VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PILOT STUDY ON DEVELOPMENT OF GPR SYSTEM USING HYPERLOG ANTENNA

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ABSTRACT

GPR is known as one of a non-destructive testing (NDT) method capable of detecting objects underground. Antenna is an important part in this system as the function is to produce and detect electromagnetic wave. As one of the alternatives, Hyperlog antenna which has high bandwidth can be used in the development of GPR system. In this paper, the GPR system has been developed using Hyperlog antenna and network analyser. Based on the results, the developed GPR system is capable of detecting a circular iron plat buried in sand around 0.06 metre depth. This shows that the Hyperlog antenna is suitable for use in GPR system.

Key words: GPR・ Hyperlog Antenna・ Vector Network Analyser・

INTRODUCTION

Ground penetrating radar (GPR) is one of the effective technique used in detecting material buried underground. The GPR technique uses electromagnetic wave properties which will interact with material with different electrical properties exist underground. It is said that based on this material's electrical properties the propagation of electromagnetic wave will be effected. There are many application involving GPR such as rebar detecting for corrosion level determination (He,Zhu,Liu, and Lu, 2009) and concrete condition monitoring (Verma,Bhadauria and Akhtar 2014).

In GPR system, antenna is used as a sensor to produce and detect electromagnetic waves. One of most popular antenna used in GPR system is TEM horn antenna as developed by Berthold (Berthold, Andrea and Abbas, 2013). It is a double-ridged horn antenna operate at 6 – 20GHz. Other type of antenna like the bowtie as studied by Bindu (Bindu et. Al, 2005) and Roslee (Roslee,Subari and Shahdan, 2011) is also a popular choice. In order to improve the performance, several approaches may be used and one of them is by sheilding the antenna (Chen and Liu, 2010) . In many cases the GPR antenna had been studied using simulation software and the results are analyzed for system's improvement.

The electromagnetic waves in GPR system are illuminated using antennas where the operating frequency should meet the objective of the detection or application. Based on Rial the detecting distance using GPR depends on the operating frequency of the antenna (Rial, LorenzoPeriera and Armesto, 2009). The relation between the detecting distances of an object underground with frequency is estimated as:

$$\Delta v = \frac{c}{2\times\Delta f} \quad (1)$$

where Δv is the vertical resolution of the system, c is the velocity of an electromagnetic signal in vacuum, and Δf is the bandwidth used by the system.

By referring to (1), the bandwidth plays an important role in determine the GPR system resolution. The use of high bandwidth is suitable in detecting objects underground which is located at shallow depth.

In addition, the speed of light in free space, *w* as related to permittivity and permeability discussed by Kazonuri is given as (kazunori,Jan,Holger, and Seiichiro 2012):

$$w = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \quad (2)$$

where ε_o = 8.854 × 10^{-12} F/m is the permittivity of free space and μ_o = 4π × 10^{-7} H/m is the free space magnetic permeability.

Expanding equation (2), the speed of light in dielectric relative can be simplified as:

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0\varepsilon_r}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}\times\sqrt{\varepsilon_r}} \quad (3)$$

where $\varepsilon_r = \varepsilon / \varepsilon_o$ is the relative permittivity (dielectric constant) of the medium and $\mu_r = \mu / \mu_o$ is the relative magnetic permeability. In most soils, magnetic properties are negligible, yielding $\mu = \mu_r$.

Inserting equation (3) into equation (1), the detected distance of GPR in dielectric relative object can be estimated as:

$$\Delta v = \frac{c\times\sqrt{\varepsilon_r}}{2\times\Delta f} \quad (4)$$

VOL. X, NO. X, XXXXXXXX ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

GPR SYSTEM

The purpose of this study is to determine the suitability use of Hyperlog antenna as a GPR antenna system. The scope of this study is to detect a circular iron material buried at about 6 cm depth in the sand. The GPR system in this study consists of a Hyperlog antenna uses as transmitter and receiver, and a vector network analyser to view the resulting response.

Hyperlog Antenna

Hyperlog antenna 7060 shown in Figure 1 is a wide bandwidth antenna which covers resonance frequencies from 700 MHz until 6GHz. The gain of the antenna as given in datasheet by the manufacturer is 5dBi .

Figure 1: Hyperlog antenna.

According to the bandwidth of the Hyperlog antenna, it is suitable to be used in GPR system for detecting object buried underground in shallow depth.

Modified Hyperlog Antenna For GPR System

The Hyperlog antenna is placed in a paper box as shown in Figure 2 to ease the measurement. The paper box acts as a support to the antenna to ensure good orientation at all time.

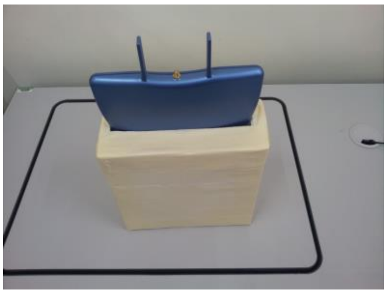

Figure 2: Modified Hyperlog antenna.

Vector Network Analyser and S11 Parameter

The proposed system uses single antenna for GPR system as transmitter and receiver, therefore a vector network analyser have been used to measure the resultig S-parameters. The calibration of the network analyser has been done using transmission open short match (TOSM) technique. The setup of the GPR system is as shown in Figure 3.

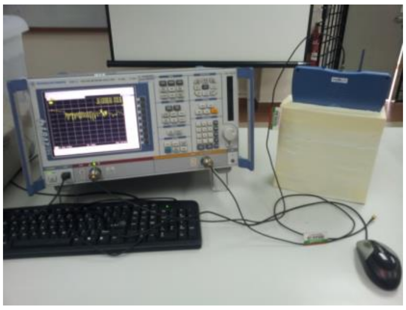

Figure 3: GPR system setup.

Signal Processing Algorithm

The scan data of the developed GPR system has to be transformed into time domain scheme to convert to pulse signal. The estimation of the characteristics of the buried object can be done by analyzing this pulse signal. The flowchart of the signal processing algorithm in this GPR system is shown in Figure 4.

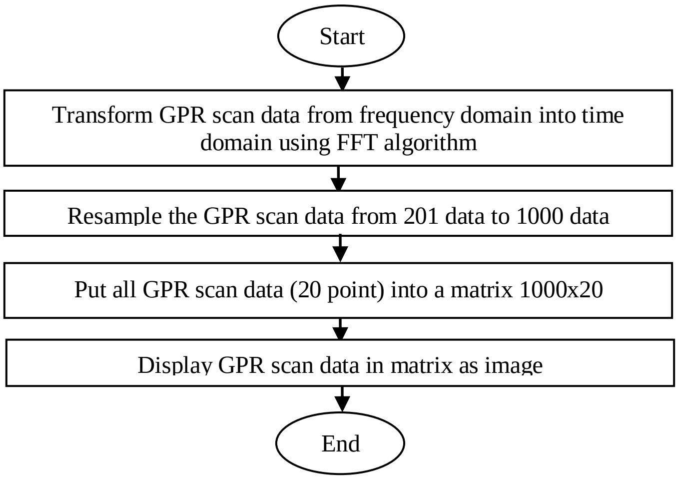

Figure 4: Flowchart of Signal Processing

EXPERIMENTAL PROCEDURE

The testing bed is made of a wooden box which is filled with sand with the size of 50cm x 50cm x 8cm. In the middle of the wooden box, a circular iron plate is buried at about 6cm depth. The diameter of the iron plate used in the test is about 12.5cm and thickness of 2cm (Figure 5 and Figure 6 respectively).

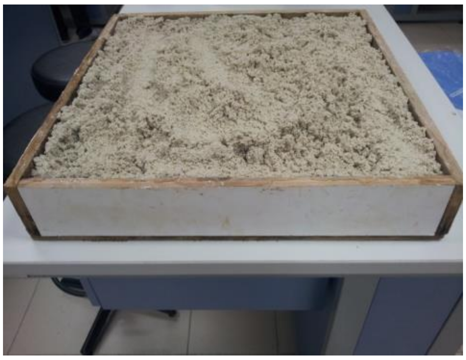

Figure 5: Wooden box filled with sand.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


Figure 6: Circular iron plate.

The testing procedure considered in this study is by scanning the wooden box from point 1 to point 20 using the propoesed system as shown in Figure 7. There are about 20 scan points involved, with distance between one scan points is about 2cm.

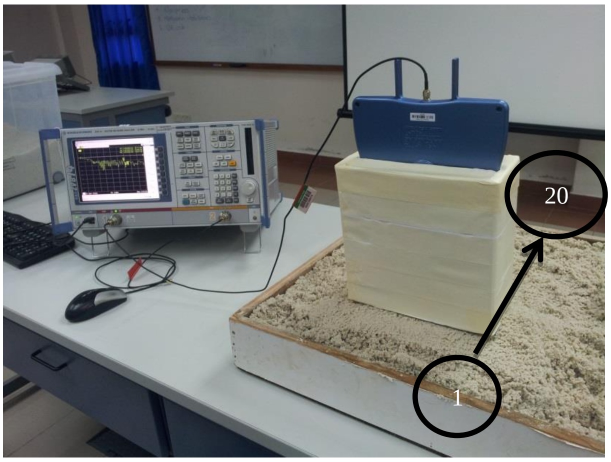

Figure 7: Scanning of GPR system.

RESULT AND ANALYSIS

The frequency domain data from the vector network analyzer measurement are imported to the computer for further processing using MATLAB software. The data were transformed into its time domain representations using the FFT algorithm.

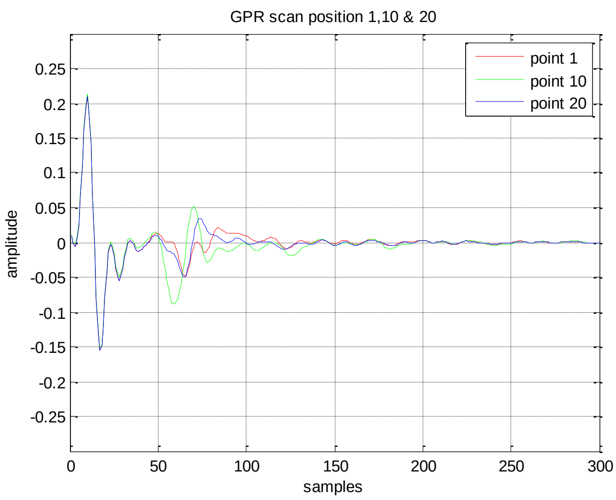

Figure 8: GPR scan signal at position 1, 10 and 20.

Figure 8 shows, the scanned signal at point 1 and 20 is almost the same. This is due to none material present under these points. On the other hands, for scanned signal at position 10, the graph shows significant ripples's amplitude for samples 50 to 100 due to signal reflections from the buried metal plate beside the reflected signal of the wooden box's based, as seen at points 1 and 10.

Based on the results, the cross section image produced is shown in Figure 9. The circular iron plate's position can be obviously identified, buried in between position 8 to 12, which is highligted as blue line in Figure 9.

Referring to equation (4), The developed GPR system can detect an object up to 0.2 metre depth because the frequency used is from 1.4GHz to 2.4GHz. This calculation is based on the permittivity value of sand used is 2 based on David suggestion which is between 2 to 6.(David 2004).

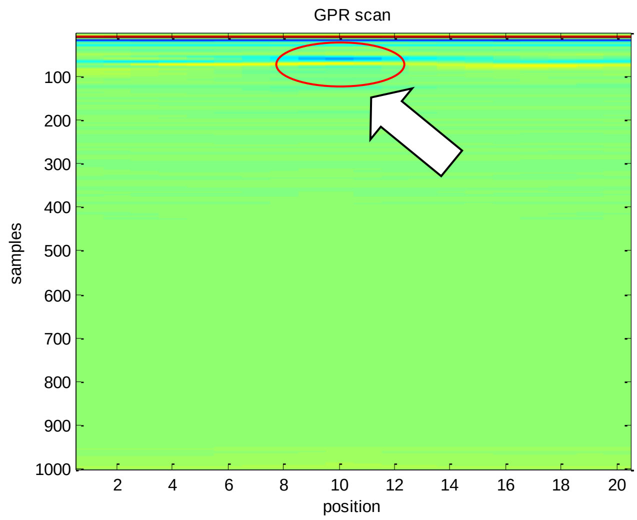

Figure 9: GPR scan of developed system.

CONCLUSION

A simple GPR system using Hyperlog antenna has been proposed. A circular iron plate buried in sand can be detected accurately. In the future, more testing will be conducted to verify the capability of the technique in detecting non matel material including woods, plastics and PVC with different size and shape.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Tun Hussein Onn Malaysia for the technical assistance support and the financial support under Multi-Disciplinary Research Grant Scheme vot 1320.

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ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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