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Detection of unmarked graves using Ground Penetrating Radar

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Abstract

Ground penetrating radar (GPR) is one of the Remote Sensing methods that utilize electromagnetic waves in the detection of subjects below the surface to record Once the data were collected, it could be presented in map and 2D and 3D. GPR method was applied in detecting graves (Tel Alags archaeological) fact, within the administrative border to spend Rumitha can be challenging. Due to the sensitivity of these sites, the challenge is to explore the subsurface without disturbing the soil Some cemeteries are hundreds of years old. Often records are vague or incomplete and there may be serious doubt about the precise extent of a cemetery .GPR is the most practical way to sort out the site was to carry out a detailed grid survey. A Noggin 250 MHz Smart Cart configuration was employed. Survey grid was 20 x 5 m with line spacing of 0.5 m. Data were acquire in 1 hour and first order maps were created on site.

Keywords: Ground-Penetrating Radar GPR, graves, Archaeological, Ramak and Easy 3D.

الكشف عن مقابر مجهولة باستخدام رادار الاختراق الأرضي

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الخلاصة

رادار الاختراق الأرضي (GPR) هي واحدة من أساليب الاستشعار عن بعد التي تستخدم الموجات الكهرومغناطيسية في الكشف عن المواد تحت سطح الأرض لتسجيل و جمع البيانات مرة واحدة ، ويمكن تقديمها في صورة خرائط D2 و D3. تم تطبيق طريقة GPR في الكشف عن المقابر (تل الاجز الأثري) الواقع ضمن الحدود الإدارية لقضاء الرميثة ، يمكن أن يكون تحديا نظرا لحساسية هذه المواقع، فإن التحدي يتمثل في استكشاف باطن الأرض من دون إزعاج التربة ، بعض المقابر هي لمئات السنين. في كثير من الأحيان سجلات غامضة أو غير كاملة، وربما تكون هناك شكوك جدية حول المدى الدقيق للمقبرة.
GPR هي الطريقة الأكثر عملية لفرز مكان الموقع لإجراء مسح مفصل الشبكة. كان المسح باستخدام هوائي بتردد (250) ميغاهيرتز. وكانت شبكة المسح 20 × 5 م مع تباعد الأسطر من 0.5 متر.تم الحصول على البيانات في 1 ساعة و تم إنشاء خرائط في الموقع.

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)

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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]

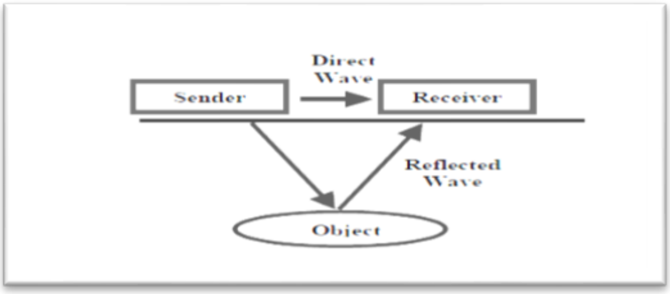

Figure 1- The different paths of reflection of radar waves

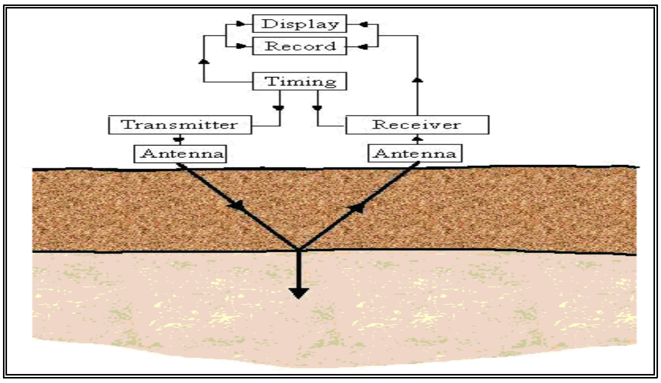

Figure 2- The behavior of the radar waves transmission and receiving. [4]

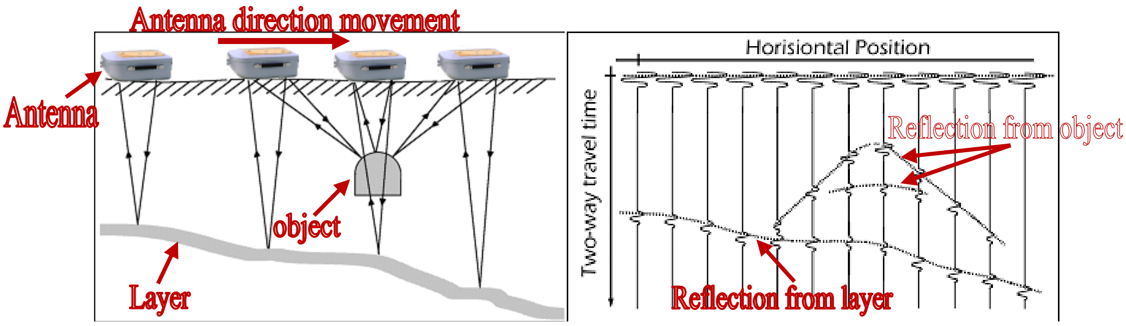

Figure 3- Space the principle of GPR detection. It shows clearly that the radar wave is reflected by the buried object (on the left). The results recording are show on the right. [3].

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:

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

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 determine using the following relation;

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

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 vice 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].

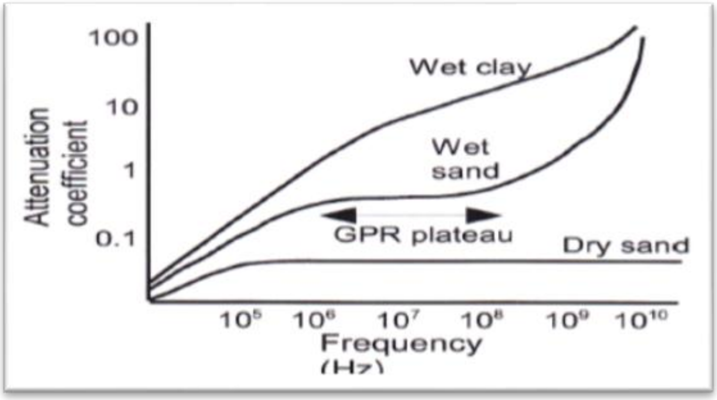

Figure 4 - The attenuation coefficient of the radar wave as a function to the frequency into the wet and dry media [5].

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

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

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

Field Work and Interpretation

The location (Tel Al ages archaeologist) and located within the administrative boundaries to spend Rumaitha / in AL Muthna city/ south Iraq the geographic coordinates (N 31o 35 '15.6' ', E 45o 20' 10.0 ") and Using antennas with frequencies (500 , 250) MHz by taking vertical clips group and horizontal on the expected direction on the graves located within the study site first to get the binary images, triple and clear dimension reflecting layers underground.The process of detecting buried objects, which include Tombs in the site, was carried out using Ground Penetration Radar as explain in Introduction. Where the form of radar waves reflected from the buried material and received by the scanning device can be notice. Each object reflects the wave in way different from other materials, based on the dielectric constant for each subject. These received waves have noise and distortion because the overlap between them and the reflected waves from the surrounding soil. In addition to the reflected waves from the elements and Oxides that make up the soil. As the soil moisture also affects the data received. So, the data of GPR must be filtered and analysis, the analysis of this data was carried out by software processing such as (RADExplorer, Ground vision and Easy 3D) it using different filtering techniques and gains. Filtering is the use of mathematical processing.Algorithms to clean noise from the data and/or enhance certain characteristics of the data. Gain is a value by which raw data are multiplied to enhance low-amplitude reflections. Signal amplitude commonly decreases exponentially at increasing travel. This was compensated by designing a custom time gain that increases the signal strength. good result of applying single filter such as the system noise, is automatically removed from the arithmetic- all data and application filtering (Bandpass, back ground removal, Automatic gain control and DC removal) on the images of the site , see Figures from [5to7] excellent filtered images were obtained when multi-filters have been applied.

GPR works best in sandy soils which do not contain boulders, stones or tree roots. A grave is a relatively well defined target, the size is typically 0.5m x 2m and it is typically within 2m of the surface. GPR may detect a number features to help identify a grave, including (a strong signal may return to a wood the coffin, metal, or vacuum indicates the presence of tomb etc.) or value Disturbed ground structure and excavation features Movement or voids caused by collapse of the coffin This applies to all the selected sites and to varying degrees , as in figure (8-c).3D/Grid Project is a tool that makes the gathering and visualization of radar data measured in two perpendicular directions easier, A typical application for which 3D/Grid Projects are effective is the mapping of re-bars and walls. The 3D/Grid Project option will guide you through all steps involved in the data collection to the investigated area. The measurement can be carried out using a grid-mat, for fast and easy data collection Figure-8a,b,c,d.For best result the grid-mat and the investigation lines should be placed as perpendicular to the searched object as possible. If no knowledge of the direction of for instance a wall and at relics net is available.

1- Creating a 3D/Grid Project

2- Migration settings and images for 3D/Grid Projects

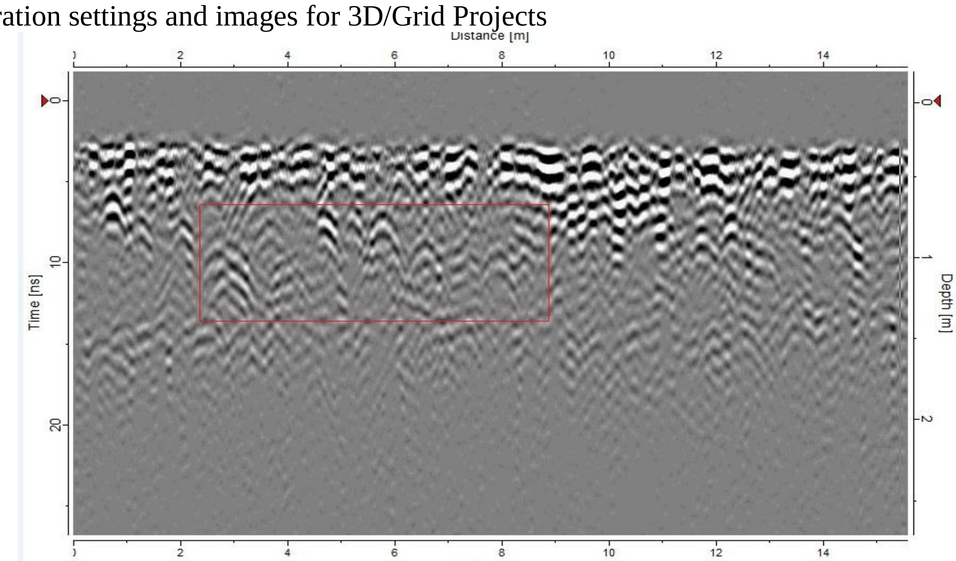

Figure 5- Historic graves with intact or partially collapsed caskets are visible when viewed in profile as distinct hyperbolic reflections derived from their upper surfaces.

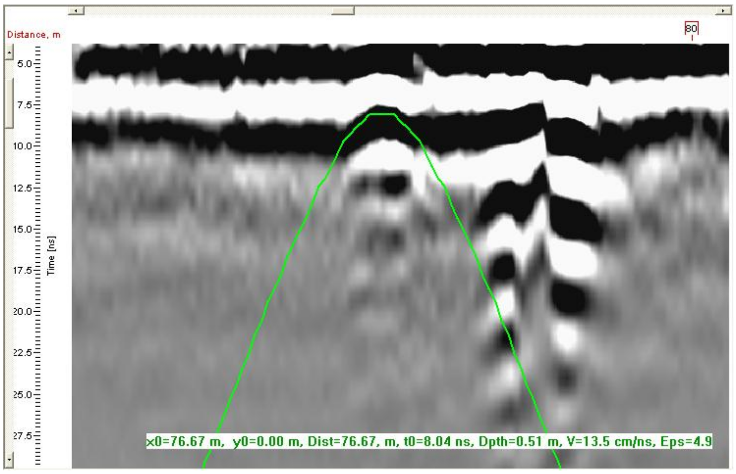

Figure 6-The body at a depth of 0.5m, where the speed of radar wave 13.5cm / ns 250 MHz antenna

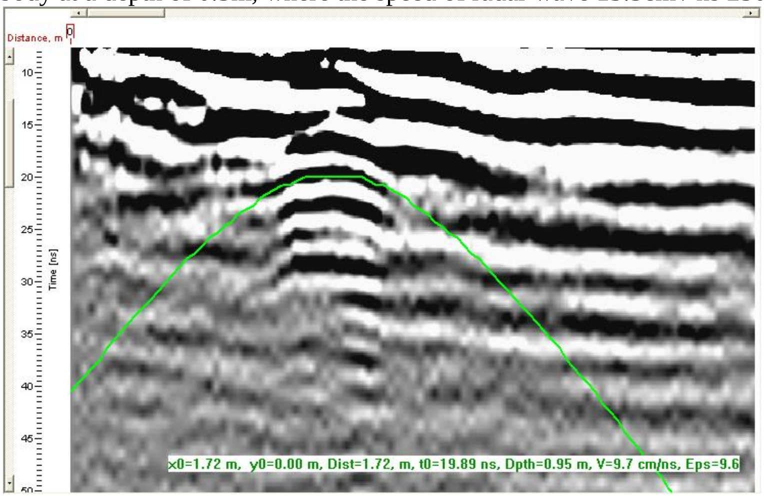

Figure 7- The Tomb at a depth of 0.95m, where radar wave 9.7cm / ns antenna user speed 250 MHz

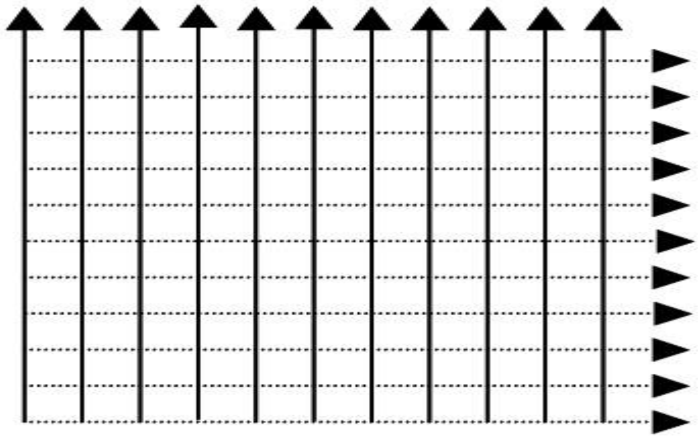

Figure 8-a - 3D/Grid Project measurements with a grid-mat area (6 × 15) m^2.

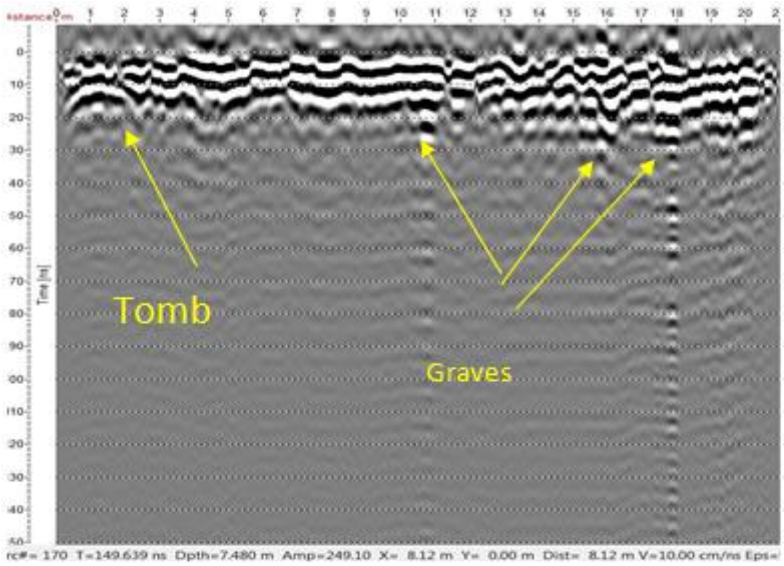

Figure 8 –b-The signal to penetrate some grave

Figure 8-c- Historic graves

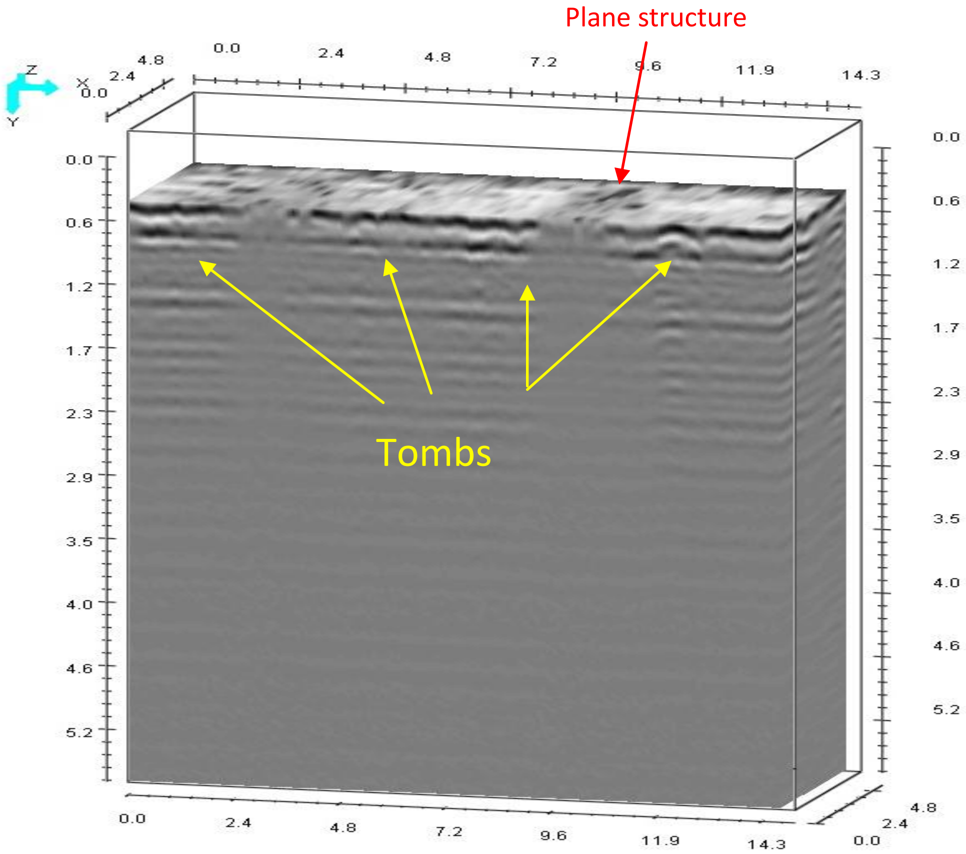

Figure 8-d-The level and form of some graves typically within 2m

Results & conclusion

The above cemetery mapping demonstrates the value of GPR for confirming grave locations. Some key benefits are:

•The Noggin Smart Cart is a compact, portable and rugged GPR for smooth to moderately rough field conditions

•Operation is simple and intuitive

•Users can be effective with only a few hours of training

•Systematic search protocols are available as best practice guides

•Locate and mark provides rapid and immediate zone of interest identification

•Grid mapping simplify data analysis and reduces false alarms

GPR responses vary greatly depending on the target being sought and the host material. GPR response variability can be challenging to new GPR users. When learning about GPR, the best practice is to review several similar case studies to develop an understanding of variability. Check for other insightful information on the resources tab to learn more. Use contact us or Ask-the-Expert to reach our application specialists who can help you tap into Sensors and Software's vast array of technical information.

References

1. Suvarna, S.S. **2004**. Reconstruction of ground penetrating radar images using techniques based on optimization, M.Sc. Thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science, pp:1-4.
2. Al-Kafaji, M.A.H .**2011**. Investigation of the Subsurface Archaeological Features Using Ground Penetrating Radar (GPR) in Ancient UR-city (Southwest Nasiriya /Iraq), M.Sc. Thesis, College of Science, University of Baghdad, p:123.
3. Hannu L uodes.**2008**. Natural stone assessment with ground penetrating radar, *Estonian Journal of Earth Sciences*. 57(3), pp:149-155
4. Charlton, M. B. **2006**. Principles of ground-penetrating radar for soil moisture assessment. *Journal of Hydrology*.

5. Geoscanners A.B.**2006**. GPR Antenna Bandwidth, Glimmervägen 3, S-961 46 Boden, Sweden, from http/www.geoscanners.com.
6. Annan A. P., and COSWAY S. W. **1992**. Simplified GPR beam model for survey design, Society of Exploration Geophysicists, New Orleans, USA.
7. Jorge, L. P. and William A. Sauck .**2007**.Ground penetrating radar profiles over multiple steel tanks: Artifact removal through effective data processing, *Geophysics*, 72(6), p:77.
8. Alaa S. Mahdi, Anas A.Mohammed.**2015**. Study the Possibility of using Ground-Penetrating Radar to Detect Walls and Archaeological Finds underground, *Iraqi Journal of Science*, 56(4B), pp: 3256-3267.
9. Khunt, T., **2009**. Application of polarimetric GPR to detection of subsurface objects, Ph.D. Thesis for Graduate School of Environmental Studies of Tohoku University.
10. Davis, J. L., and Annan, A. P. **1989**. Ground Penetrating Radar for high-resolution mapping of soil and rock stratigraphy, *Geophysical Prospecting*, 37, pp:531-551.
11. Griffin, S. and Pippett, T. **2002**. Ground Penetrating Radar, *Geophysical and Remote Sensing Methods for Regolith Exploration*, 144, pp: 80-89.