The Effect of the Different Frequency on Skin Depth of GPR Detection

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Abstract

Today the utilization of Ground Penetration Radar are increasing with development civil works , the requirement is increase a low cost technique, time and accuracy, all these should be founded in same time to achieve the project with fullest. In this study will use GPR instrument with three frequency(500,800,1000 MHz),and applying the experiments in various medium with different object's materials for pipe that expected founded object underground for the purpose of extract the fixed data that serve who work interest in this field. This technique will help in solve problem of underground detection ,such as water leakage in underground pipe for different depth that considered complex and expensive problem in same time in urban life .The study contribute in solve issue of utilizing the suitable frequency with penetration for detection, this is clarify through the result gotten that refer to excellent outcome.

Keyword: GPR, leakage, frequency, penetration depth.

الخلاصة

استعمال جهاز الكشف الاختراق الارضي تزايد مع تطور الاعمال المدنية وبرزت الحاجة الى استخدام تقنيات ذات تكلفة واطئة ووقت تنفيذ اقل والعمل الدقيق، كل هذه الشروط يجب ان تتوفر لكي يتم انجاز عمل متكامل. في هذه الدراسة تم استخدام جهاز الكشف الاختراق الارضي بثلاث ترددات (500,800,1000 MHz) وتطبيقها في اكثر من وسط واستخدام اكثر من معدن للانابيب المتوقع وجودها تحت الارض لغرض استحصال بيانات ثابتة تخدم العاملين في هذا المجال. هذه التقنية ساعدت في حل العديد من المشاكل تحت سطح الارض، على سبيل المثال التسرب في مياه الانابيب تحت الارض ولاعماق مختلفة الذي يعتبر مشكلة معقدة ومكلفة في نفس الوقت في الحياة العصرية. الدراسة اسهمت في حل مسألة استخدام التردد المناسب مع العمق للكشف وهذا موضح خلال النتائج التي تم الحصول عليها وكانت النتائج ايجابية.

الكلمات المفتاحية : كشف الاختراق الارضي ، التسرب ، التردد، عمق الاختراق .

1. Introduction

The problem of different frequency and its effect on skin depth have a vital role in practical life, so in this study we will use a leakage that happen in pipe such as sewer to explain the utilization of various frequency and skin depth impact.As a prefix, the loss in sanitary water has adverse reactions also causes economic losses for the authority of sanitary in different sides where pumping used for charge and discharge of the tank, additional costs are induced by the detection, localization and repair of the leak and the pollution effect on human health. In fresh water side the countries have scarce water, saving water as well minimum the use of very energy–consuming desalination processes [BBC, 2011].The join between the sewer pipe and fresh water pipe is strength, where the pollutants can contaminate the drink water specially when there is a compression in pipe decreases, moreover this causes public health issues. Finally ,if the leak remain undetected may be cause a local erosion and may induce infrastructure damage (such as, cave, Etc.).The water supply company of Wallonia(SWDE)estimate the excavation to verify and/or repair a leakage overwhelmingly costs above 1,000€.So with fast development of huge complex pipe networks and the growing utilize the plastic pipe, the need for high resolution imaging of the subsurface is necessary. The Ground Penetration Radar is a technology which have the ability to answer this need. Concerned by these issue, many companies search to systematically detect and repair leakage, currently the most widespread technology for leak detection and investigation is based on acoustics and leak noise correlation (such as sound and vibration anomaly detection).Nonetheless, these technique have difficulty in pin pointing leaks for pipes with ill sound propagation like asbestos cement pipe. Moreover these techniques will do not provide details about the subsurface which can generate extra costs during the repair. So conclude from upper paragraphs the GPR is the best instrument and technology for leak and pinpointing the position of pipe with full information such as depth, materials and etc., the study contribution in problem solution is by using a model and field test in more than one location with multi condition, to arrive to solution for the problem, the testes and model measurement redound in solution of the problem, the data and method will explain the full measurement and details. The selection of the antenna frequency to implement in field work is depend on the desired application, a high frequency antenna (such as 900 MHz) has a low or shallow penetration (classically 1 meter maximum, if the milieu is dry) and a higher resolution (such as able to be utilize for the characterization of substances, void detection) [Presente , 2013]. Whilst a low frequency antenna (such as 200 MHz) means a deeper penetration (5 meter, if the medium is dry and not saturated) and a lower resolution of the signal (like utilize in detection the deeper subterranean bodies, but makes them harder to describe) [Presente, 2013]. So the use of GPR commonly implies enhancing the trade-off among resolution and skin depth [Presente , 2013]. The radar wave have depth of penetration is depending on both the frequency of the wave and electrical characteristic of the milieu, the higher frequencies utilized, the lower depth is achieved. While using high frequencies is commonly attach with high resolution of the radargram and contra [Sabah, 2009], [Annan, 2003]. The preferable penetration is accomplished in high resistivity media. Low resistivity media on the other side attenuate the signals which results in shallow penetration [Bernth, 2005], [Jorge, 2007]. While in a paper aforementioned the GPR considered is one of the commonly utilize tools in the field of the water monitoring and management especially in the practical work of the drainage pipes detection and properties [Soldovieri et. al., 2011], [Jeffrey *et.al.,*2008], water leakage in pipe detection [Crocco *et.al.,* 2010] determination of the time–behavior of water content in the soil [Sébastien *et.al.,* 2008], [Lambot *et.al.,* 2004]. The optimum selection of frequency of operation to accomplish the best performance in terms of depth and ability to see information in the target structure, this selection range was between 1 and 1000 MHz [Eltesta Company]. Commonly low frequency are utilized for deep probing (>50 meter) and high frequencies are implanted for low penetration (<50 m). The lesser the frequency, the larger the probability of locating signal back through into the milieu, frequencies are preserved as small as probable to highest back through moreover if resolution is equalize [Harry, 2009].

2. Fundamentals

2.1 Ground Penetration Radar

GPR have the ability to provide high resolution imagery of the subterranean involving pipe, cable network geometry and leak location. GPR is particularly beneficial for the investigation of plastic pipes and exceed the conventional acoustic procedure in this function. It is implemented in a diversity of domains, involving, but not limited to, archaeology, sediment deposit detection [Neal, 2004], road [Jean *et. al.,* 2012], and construction material characterization [Lai *et. al.,* 2011], pipe examination [Matthaios *et.al.,* 2011], polluted sites observing [Ralf et. al., 2000], [David et. al., 2003] and soil humidity estimation [David *et. al.,* 2003]. Like the other technique, the GPR as well has limitation. Its sensibility to soil humidity, this mean the GPR cannot be utilized during and immediately later the rainy climate or when the water table is close to the surface. Moreover it need a specialized image interpretation (called radargram) skills and software [Costello *et.al.,* 2007], a brief of the GPR is provided in Table 1.

2.2 Frequency and electromagnetic wave

A wave is a transfer of energy from one place to other without the moving a material between the two places, or a wave is a disturbance that carries energy from place to place. A common example of a wave is a wave on the ocean where know they carry energy, as they cause erosion on the shore, but material such as water is not continuously being transferred onto the shore. There are waves do not need matter (named a "medium") to be qualified to move (for example, through space) these are called electromagnetic waves (or EM waves). Some waves must have a milieu so as to move these are called mechanical waves [Stewart , 2012]. The number of occurrences per unit time of a repeating event that a periodic function repeats the same sequence of values during a unit variation of the independent variable this called as temporal frequency, which confirm the disparity to spatial frequency and angular frequency, the period is an interval of one cycle in a repeating event, thus conclude from that the frequency is reciprocal of the period [Randall, 2016]. Moreover in case of increasing frequency we will get short wavelength whereas decreasing the frequency the wavelength will be long, but at the same time the resolution will change related with frequency therefore the use high frequency antenna will get high resolution but will get low depth. So selection an antenna is based on work condition and requirement. If you require long skin depth you will tend to choose low frequency antenna and conversely [Lawrence, 2013]. The depth that GPR can be effective is function of some factor like water content, material conductivity, antenna gain and efficiency, receiver sensitivity and transmitter pulse width [Lawrence, 2013]. The execution of GPR is estimated from the below radar range equation. Maximum radar range is depend on radar system factors, target parameters, and the electromagnetic properties of the materials that being probed.

$Q=10\log\left(\frac{Pmin}{Pt}\right)=10\log\left(1\frac{E_t E_r G_t G_t v_m^2 g e^{-4\alpha r}}{64\pi^3 f^2 R^4}\right)$, [35]. Q is the factor of system performance in decibels (dB) and the various component are:

1-System dependent: Pmin = minimum detectable power , Pt = output power of transmitter to antenna, Gt and Gr = gain antenna, f = frequency of operation

Media dependent: v_m= velocity of propagation in milieu, α = milieu attenuation coefficient, e= natural logarithm

Target dependent: G = target back scatter gain, σ =target scattering cross-section area

Range dependent: R= distance to target from antenna

GPR system classically acquisition vertical radar "scans" data rate reach to 100 scans per second, permitting data collection rates at driving speeds in case of using vehicle. Here an instance using 100 scans/second, shill produce 55 scans per meter if the survey done at 70 km/h. During a survey the data are digitized and recorded on digital tape or hard disk [Rexford, 1998]. The overall philosophy for GPR design is largely applications-oriented where the details of design depend on intervening earth medium and target type. The subject of electrical properties ($\mathcal{E}$, μ, **σ**) of mineral is a wide-ranging subject. More about found in [Gary, 1981], [Santamarina *et.al.,* 2001]. So will explain a brief about the frequency and wavelength, moreover in most GPR applications, difference in $\mathcal{E}$ and μ are more substantial whereas differ in **σ** are hardly of depend. The basis of GPR lie in electromagnetic (EM) theory. The chronicle of this field extension more than two horns and is the topic of numerous document like

[Jackson,1962], [Smythe,1989], [Reitz *et.al.,*1960]. Maxwell's equations mathematically illustrate the physics of EM fields, while constituent relationships quantify mineral characteristic. Integrate the two provides the basis for quantitatively explaining GPR signals. In mathematical expression, EM fields and relationships are explicit as follows [Annan, 2003]:

$\nabla\times E=-\frac{\partial B}{\partial t}$ ……… (1), $\nabla\times H=J+\frac{\partial D}{\partial t}$ …..(2), $\nabla\times D=q$……. (3), $\nabla\times B=0$…………. (4)

Where E is the electric field power vector (V/m), q is the electric charge intensity (C/m3), B is the magnetic influx intensity vector (T), J is the electric flow intensity vector (A/m2), D is the electric displacement vector (C/m2), t is time (s), and H is the magnetic field density (A/m). Maxwell's equations (equations1–4) explain a coupled collection of electric and magnetic fields when the fields change with time. Depending on the relative quantity of energy wastage (related with conductivity) to energy storage (related with permittivity and permeability), the domains may widespread or propagate as waves. The magnetic and electric domains are normal to each other in same one plane, while the propagation direction is perpendicular to that plan see Figure 3. Note that all frequency transition is depending on relative permittivity and conductivity. At GPR frequencies (10-1000 MHz), the pore water is the major contributor to bulk conductivity, the reason that water is significant is that water is essentially a polar particle. This signify that the water particle has a built-in net displacement of positive and negative elective charges in its molecular structure, water is very polarizable because the dipole moment of the water molecule shill align itself within an applied electric field. In other words, the dipole dispersal in liquid water shill redistribute itself to try to bring into line with the applied electric field. This results in a relative permittivity for water in the range of about 80, information discussions about the properties of water can be establish in the educational book [Hasted, 1972]. The permittivity is temperature dependent, with water existence a polar molecule, it shill dissolve ionic substances. When ionic materials are placed in water they separate forming positively and negatively charged ions which behavior electricity by existence moveable in the water. Pure water is a bad electrical conductor. Conductivity is relational to the amounts of dissolved ions current. Salinity and total dissolved solids (TDS) are processes of dissolved ion concentrations in water. Water acts as a polarizable substance till frequencies surpass a few thousand MHz, naturally in the variety of 10,000 MHz, the water particle dipole moment might no longer track the practical electric field. The water particle dipole moment rotation or arrangement with an exterior exciting field is not harmonized which reasons energy dissipation in the substance. This episode is mentioned to as a natural relaxation process [Annan, 2003].

2.3 Skin depth and resolution

Can be defined as the maximum depth range a radar signal have the ability to penetrate in a given milieu. The maximum depth penetration of Ground Penetration Radar signals in the terrain is generally unknown among GPR employers because the propagation of the electromagnetic signal rely on the electrical characteristic of the particular soil and the domain of the antenna frequency. Through the EM propagation in ground minerals, the waves will be losses in many compose of loess and this limit the penetration depth in terrain minerals. The level of this loss is chiefly rely on the water content and mineralization current [Reynolds, 1997], [Sabah, 2009]. The frequency antenna is proportionate inversely with penetration depth. Signal penetration depth minimize with rising conductivity [Fall, 2007]. The resolution can clarify as expression utilize to describe the number of dots, or pixels, implemented to display an image in digital monitor screen. In GPR technology, the resolution have another expression, it define as the radar system capability to distinguish individual elements in the underground soil, in one of these two on thickness or in size and show the outcomes on monitor screen of Ground Penetration Radar instrument [Daniels, 2004], as well known as the capability of the measurement system to recognize between two signals, or the smallest separation that two bodies can be separated by and still be singular imaged, [Fall, 2007], [Annan *et.al.,* 1992]. In GPR techniques the resolution notion is substantially split in two portions: vertical (down-range, depth or linear) resolution (▲v), and horizontal (side displacement, cross-range, angular) resolution (▲h) [Daniels, 2004], [Annan, 2001]. The radar energy propagates in the earth as a roughly conical spreading the domain of spreading is relying on wave characteristic like frequency, wavelengths etc. Resolution has directly commensurate with frequency and contrary with wavelengths [Annan *et. al.,* 1992], [Olhoeft *et. al.,* 1993]. The vertical and horizontal resolution of GPR enable to predestined from the middle frequency, (Center frequency (fc) refer to the total of number of oscillate in time units)[Annan, 2003] of the antenna and the relative permittivity (εi) of the terrain from which the wavelength can be obtain as shown in Table 2. The 'footprint' of the (fc) conically propagate energy raise with depth (D) decrease the effective horizontal resolution [Annan et.al., 1992] see Figure 2. The longer wavelengths generated by low-center-frequency antennas will decrease the vertical and side resolution of inhumed objects. By the wavelength and polarization of the electromagnetic energy the resolution will controller. The contrast in electromagnetic characteristic, the volume, the form, and direction of the target, may be a function of noise in practical work [Olhoeft *et.al.,* 1993], [Annan *et.al.,* 1992]. For a given material, penetration depth will generally be a function of wavelength [Neil *et.al.,* 1976], the penetration will be shallow in moisture medium and it will be midst between shallow and deep penetration, the other variable is silt where it is the bigger effectible factor on penetration depth because of the silt play vital role as dipole moment and water is present in all materials to some degree. The skin depth of a GPR signal based on [Hasted, 1972]:

1-The frequency of the GPR foundation signal.

2- The GPR antenna radiation efficacy.

3- The electrical characteristic of the subsurface.

2.4 Wave speed and frequency

Wave speed depends on the milieu in which the wave is roving. It varies in solids, liquids and gases.

A mathematical way to calculate speed:

Wave speed = wavelength (in meters) x frequency (in Hz) or V = F *ג

Many dry materials, such as soil or sand, when small amounts of water are put into the mix, the dielectric of the wet material becomes higher and thus the microwave velocity will decrease. For instance dry clayey soils have microwaves which travel twice as fast at wet clayey soils [Rexford, 1998].

3. Methodology

The practical work made for multipurpose, one of them is to prove the theoretical part that talk about resolution, depth and frequency effective and properties of materials. There is more cases done in this study, the first has been done in a model compose from box have a material of compressed wood, general road and tub of water (same box of wood but cover it by piece of nylon). While the pipes using in this testes is plastic, asbestos cement and iron, where the diameters of pipes is different according to case of study. Below will explain the cases of study with radargrams in brief details. The flowchart below explain the approach of work.

- Case 1: three plastic pipes empty scanned with antenna frequency 1000 MHz, the milieu is dry sand where the signal have free translation in the medium, while the depth of buried pipe is considered compatible with the frequency, also called shallow depth, some details about the frequency and appropriate depth [Sabah, 2009], see Figure 5.
- Case 2: First pipe is dry, second and third is saturate in this case made an artificial leak to recognize what happen in radargram, if looking to the Figure 6 will see the first pipe appear more altitude than the other pipes because of the speed of return signal for the first pipe is higher than the other, the reason beyond that is the humidity of medium [Annan, 2003].
- Case 3: Use two pipes one of these is plastic pipe have thickness 1cm, also diameter 10 cm and second pipe is iron with diameter 30 cm, here notice a change in diameter of pipe and material, while in process and interpretation steep recognize the iron have radargram clearly than plastic pipe, because of the conductivity for iron is bigger than the plastic pipe [52].
- Case 4: try for showing the pipe in water medium, this trail of measurement in water medium while the result appear excellent, because it is considered on medium just water see Figure 7. While in the next test see Figure 8 notice the same medium (water) but the pipe filled in half of water, notice there are a reflection on signal, one reflection is come from first surface of water, and the next reflection is come from pipe surface.
- Case 5: showing the iron pipe buried in water milieu, where see the iron pipe is so much clearly than a plastic pipe, for the same reason the high conductivity [Annan, 2003]. Through the measurement notice there is no different if the iron pipe filled by water or not because of the iron have high conductivity, while this consider the answer about why there is no more reflection back from the pipe Figure 9.
- Case 6:done by chose a typically road with full layers (asphalt, sub-base and clay), and make an artificial leak under the road by using pipe with open hole in different position see Figure 10, there is more than one antenna frequency used in this test all take approximately convergent result because of the design of pipe level or depth is considered shallow so any antenna can detect the pipe especially that have high frequency,
- Case 7: will explain the different between the frequency and the effective of it on the scanning process. In this test done in resolution is considered approximately high where the pipe that have diameter (3cm) at depth (1.07cm), at same time notice the speed is essential part in penetration where if the medium is dry the speed will increase and the penetration shill be more than current. In this cases the milieu is dry sand, where the antenna used is 1000MHz see Figure 11. While when change the antenna frequency to 800 MHz, can be recognize the pipe but little clearly than antenna that have frequency 1000 MHz this reason is related to frequency that is used see Figure 12. Here can notice some of shape of different in antenna frequency and its impact. The using antenna with low frequency (500MHz) so as to detect object that have small size like pipe with diameter 3cm is difficult because of as mentioned upper, the low frequency permit to detecting a little big object while the depth is maximum than using antenna have frequency bigger than 500 MHz, see Figure 13, where notice there is no vestige to the pipe in radargram. Moreover return the case 6 previous mentioned but rising the depth to 1.5 meter and pipe with diameter (10 cm) and antenna with frequency 1000MHz,

can recognize the layers with full details but cannot able to recognize the pipe was buried under road's layers. While use antenna with low frequency (800 MHz) that allowed us to inspect the pipe, but the road's layers has become less clear because of the low frequency led to low resolution with increase depth see Figure 14.

- Case 8 : will be conclusive the ambiguity through by burying four pipes in sand medium on the wood box with different size, Figure 10 explain the radargram scanned by GPR with antenna frequency of 500 MHz, while the diameter of pipe is (1, 2, 3, 0.5 cm), where the small diameter of pipe cannot recognize by the low frequency antenna (500MHz) [Annan *et.al.,* 1992], just the little big pipe in comparable with others pipes that have diameter of (3cm), but when using another antenna frequency (800MHz) clarify the little small size of pipe (3, 2 cm) is obvious appear in the radargram see Figure 15, while using antenna with high frequency that rejoice in good characteristic like high resolution with disadvantage is shallow detection, so by this frequency permit to detect a pipes with small size reach to 0.5 cm in general conditions, see Figure 16. Final test was done in general street to detect the buried pipes and check the validity of pipes underground, by scanning by utilize GPR instrument, in this field work find result consider important in comparable with upper feedback, when did the scanning by using antenna with frequency 1000 MHz notice cannot recognize the pipe underground depth of 0.5 meter [1], in this tour of scanning observe some pipe with good circumstance figure 17. While in using antenna frequency 500MHz allow to see the pipe underground in depth approximately 1.6 meter figure 18.

4. Result and discussion

The deduce from a practical work and the theory basis is considered important, the goal of this study is to explain the difference, when using antenna with low frequency and antenna with high frequency and its affection on penetration depth. The consequence from the cases of the experiment will explain below.

Cases study:

- Case 1 explain the three pipe in dry medium. Notice the radargram has a little clear imagery the reason beyond that is the absence of humidity in the milieu, so the penetration will be in an optimum configuration and the frequency shill work in ideal performance , without side effect from the around conditions , the depth of buried object (pipe) is considered compatible with frequency antenna that selected , at the expense the antenna frequency of 1000MHz count shallow scanning antenna frequency , with high resolution and low penetration.
- Case 2 identify another case study where in this case select the same three pipe, but in various medium, and in the same time differ than the case 1 milieu .The first pipe medium is dry , where the signal will propagate through the medium with free limitation , like the first case, but the other two pipes medium is saturate , this is indication for the radargram of the two saturated pipe will be not same for the dry pipe , the reason is water content Impedes movement of wave that refer to the velocity of separation of electromagnetic wave will be less than the velocity of dry medium.
- Case 3 show two pipes the first plastic with thickness and diameter of 1 cm and 10 cm sequent and the other iron with diameter of 30 cm, the buried depth is same, but the resolution and clear standard for the iron pipe is higher than the plastic pipe because of the conductivity factor, that consider one of the great affective parameter, have influence on the penetration depth and velocity of translation of electromagnetic waves.

- Case 4 utilize a stranger medium comparable with other milieu, the water medium chosen for idea like, when a disaster happen such as flood in a given location, and need to make scanner for the area with a given depth to detect the underwater bodies, the other idea is test the penetration of the signal into the water, the result that gotten from the study experiment is excellent, where the underwater pipe appear clearly and with details approximate close to actual, in the plastic pipe radargram appear more than one reflection, because of the pipe is filled in half and the reflection of signal part from surface of pipe and the other from the surface of water inside the pipe. The other result about the other testes will briefly explain below, the use a general road with full layers asphalt, sub-base and clay, all compacted. The testes done in different antenna frequency (500,800 and1000)MHz but when utilized a low frequency the penetration depth is a little high in trade-off the 1000MHz antenna frequency, but in same time the detection resolution will decrease, in other mean, the small body will appear in weak configuration and /or not appear. Versus with high antenna frequency detection. The test than put four pipes in sand box and the scanning done, the small pipes appear clearly in scanning done by antenna frequency of 1000MHz, while in utilization of antenna frequency of 500MHz cannot recognize the small pipe. Big pipe appear clearly in implementation of antenna frequency of 500 MHz., below some of radargrams for the practical work.

5. CONCLUSION

Meanwhile the last two decades, GPR has appear as a hopeful technology for booby trap and UXO detection. Under several ecological conditions, the GPR sensor pretend a high detection rate for UXO and antitank mines. The detection of AP mines is more tricky, but here very favorable results are pretended as well (particularly for shallowly entombed mines).The GPR sensor has a many of usefulness over other landmine investigation sensors. First, it is complementary to traditional metal discoverer. Instead of detecting especially the existence of metal, it senses difference in the electromagnetic characteristic of the terrain and therefore it can discovery mines with a wide variety of kinds of cover (not just those with metal). So will explain summary conclusion about the study below:

1) The selection of antenna frequency is depend on the purpose of project if it require resolution without high penetration where this led to work on instrument have a high frequency antenna, and the versus work when the project require high penetration.
2) In this study using technical of GPR that consider good, cheap, and the best aspect is non-destructive instrument for engineering investigation work, the study applied in parts:
3) First part was applied in wood box:
   a) Two medium used: a. soil medium b. water medium.
   The first part was done in box have dimension 2.4*0.6*0.6 where the depth of this box consider shallow in comparison with depth of GPR can reach it.
   b) Second part was applied in pavement road.
4) The degree of visibility of underground bodies does not depend on their dielectric constant, but on the dielectric contrast between the object and the host medium and the size of the body.
5) The moisture condition work on decrease the penetration depth and the reflection will be lack, and the object in shallow depth will be more clearly than the deep object.

6) The velocity of microwave signal will be little slow in wet medium than the velocity in dry milieu.

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Table 1: Summary of GPR properties [41].

Method	Principle	Advantages	Limitations	Cost
Ground penetrating radar	Emits electromagnetic microwave and registration the reflected signal from subterranean	Non-destructive method supply high resolution images of underground Independent of the pipeline mineral Can discover bodies, changes in mineral and voids Cool penetration depth	Need data processing and interpretation signal attenuation with conductive soil	High

Table 2. Explain estimated values for the difference of GPR penetration depth and resolution with center frequency for normal soils (geophysical survey in archaeological field evaluation, 2008)

Center frequency (MHz)	Depth penetrating for typical soil (m)	Wavelength (λ) in soil E1 = 15 (m)	Horizontal resolution-width of fresnel zone at maximum depth (m)	Vertical resolution λ/4 (m)
1000	1.0	0.08	0.2	0.02
500	2.0	0.16	0.4	0.04
200	3.0	0.39	0.8	0.10
100	5.0	0.77	1.4	0.19
50	7.0	1.55	2.4	0.39

Table 4. Explain material or medium, conductivity, dielectric and velocity [Rexford, 1998].

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	0.112	0.4-1.0
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

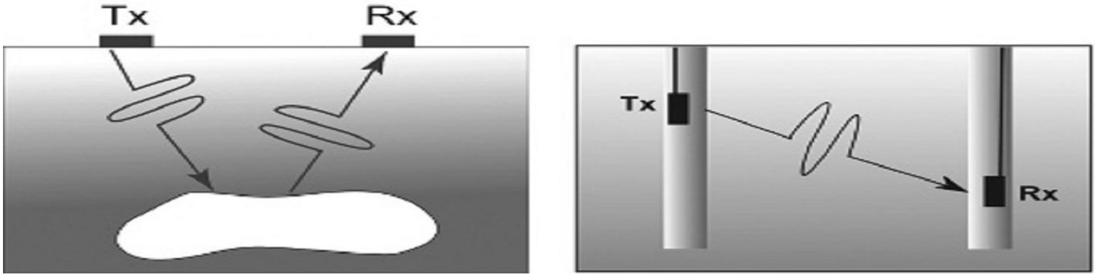

Figure 1. Ground penetrating radar (GPR) implement radio waves to probe the underground of lossy dielectric mineral. Two manner of measurement are generally. In the first, send back or scattered energy is detected. The second, impact on energy transmitted through the mineral are spotted [Harry, 2009].

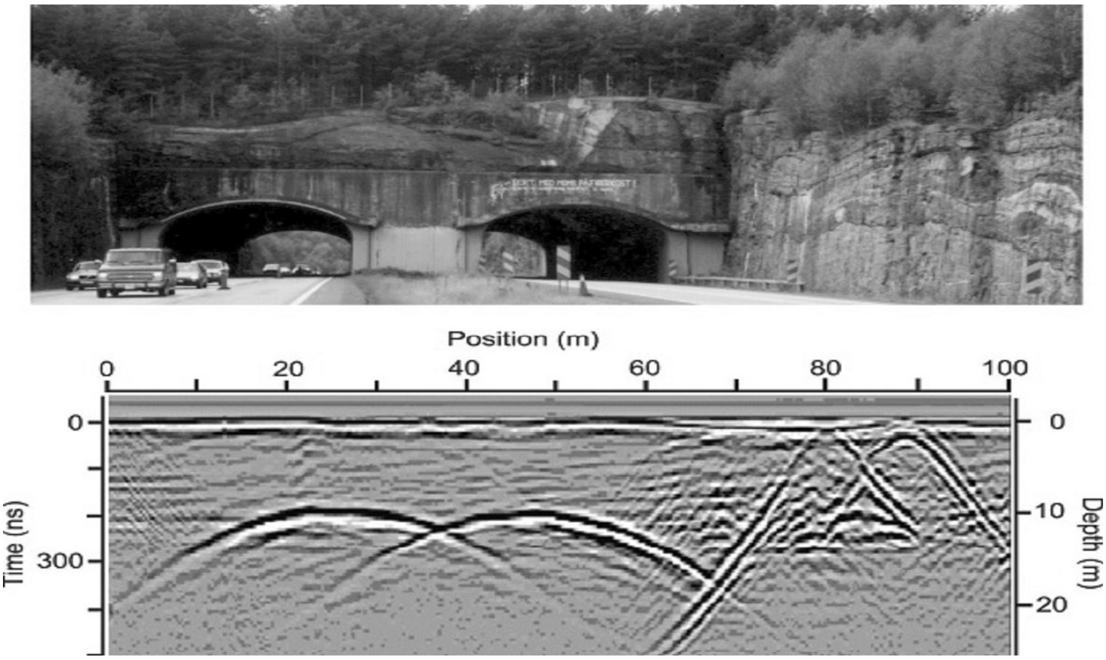

Figure 2. GPR cross section acquired with a 50-MHz system travel over two road tunnels. Ground penetrating radar signal capacity is showed as a function of position (horizontal axis) and time of travel (vertical axis) [Harry, 2009].

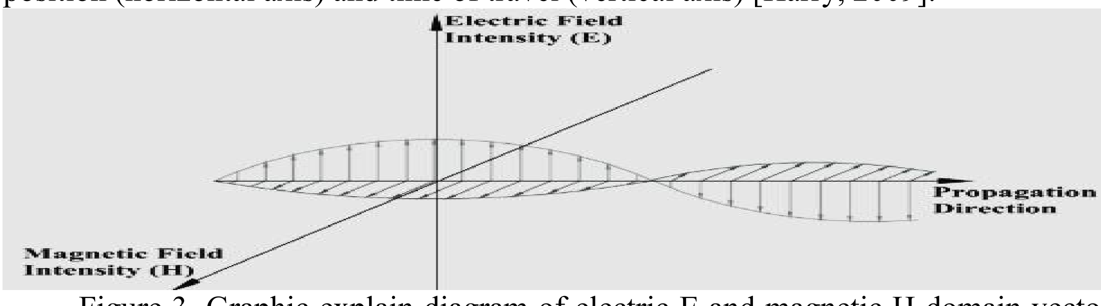

Figure 3. Graphic explain diagram of electric E and magnetic H domain vector component for electromagnetic waves propagation [Baker *et. al.,* 2007].

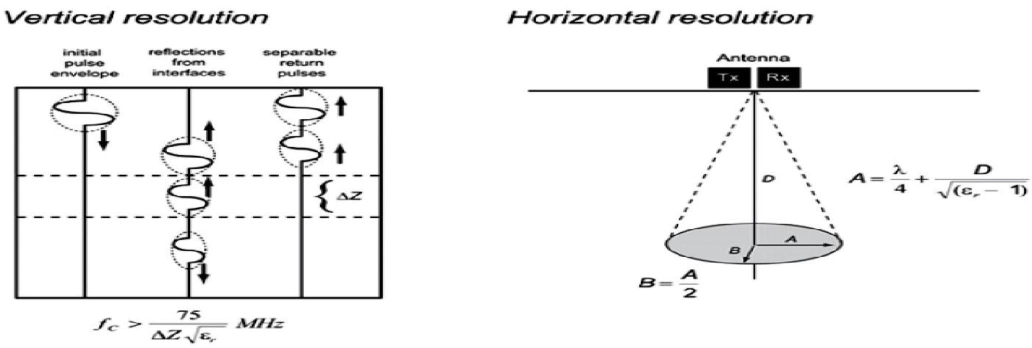

Figure 4. Explain the vertical and horizontal resolution [Annan et.al., 1992].

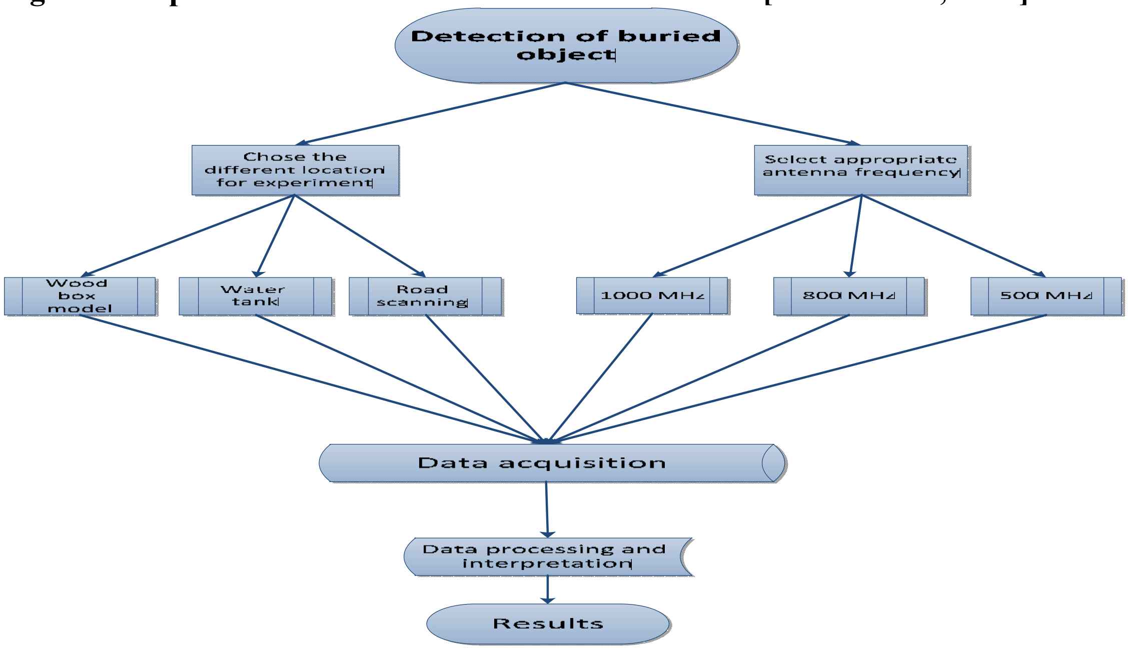

Figure 5. Explain the work approach in the methodology

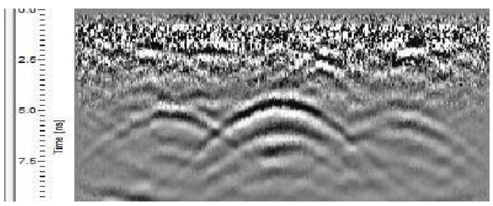

Figure 6. Three plastic pipe empty scanned by antenna frequency 1000 MHz.

Figure 7. Explain three pipe the first is dry and the other two pipe is saturated

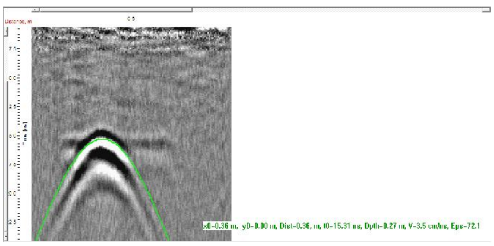

Figure 8. Explain a plastic pipe in water medium empty from water.

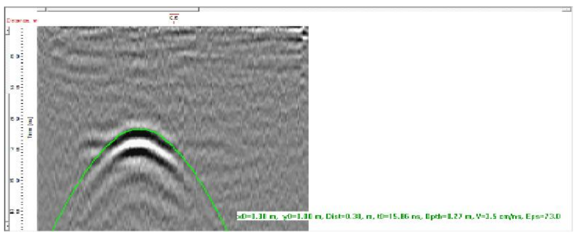

Figure 9. Plastic pipe buried in water medium ' the pipe filled in half of

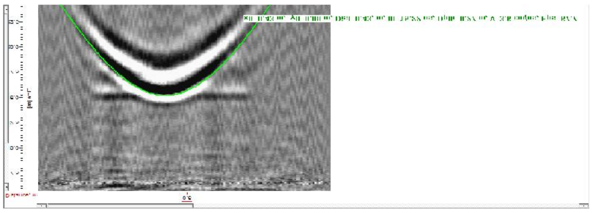

Figure 10. Iron pipe buried in water medium.

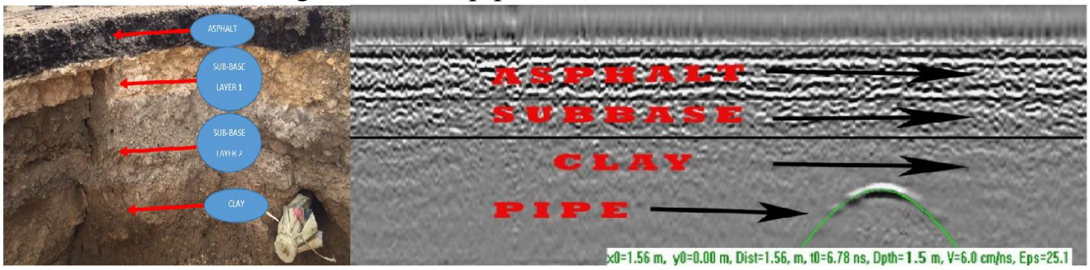

Figure 11. Radargram illustrate road layers with pipe and actual photo for the road and layers.

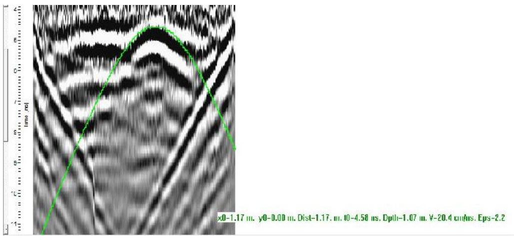

Figure 12. Illustrate pipe with diameter 3cm can recognize by antenna have frequency 1GHz.

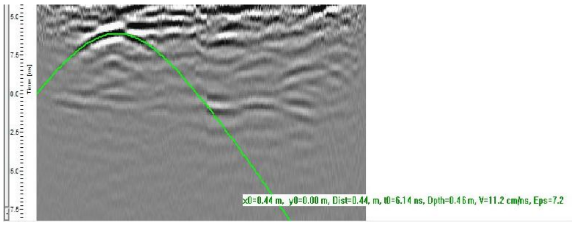

Figure 13. Illustrate pipe with diameter 3cm can recognize by antenna have frequency 800MHz.

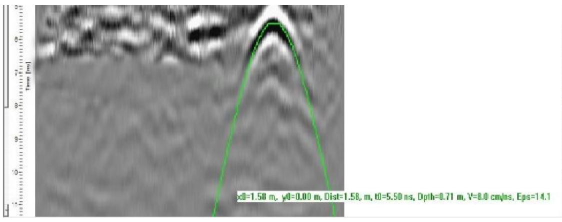

Figure 14. Explain radargram of with antenna have frequency 500 MHz.

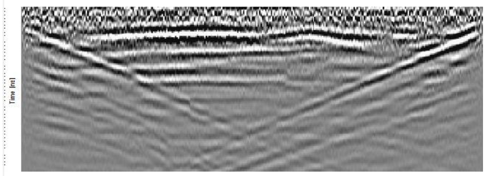

Figure 15. Illustrate the radargram scanned by GPR with antenna frequency 500MHz with pipes buried diameter (1, 2, 3, and 0.5) cm.

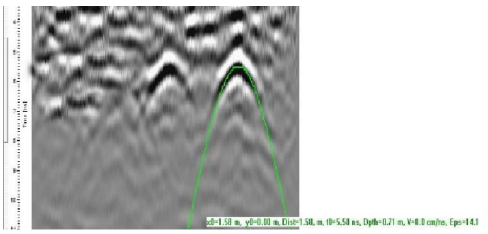

Figure 16. Illustrate the radargram scanned by GPR with antenna frequency 800MHz with pipes buried

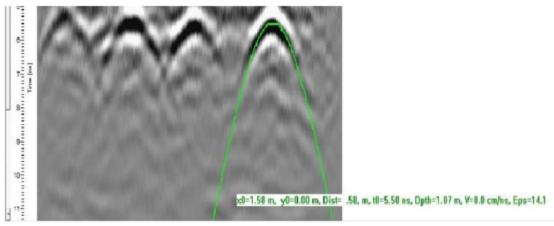

Figure 17. Illustrate the radargram scanned by GPR with antenna frequency 1000MHz with pipes buried diameter (1, 2,

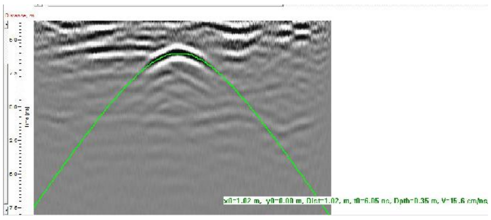

Figure 18. Illustrate the radargram scanned by GPR with antenna frequency 1000M.

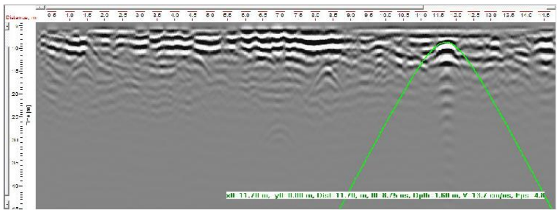

Figure 19. Scanning with antenna frequency 500MHz.