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Effect of Stolt f-k migration filters on ground penetrating radar imaging

Hussain M. Almusawi[1], Musadage I. Alhemiri[1], Basim A. Almayahi[2]*

[1]Department of Physics, Education College for Girls, University of Kufa, Najaf, Iraq

[2]Department of Environment, Faculty of Science, University of Kufa, Najaf, Iraq

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Abstract

Background: Some filters such as (Stolt F-K Migration) and complimentary filters (Time –Zero Adjustment, Background Removal, and Band –Pass) are used to study the effectiveness, digital filters, and to enhance the quality of radar grams. This filter considered one of the advanced processing filters in general. **Materials and Methods:** Ground Penetrating Radar (GPR) is a device that transmits short pulses of electromagnetic energy with pulse duration about 1 ns to 20 ns with a high-frequency range from 10 MHz to 1000 MHz in the ground by a transmitting antenna. The input analogue signals digitized and quantified using an analogue-to-digital the converter in order to be ready for processing in the computer to create images called the radar gram. **Results:** The important feature focused on making visible the weak signals and improves certain components required to interpret the data. **Conclusions:** Applying Stolt F-K Migration filter on profile GPR cretaceous limestone rock detected at a depth of 3.75m. Whereas, applying the filter to the same profile of water pipe at a depth (0.632m)near the road for the faculty of pharmacy at the direction from north to south. When applying the filter) to the same profile of difference in the thickness of pavement layers which consist of a foundation layer and a layer of asphalt.

Keywords: Radexplorer software, hyperbola cretaceous, limestone rock, Time–Zero Adjustment, Background Removal, Band-pass filters.

1. Introduction

The Groundpenetratingradar (GPR) is a high-resolutionelectromagnetictechnique designed to investigate the shallow subsurface of the earth, building materials, roads, and bridges. GPRdeveloped over the past 30y for shallow, high-resolution investigations of the subsurface.A time-dependent geophysical technique can provide a 3-D pseudo image of the subsurface, including the fourth dimension of colour, and can provide accurate depth estimates for many common subsurface objects (Daniels, 2000; Alaa et al. 2015; Muhammed and Ali. 2015).If Stolt F-K Migration filter applied properly, the repercussions hyperbolic collect in the points corresponding to the real site objects through quantitative information such as speeding versus depth for this filter re-shape the real location of the boundaries of reflection (AL-Khafaji, 2011). GPR data used to estimate the vertical movement of rotational slides in combination with other surveying techniques (Lissak et al. 2015, Harry, 2009).In this study, study the effectiveness, digital filters, and to enhance the quality of radargrams using (Stolt F-K Migration) and complimentary filters. Stolt f-k Migration and complimentary filters (Time –Zero Adjustment, Background Removal, and Band –Pass) are studying the effectiveness, digital filters, and enhance the quality of radargrams. The basis of the work of filter Time-Zero Adjustment is to set the starting point to measure vertical time to zero time, that is the moment in which emits already wave from the transmitting antenna to find out the correct depth of penetration. The application of filter (Background Removal) is a necessary measure when it removes the horizontal features, semi-horizontal data, and unwanted noise from the desired signal. Band -Pass filter of frequencies of unwanted effects of frequencies to remove, remove any unwanted effects from the raw data free of noise and make it, and is effective this candidate set up and a minimum value for the cutoff frequency. The band-Pass filter works on the unwanted frequencies removal. Remove any unwanted effects of data make it free from noise, is the effectiveness of this filter, set the

Corresponding author
Full Address :
Department of Environment, Faculty of Science, University of Kufa, Najaf, Iraq
Phone:+9647823004353
E-mail: basimnajaf@yahoo.com

highest and the lowest values for the cutoff frequency. Notice that the graphic radar pre-treatment cannot determine the depth of objects buried under the earth's

Figure I. Basic principle of GPR (GPR, 2000)

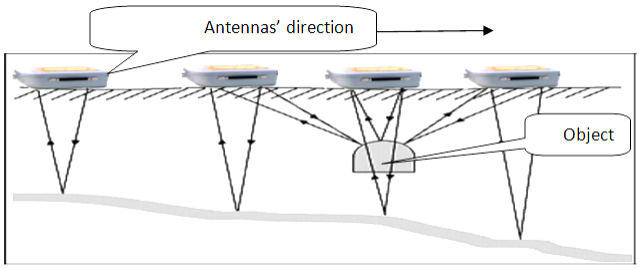

Figure II. Radar wave reflected by the buried object

surface accurately, while the post-processing of these advanced filters can determine depths and accurately. In this study, Ground Penetrating Radar technique (GPR) has been used to determine the level of ability of this modern technology in detecting and identifying materials buried under the floor of some of the sites at the University of Kufa. This study was carried out in eight different locations of the University of Kufa, through a survey of seventeen paths. Two antennas of 250-500 MHz are used and nine pathways scanned by an antenna with a frequency of 250 MHz and deep of 5m. Whereas, the other eight pathways scanned by an antenna with a frequency of 500 MHz and deep of 1m. Radargram has been drawn from the device memory using a special treatment program (Rad Explorer), which contains several filters that process the signal received or reflected and removing unwanted frequencies. The study showed that the Time - Zero filter has been applied to all radar paths because it represents the actual zero point line for the emission of the wave. Some filters are useful in showing anomalies clearest and most important of these filters are Bandpass Filtering, Background Removal, and Stolt F-K Migration. There are some materials buried under the earth's surface, such as piping, electrical cables and pieces of iron, and limestone. It has been identified on the thickness of the asphalt layer of roads and the thickness of the cement layer in the University of Kufa garages and the thickness of the other layers of the studied areas. The determining factors causing abnormalities and deformities in the acquired data, including the presence of a metal fence trap in the road leading to internal departments and the industrial trap of the road opposite the faculty of pharmacy. GPR was used in the detection of buried material under the surface of the ground without resorting to the drilling process or destruction in the study area and get good results and information valuable and useful. The present investigation performed near the road for the faculty of pharmacy, university of Kufa, Najaf city, Iraq in coordinates of N32˚ 01.374 and E44˚22.343.

2. Materials and Methods

2.1 Study Area

GPR is a device that transmits short pulses of electromagnetic energy with pulse duration about 1 ns to 20 ns with a high-frequency range from 10 MHz to 1000 MHzin the ground by a transmitting antenna. The energy propagation speed through the ground depends on the dielectric constant of the medium. When the radar waves encounter an interface between two different materials (with different refraction indices), some of the transmitted wave energy reflected back to the surface. A receiver picks up these reflections as analogue signals. The input analogue signals digitized and quantified using an analogue-to-digital converter in order to be ready for processing in the computer to create images called the radargram, as shown in the Fig I and II.

The depth of the body determined using the following relation:

$$d = \frac{vt}{2}$$

where, d=the depth of the body,v= a radar wave speed; t = the travelling time of the radar wave is the two-way travel times to the reflector (GPR trace).

3. Results and Discussion

Rad Explorer software is used in some filters for removing unwanted signals in the study area with the antenna survey frequency of 250MHz, the length of the path around 80m (before processing), a direction from north to south at the coordinates of (N32˚01.374, E 44˚22.343), and at a height of 33m(sea level) as shown in Fig III.

Fig III shows the depth of penetration of 5.38m(before processing). When Time-Zero applied to the profile, then

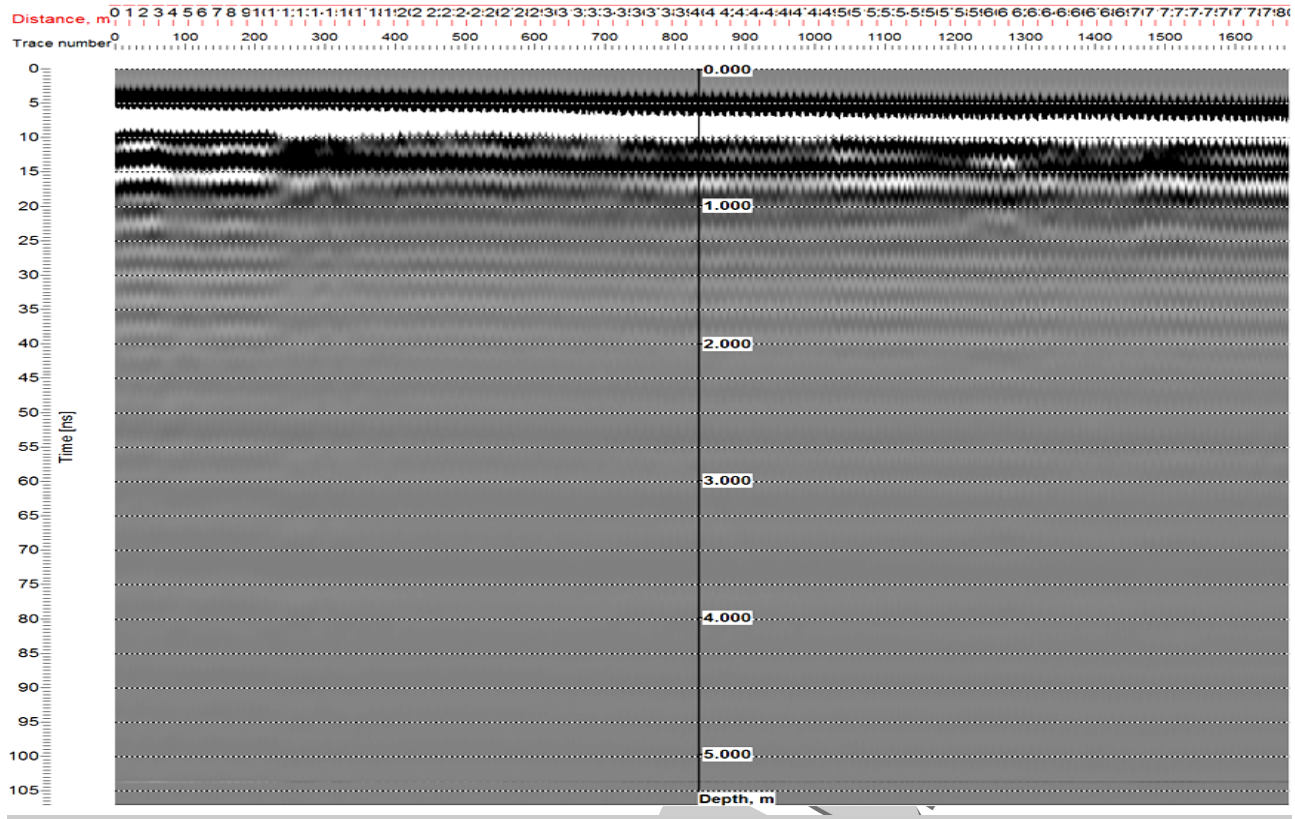

Figure III. Profile (GPR, No.15) near the road for the faculty of pharmacy

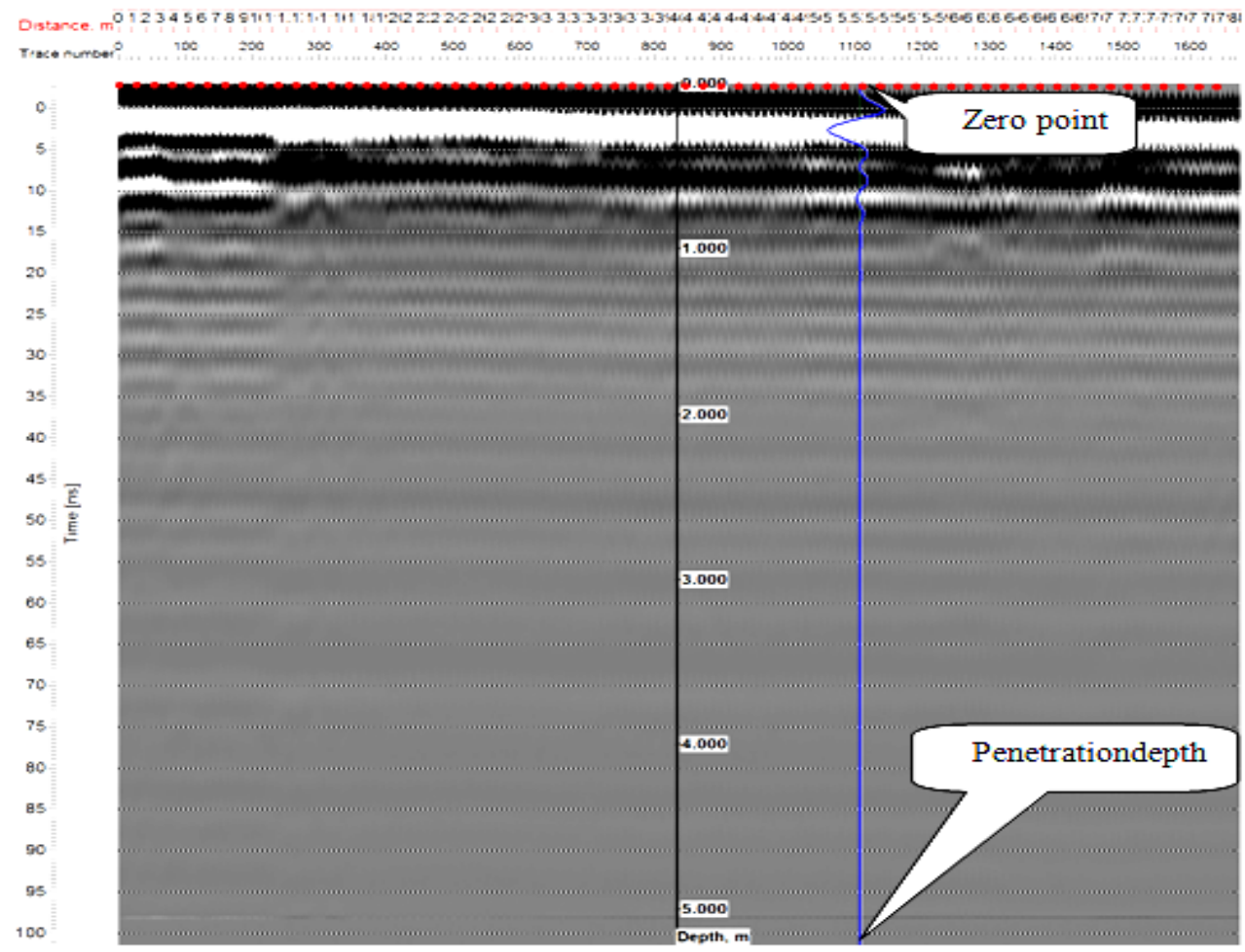

Figure IV. After Time-Zero: Profile (GPR, No.15). The red dotted line represents the zero point of the depth of penetration

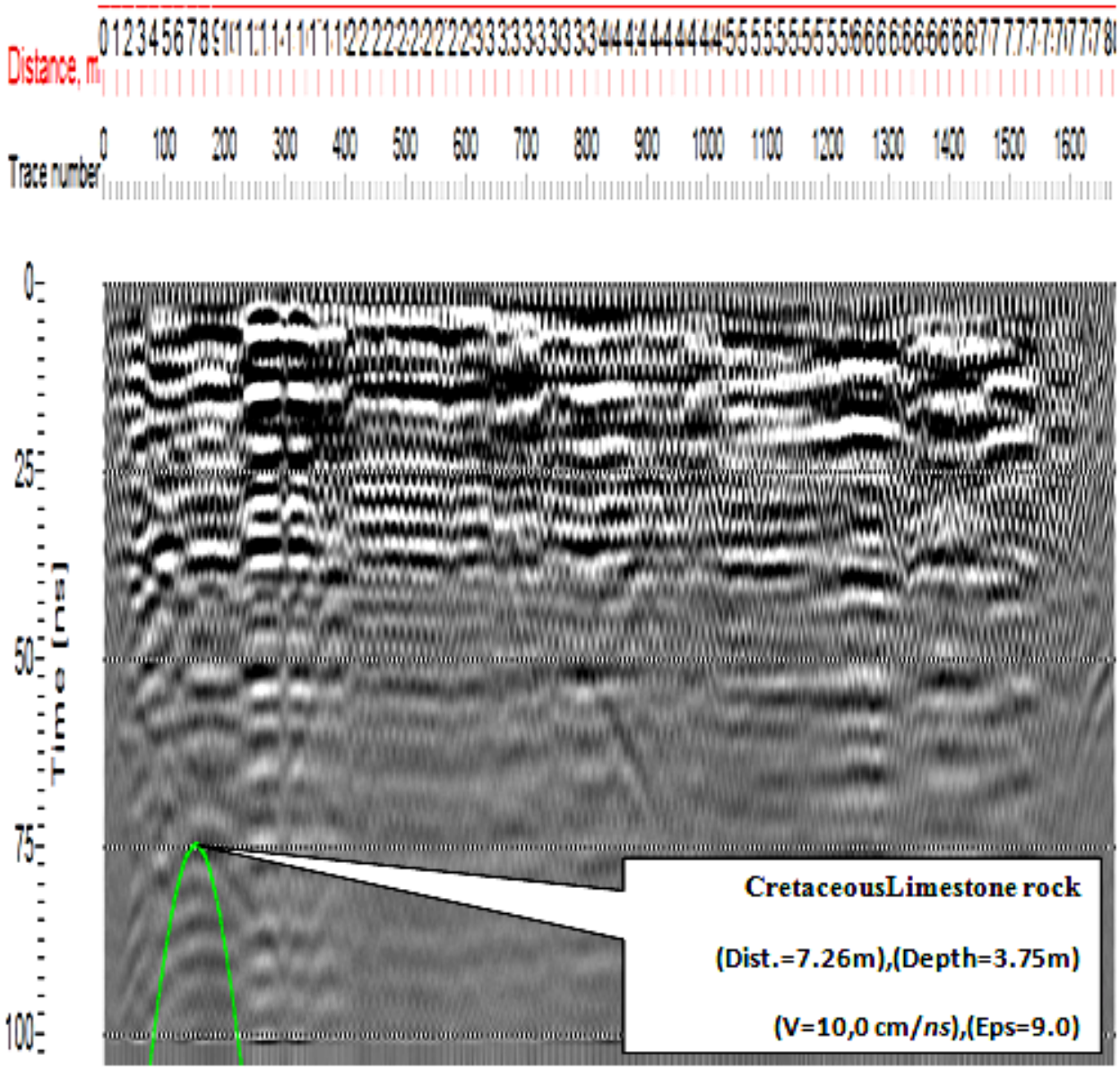

Figure V. After the applying Stolt F-K Migration with cretaceous limestone rock

Figure VI. Artificial bump of car

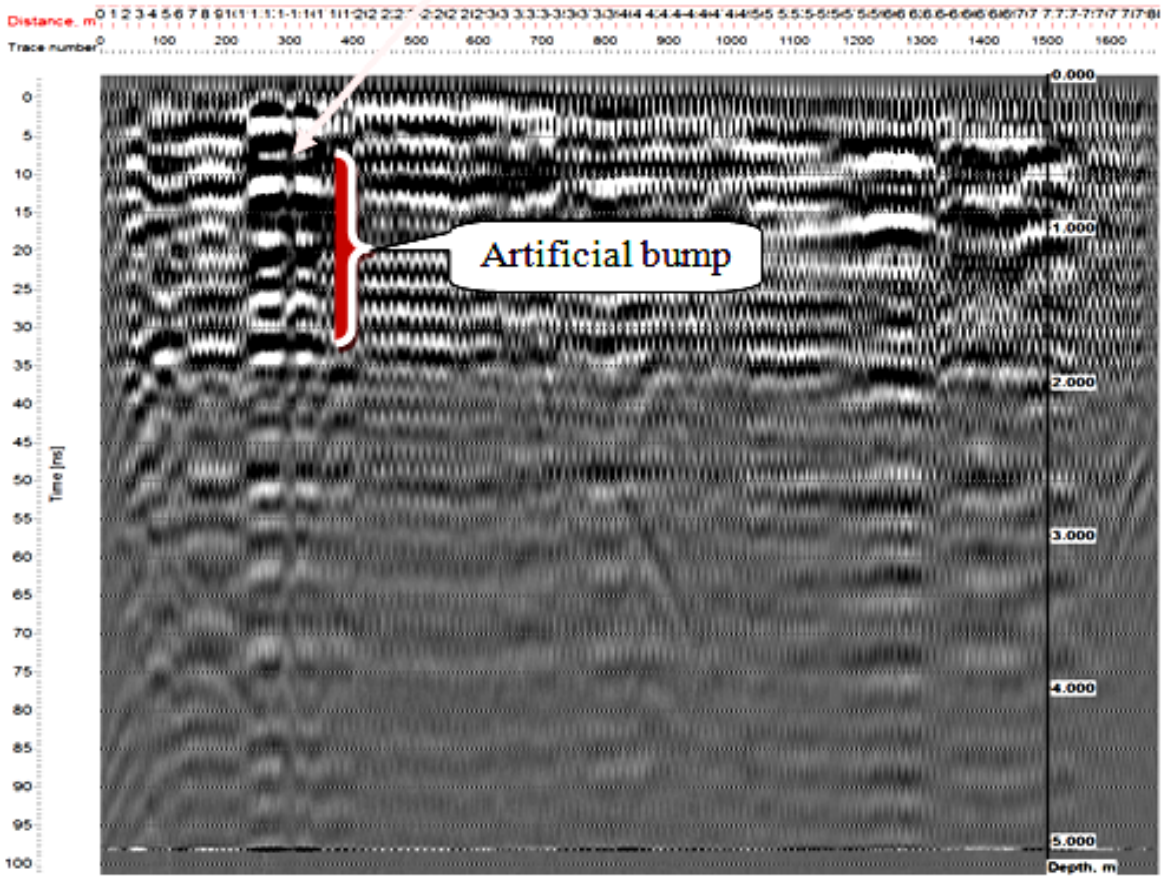

Figure VII. Processing profile (No.15) filter

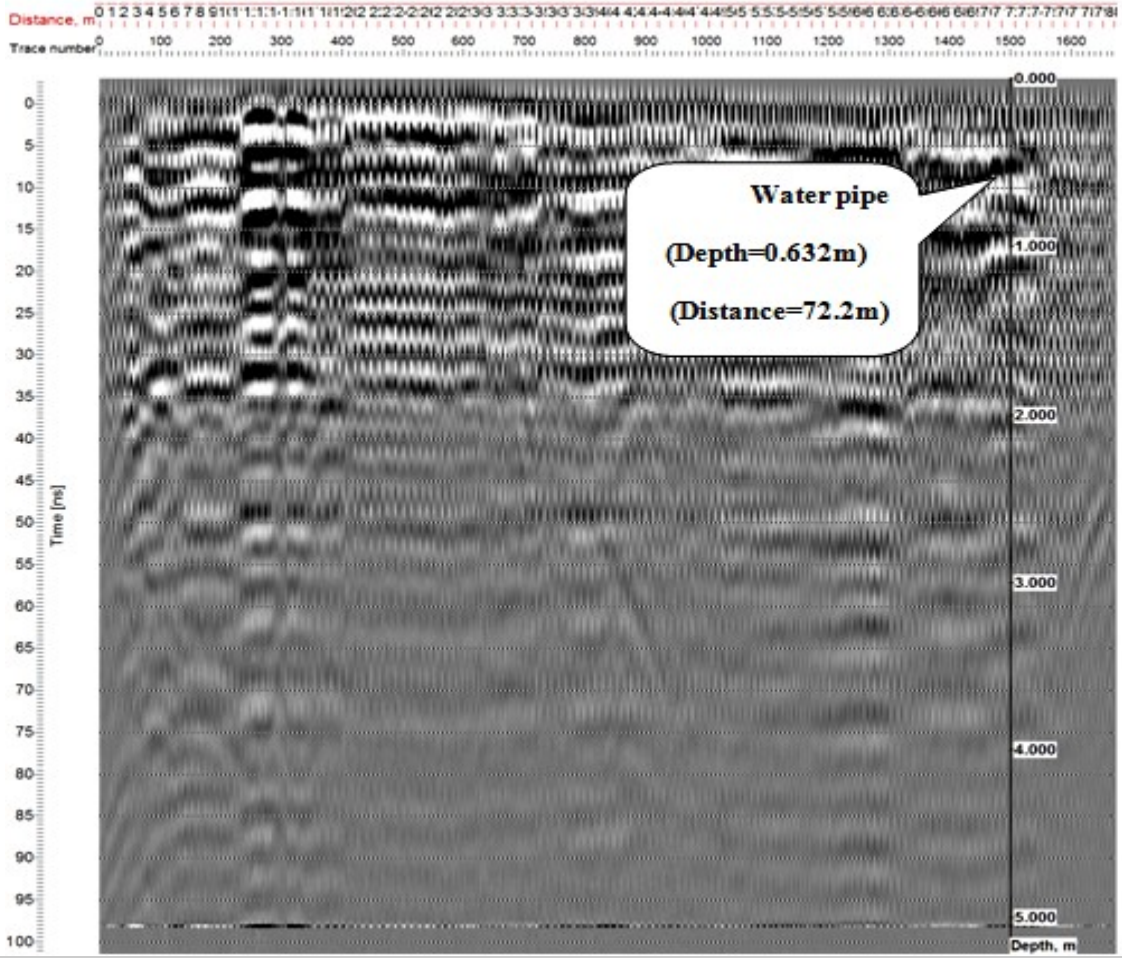

Figure VIII. Water pipe at 0.632m depth and at a distance of 72.2 m using profile GPR (No.15)

Table I. Information about (Band-Pass) filter

Low-Cut	74 MHz
Low-Pass	195 MHz
High-Pass	595 MHz
High-Cut	902 MHz

the depth of penetration became less about 5.22 mas shown in Fig IV.

The red dotted line represents the actual zero point to determine the depth of body with high accuracy in the ground (First Break (*ns*)=3.5). When applying to the filter (Stolt F-K Migration) at a hyperbola deep by 3.75 m and a distance of 7.26 m as shown in Fig V.

The speed of the wave is 10.0 cmns^{-1} and insulation constant is Eps=9.0. These values are practical measurement approach where the hyperbola is overturned off the opposite direction from one point that represents the actual location of the cretaceous limestone rock in the subsoil. During scans, the GPR is having an artificial bump of the car near the road for faculty of pharmacy as shown in Fig VI. When processing profile (No.15) filter (Removed background) being clearly the impact of industrialization applied abnormality of distance (14.5 m), because of screws of iron bolts installed to bump as shown in Fig. VII.

The cause of this anomaly of screws iron installed to artificially bump. When using the filter the same profile shows a water pipe at a depth of (0.632m) and at a distance of (72.2m) as shown in Fig. VIII. Applying the filter (Stolt F-K Migration) for profile GPR (No.15) cretaceous limestone rock is detected at a depth of 3.75m. Whereas, applying the filter (Background Removal) on the same profile of water pipe at a depth (0.632m) near the road for the faculty of pharmacy at the

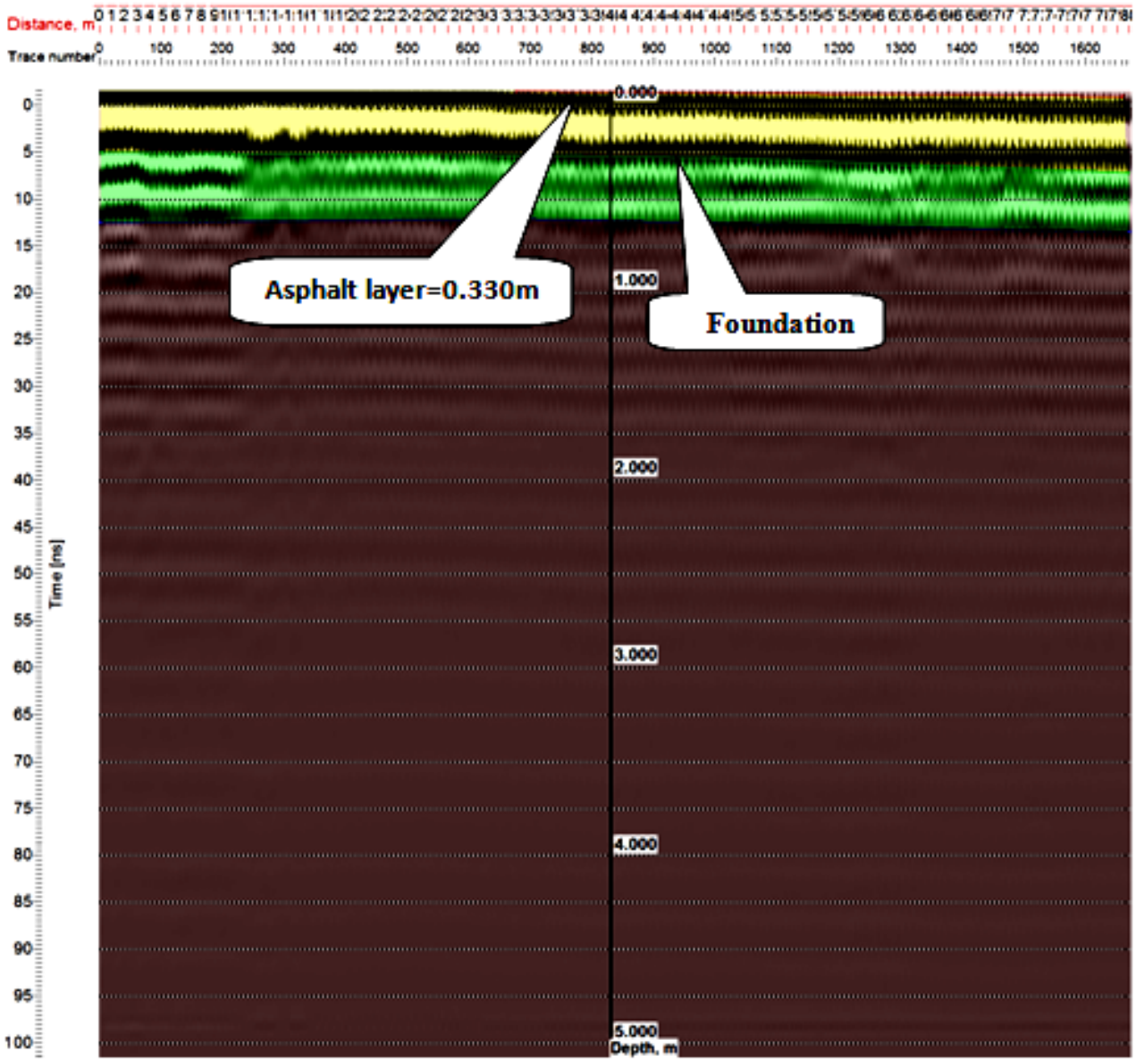

Figure IX. Strong repercussions in pavement layer using profile GPR (No.15)

direction from north to south. When applying the filter (Band-Pass) on the same profile of difference in the thickness of pavement layers which consist of a foundation layer and a layer of asphalt.

Table I shows the layer roadbed conditioners (Band-Pass), choosing, and push the button (Run). Strong repercussions are noted in pavement layer which limits (0.675m) include paving asphalt layers yellow and a thickness (0.330m) and green layer foundation and a thickness (0.345m) as shown in Fig. IX.

The depth of penetration of the radar wave also depends on both the frequency of the wave and the electrical properties of the media. The higher frequency and the lower depth are achieved. However, high frequency is usually accompanied with high resolution of the radiogram and vice versa (Annan, 2004). The best penetration achieved in high resistivity media. Low resistivity media attenuate the signals, which results in low or shallow penetration. The conductivity of ground imposes the greatest limitation on the use of radar probing (Annan et al., 1992). The depth to which radar energy can penetrate depends on the effective conductivity of the strata being probed. This is governed mainly by the water content and its salinity. The value of effective conductivity is also a function of temperature and density, as well as the frequency of the electromagnetic waves being propagated. The least penetration occurs in saturated clayey materials or the moisture content is saline. Attenuation of electromagnetic energy in wet clay and silt means that the depth of penetration has frequently been less than 1 m. The technique appears to be reasonably successful in sandy soils and rocks in which the moisture content is non-saline. Rocks such as limestone and granite can be penetrated for distances of 10 m and in dry conditions and the penetration may reach 100 m. The propagation of the radar signals into earth layers depends on the electromagnetic properties of soils and rocks, which are dielectric permittivity and electrical conductivity (σ) (Muhammed and Ali. 2015; Alaa, 2013;Huilin et al. 2011; Damien et al. 2013). This filter is considered one of the advanced processing filters. Overall, an important advantage that they focus on making weak signals visible and improve certain components required to interpret the data. If the filter (Stolt F-K Migration) is applied properly, the reflections of hyperbolic collects in the points corresponding to the real site objects through quantitative information such as speeding versus depth to this filter re-shape the real location of the boundaries of reflection. In this study, it was to reach good and accurate results [15, 14]. There are some materials buried under the earth's surface, such as piping, electrical cables and pieces of iron, and limestone. It has been identified on the thickness of the asphalt layer of roads and the thickness of the cement layer in the University of Kufa garages and the thickness of the other layers of the studied areas. The determining factors causing abnormalities and deformities in the acquired data, including the presence of a metal fence trap on the road leading to internal departments and the industrial trap of the road opposite the faculty of pharmacy.

This work is original in the University of Kufa and it contains new results that significantly advance the research field.

4. Conclusions

It is concluded that applying the filter (Stolt F-K Migration) for profile GPR(No.15) cretaceous limestone rock is detected at a depth of 3.75m.Whereas, applying the filter(Background Removal) on the same profile of water pipe at a depth (0.632m)near the road for the faculty of pharmacy at the direction from north to south. When applying the filter (Band-Pass) on the same profile of difference in the thickness of pavement layers which consist of a foundation layer and a layer of asphalt. The results are interesting and important to researchers in relevant fields which it used the filter (Stolt F-K Migration). Other filters can use to address these radar drawing by the researcher may add some improvements to these charges and these filters, such as DC Removal and Trace Edit filters.

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Conflict of interest

The author’s declares none.

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