0,01	0,15	0,001
Saturated Sand	20 – 30	0,1 - 1,0	0,06	0,03 - 0,3
Limestone	4 – 8	0,5 – 2	0,112	0,4 – 1
Shales	5 – 15	1 – 100	0,09	1 – 100
Silts	5 – 30	1 – 100	0,07	1 – 100
Clays	5 – 40	2 – 1000	0,06	1 – 300
Granite	4 – 6	0,01 – 1	0,13	0,01 – 1
Dry Salt	5 – 6	0,01 – 1	0,13	0,01 – 1
Ice	3 - 4	0,01	0,16	0,01

The Field Work

The study area is site of Baghdad University, which is located in the southern part of the city of Baghdad, to the east of the Tigris River. Location in the college of Science, Department of Physics, of is located by latitude 33° 16´29.33" N and longitude 44°.22 ´ 49.01" E to 33° 16´28.72"N and longitude 44° 22´ 49.25" E , Elevation 39.

We have selected three examples of application of ground penetrating radar inside location. The first is the detection of wall and archaeological finds buried underground depth of one meter vertically appears to be evident.

The second is a Detection of wall and archaeological finds buried underground depth of one meter horizontally appears to be evident. Third the possibilities of GPR estimating the variations in the thickness of the wall and archaeological.

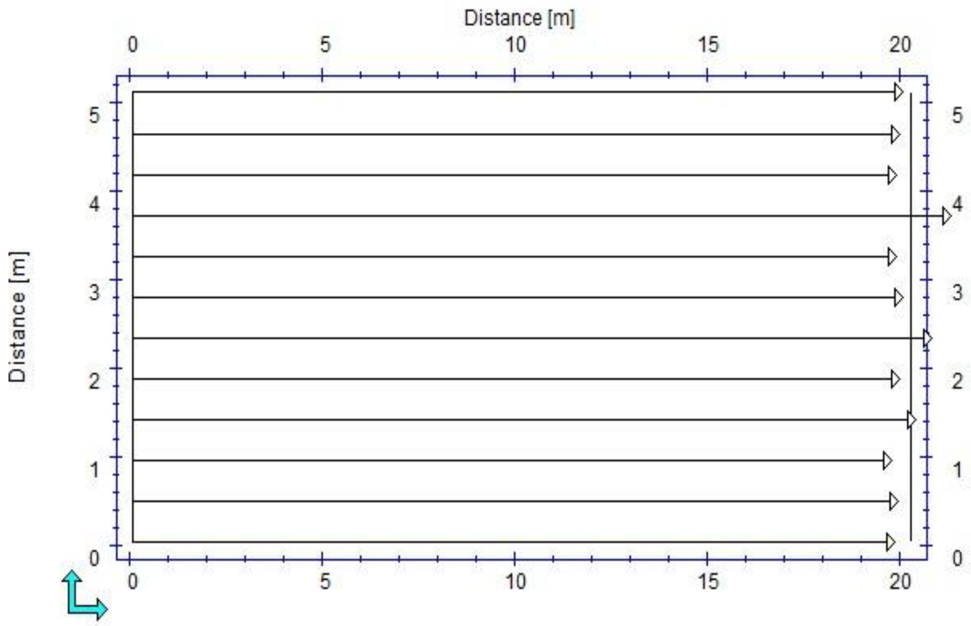

Figure 5- Collection of 12 tracks on the wall and finds is a vertical area (5x20) m2.

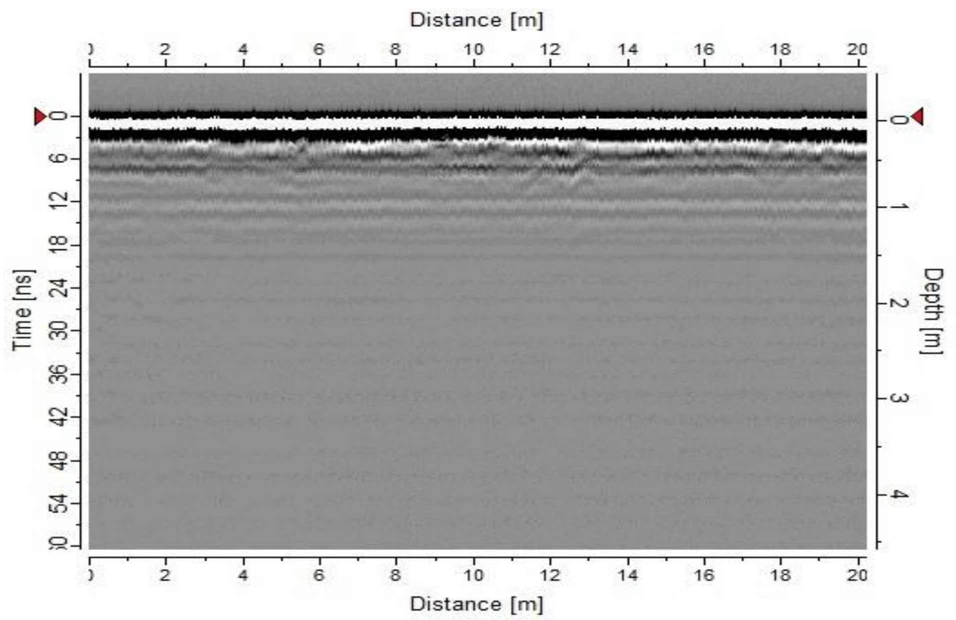

Figure 6- Tracks without filters.

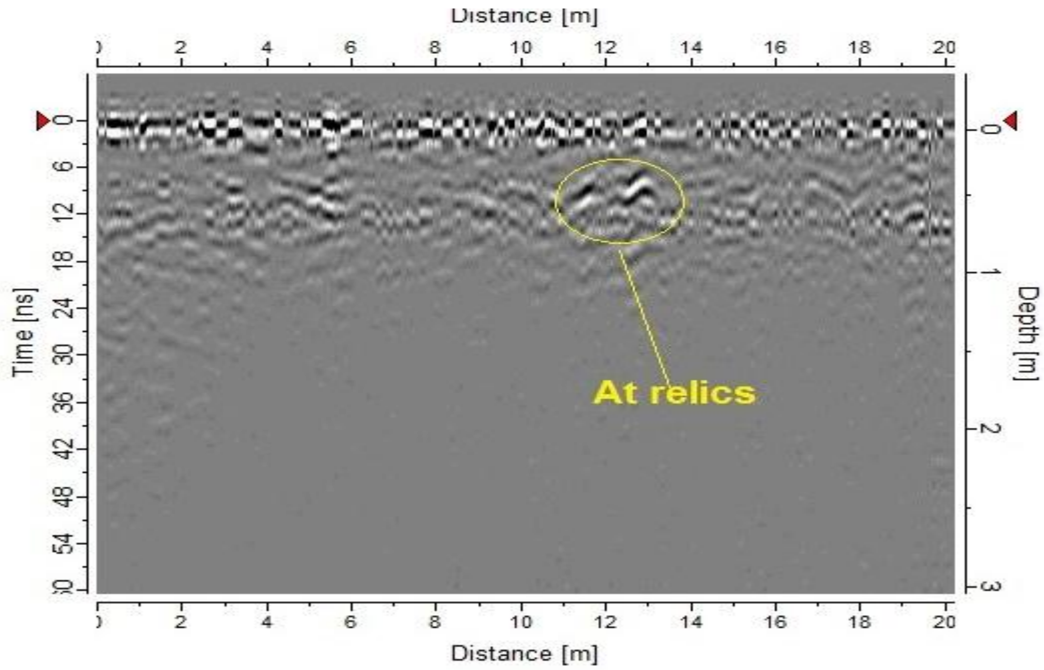

Figure 7- Reflection of the deeply buried archaeological finds 1m.

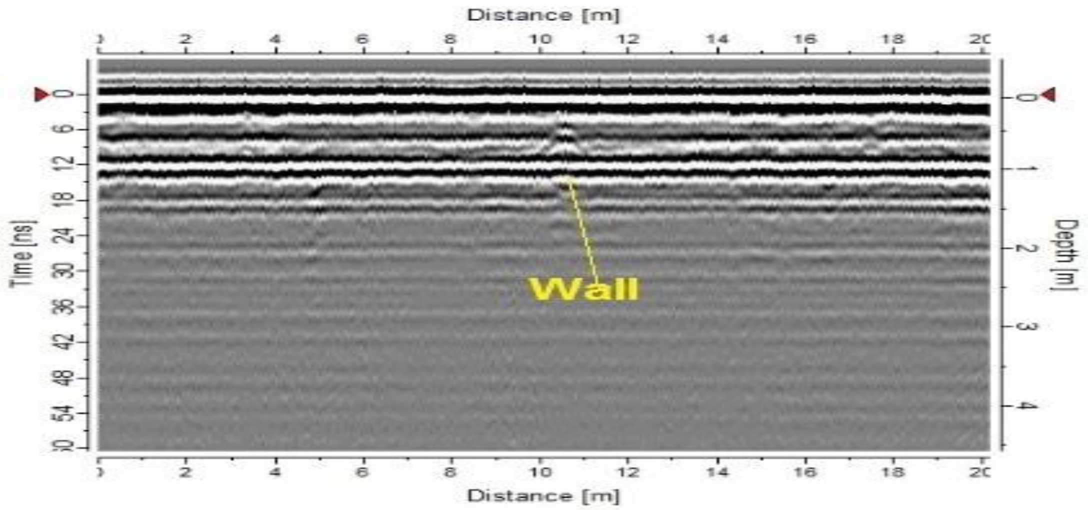

Figure 8- Reflection of the deeply buried wall finds 1m.

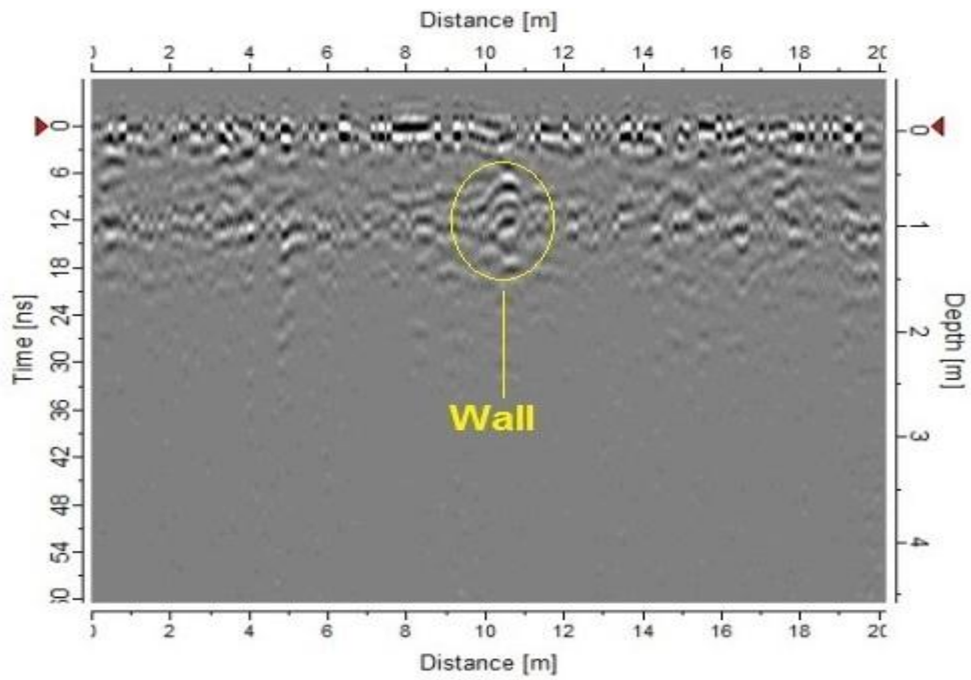

Figure 9 - Reflection of the wall buried deeply 1m.

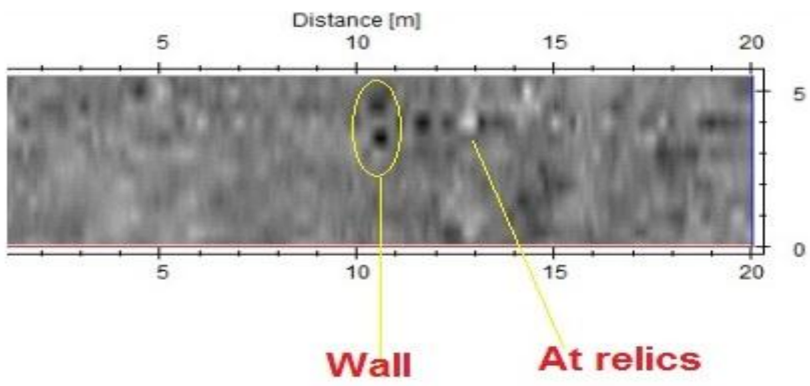

Figure 10- Top view cut at 1m Walls, Archaeological

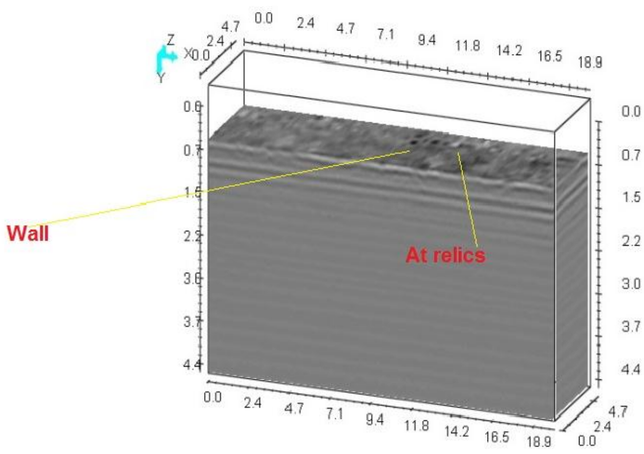

Figure 11- Main view 3D cube cut at 1m Walls, Archaeological.

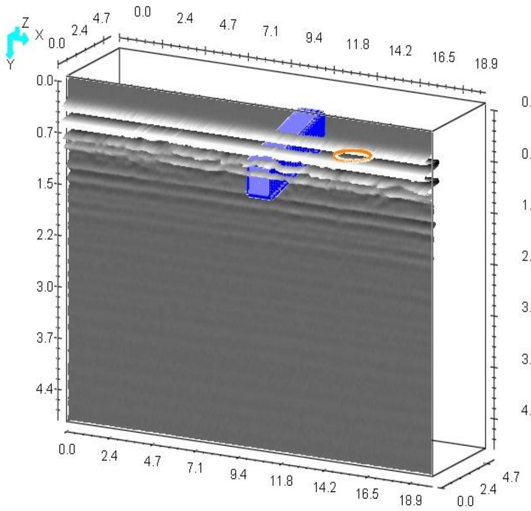

Figure 12- Main view 3D Walls, Archaeological.

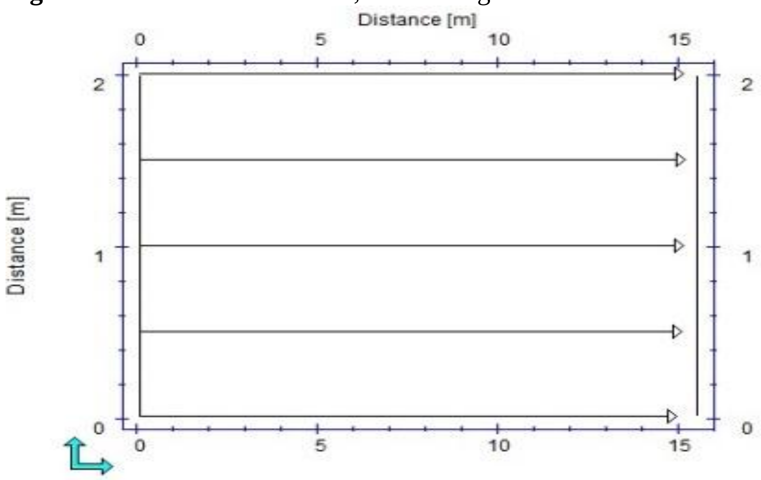

Figure 13- Collection of five tracks on the wall and finds is a horizontal area (2 ×1 5) m^2.

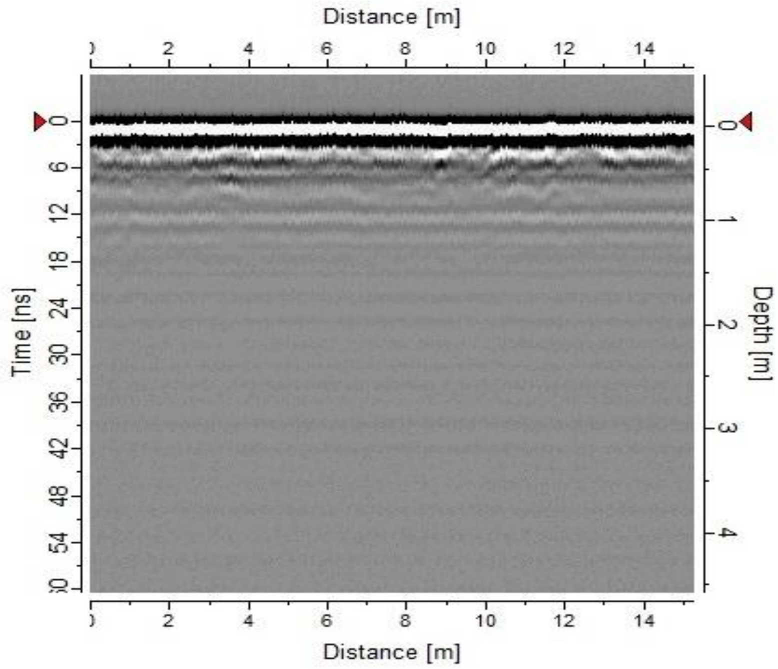

Figure 14-Tracks without filters

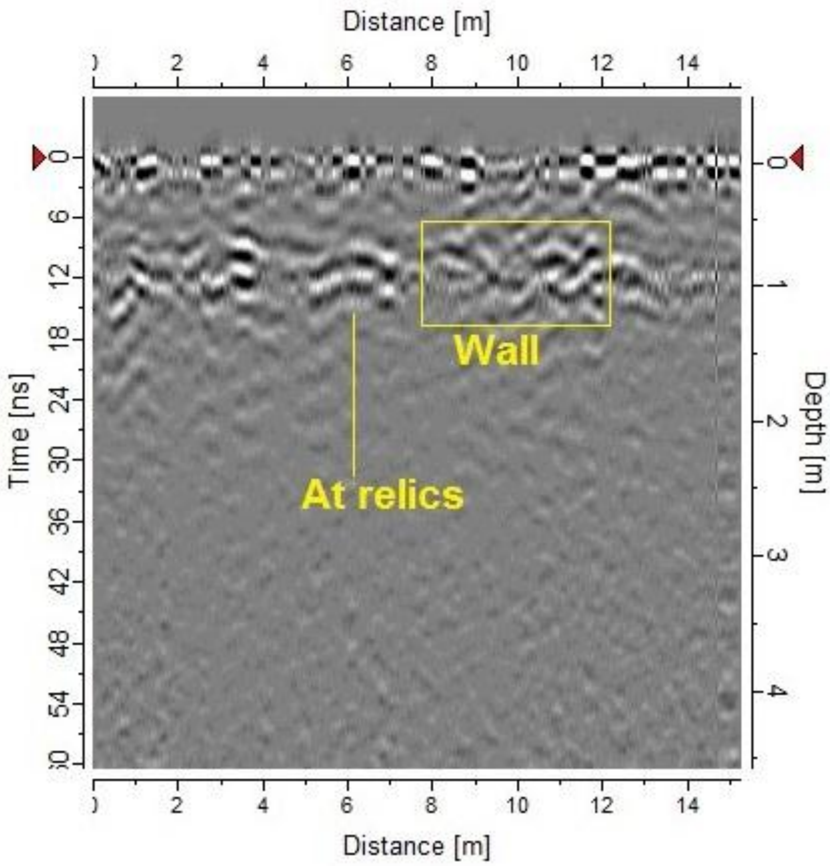

Figure 15- Reflection of the wall and deeply buried archaeological finds 1m.

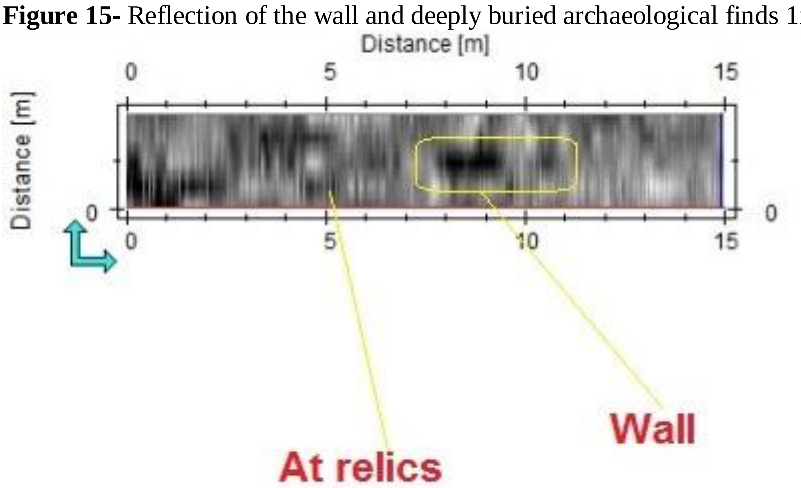

Figure 16- Top view cut at 1m Walls, Archaeological.

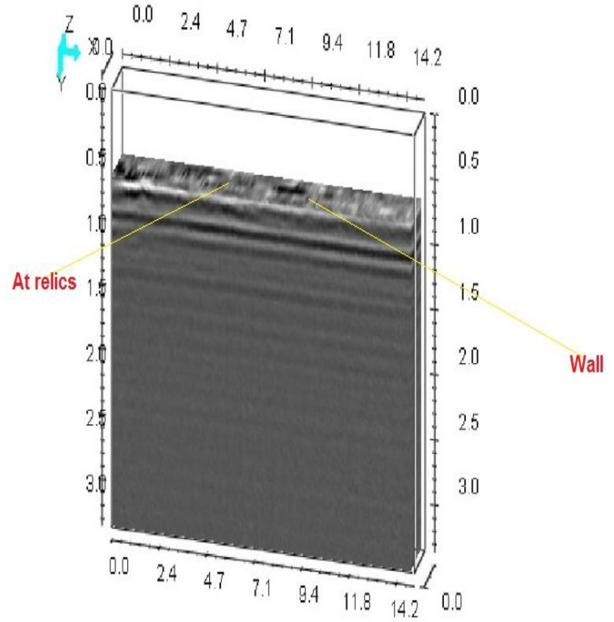

Figure 17- Main view 3D cut at 1m Walls, Archaeological.

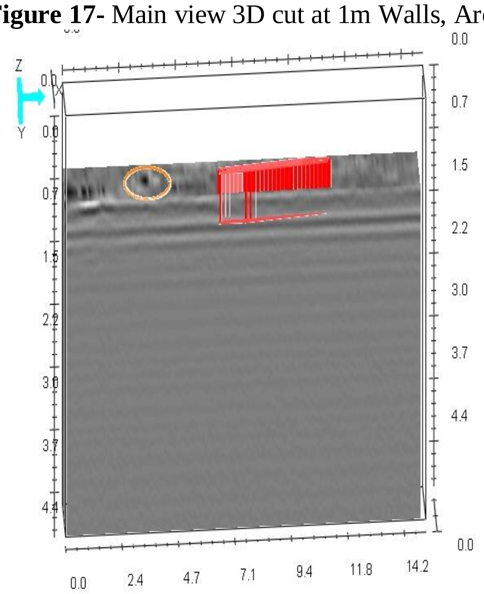

Figure 18- Main view 3D Walls, Archaeological.

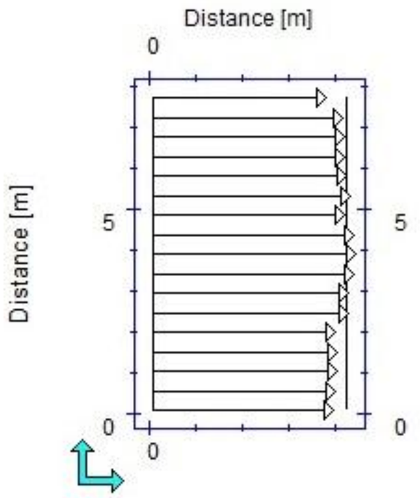

Figure 19-Collection of 17 tracks on the wall and finds is a vertical area (4×8) m^2.

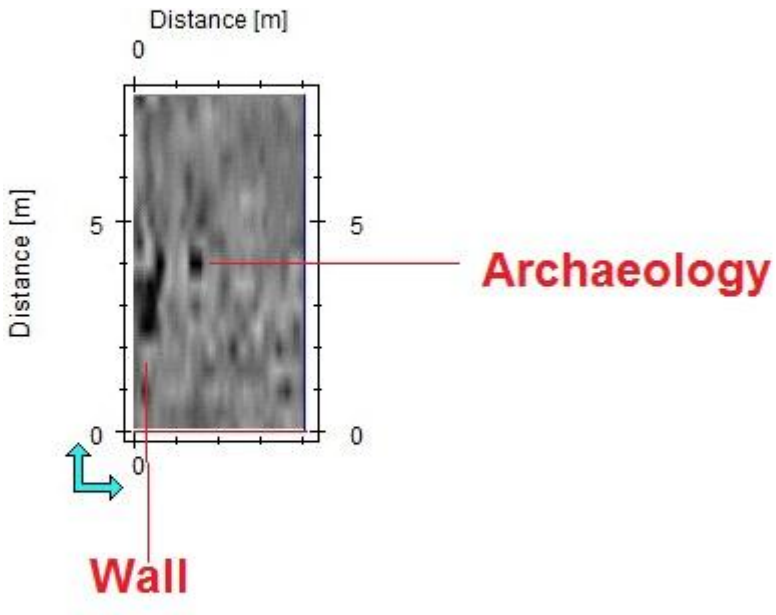

Figure 20- Top view cut at 1m Walls, Archaeological.

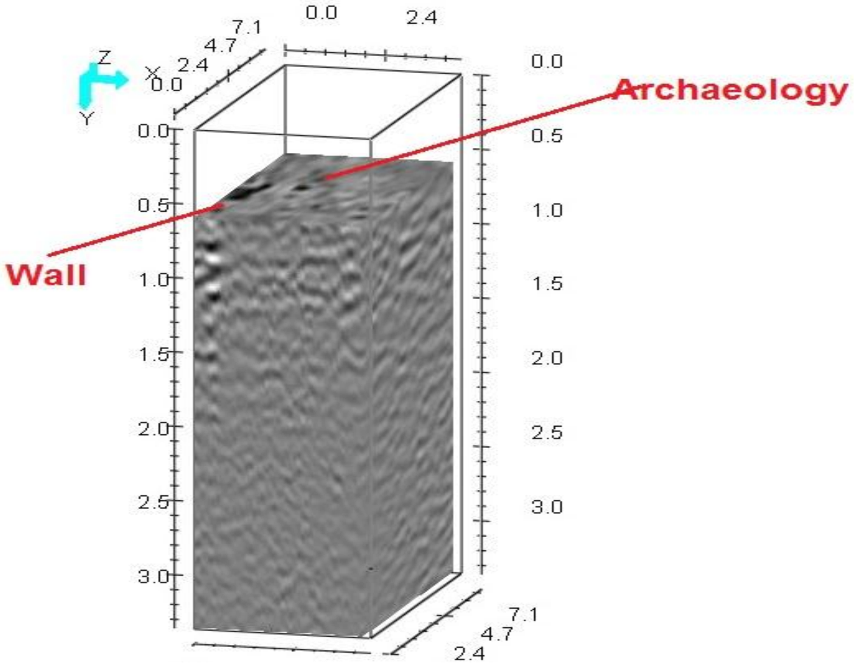

Figure 21- Main view 3D cut at 1m Walls, Archaeological.

Data Processing and Interpretation

After obtaining GPR data, Processing and modifying GPR data to be more easily visualized and interpreted. , very little processing of the data could be summarized by the following steps:

1. Converting the data to a usable digital format.
2. Amplitude adjustments to the data.
3. Gain adjustments to the data.
4. Static adjustments to the data—this involves removing the effects of changes in elevation and effects from leveling the GPR.
5. Applying filterers.
6. Apply the Velocity analysis.
7. Migration.

After processing GPR data, the data is ready to be visualized. Methods for visualizing GPR data are discussed in the next section.

Data Processing

The general processing sequences consists of the following procedures: RAMAC Ground Vision software.

1. DC Filters.
2. Time Gain.
3. Background Removal Filter.
4. Band-pass Filter.
5. Running.
6. Average, Subtract Mean Trace

The 3-D Viewing

1. Correction.
2. Offset range selection for the stack.
3. Weighted stack.
4. Time variant filtering.

Data Interpretation

The design and estimate of the velocity value of electromagnetic waves in the materials is an important factor in the interpretation of the GPR method. The velocity value is used for conversion of the profile from two-way travel time scale to depth scale. The velocity of the EM wave in the material is sufficient to estimate the velocity of the material type present. Table -1 gives estimates of velocities and relative dielectric permittivity for various materials according to equation.The basic unit of electromagnetic wave travel time is the nanosecond (ns), where 1 ns = 10^{-9} s. [10].

$$V_m = \frac{c}{\sqrt{\varepsilon_r}}$$

Where (V_m) the speed of radio waves in any medium is dependent upon the speed of light in free space (c = 0.3 mns^{-1}) and (ε_r) the relative dielectric constant.[11].GPR sections can be presented as grayscale or color images that use the different shades of grey or colors to represent the variation in the signal amplitude. Although, it is generally assumed that at any instance, the recorded Wave form is composed of reflections from targets located directly below the antenna [10].

GPR method are employed using 500MHz shielded antenna to identify buried anomalies in individual transects that might represent features of interest. Survey lines executed in East-West direction Figures (- 7,-9,-15). The Ground Penetrating Radar Survey the most effective technique is to survey the required area on a regular orthogonal grid with scan lines. Figure (-5,-10,-11,-12) vertical and Figure (-13,-16,-17 ,-18,-19, -20,-21) horizontal . A MALA GPR control unit would typically be used with a 500MHz antenna. GPR works best in sandy soils which do not contain boulders, stones or tree roots. Archaeology and wall is a relatively well defined target at depth 1m of the surface.

Figures (-7,-9, -15) shows GPR cross section of East-West survey lines. Two anomalies are detected at 7 and 9 at 10.5m and 13m with depth of 1m respectively. The anomalies due to the occurrence of buried archaeological structure (metal) and wall beneath the location of surface.

The study area is presented in 3-D cube with top view, side view and front view. Results are cut at depth <1m for the top view which shows an anomaly distribution. The 3-D cube also cut at 1m distance in order to show better anomaly distribution. Figures (-10,-11,-12) vertical and (-16,-17,-18) horizontal shows the 3-D view of the study area in the North-South direction.

Get useful data, each computer configurations candidate to remove many of the frequencies that seem to produce the noise, and has removed all frequencies above 500 MHz, which cleans the backup data significantly. The system noise is automatically removed from the arithmetic- all data and application filtering removes the background as in Figures (-6, -8 and -14). After this step reflections emerged from within the earth (walls and At relics) as in Figures (-7, -9 and -15).

Conclusion:

1. GPR successfully detected walls and at relics with depth of 1m,(surface finding). 3D views give clearer image of the subsurface over the survey area where the distributions of anomalies are well mapped. GPR is useful in mapping the subsurface for preliminary evaluation of any structure that favorable with archaeology.

2. It has been proven that GPR is a very simple tool and measuring the high-speed so it can be used to detect walls in the sandy soil.
3. Some obstacles related to ground condition may affect the radargram images. This can be overcome by utilizing some filters which give high resolutions after processing.
4. Before processing, most of the raw data of radargrams do not display the presence of weak zone. By applying suitable filters and other interpretation tools, many of the investigated subsurface structures appeared clearly that reflect the high resolving power of the technique.
5. The best arrangement of GPR survey is obtained when the transmitter and receiver antenna are parallel to the underground layer.

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