The Analysis of EM Wave for Different Media by GPR Technique

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Abstract - ***Ground Penetrating Radar (GPR) is a near-surface geophysical tool with a wide range of applications such as locating utility, concrete inspection, archeological and geological studies. GPR is chosen for this survey for its ability to distinguish different pattern of electromagnetic (EM) wave that represents different types of media. This survey was conducted at the hilly part of Universiti Sains Malaysia (USM), Pulau Pinang. The survey site features were known subsurface architecture constructed with three different kinds of media, they are asphalt, air and concrete. The aim of this survey is to analyze and understand the signal of 3 different media. Equipments used are MALA 250 MHz shielded antenna, MALA ProEx Control Unit, MALA Monitor XV11, 50 m measuring tape rope, wheel and optical cable. The results obtained are enhanced using the RAMAC GroundVision software with 3 types of filter which are band pass, time varying gain and DC removal. After the enhancement of radargram, it is exported to ASCII format to be open with Microsoft Excel. From the Microsoft Excel, the trace of 3 different types of media is chosen and the graph of amplitude vs time (ns) is plotted. The results were interpreted accurately in order to properly assess any feature of the study particularly the length of period in the first wavelet of the graph of amplitude vs time (ns) and comparing it to the actual theory electrical properties and velocities of the medium. The results showed that air (53.04 ns) has the lowest period compared to asphalt and concrete indicating that air has the highest velocity for EM wave propagation among the three mediums.***

Key Words: *EM wave, period, medium, GPR*

1. INTRODUCTION

Ground Penetrating Radar (GPR) is one of the geophysical techniques used to study the subsurface characteristic. It is a non-destructive method and easy to operate. GPR produced a radargram during data acquisition that shows the results for different types of media.
The survey is done to distinguish the electromagnetic (EM) wave for different media such as asphalt, air and concrete. The GPR signal as displayed on radargram is difficult to be interpreted and identified, therefore a few types of filter needs to be done to make the radargram image more clearer. Based from the radargram, the signal will give different values of amplitude and attenuation properties in relation to the types of media.

In this study, the trace for each type of media is analysed. The main concerned parameter is the period which can be related to the velocity of EM wave that travelled through the different types of media.

2. GPR EQUIPMENTS

The GPR device used in this study is MALA 250 MHz shielded antenna comprises data acquisition transmitter and radar receiver. The device used during data acquisition consists of MALA ProEx Control Unit which connects the shielded antenna to the MALA Monitor XV11 that displays the radargram. An optical cable is connected from the control unit to the monitor. A wheel is attached at the back of the shielded antenna for measuring the acquisition distance. A rope is used to pull the shielded antenna while acquiring the data. The data processing equipment is basically a laptop and suitable software to visualize, filtering and interpret the radargram. The procedure of data acquisition was carried out in a line covering different types of media which are asphalt, air and concrete. Figure 1 and Table 1 shows the listings of the GPR equipments.

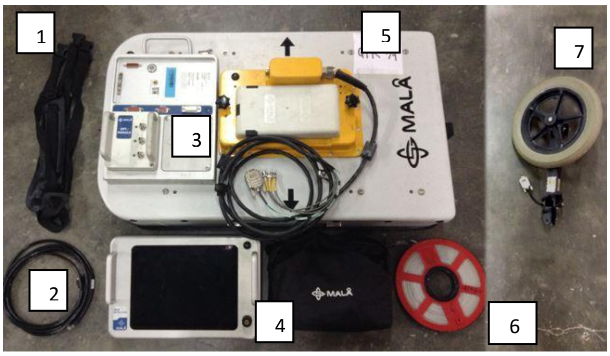

Figure 1: GPR Equipments.

Table 1: Equipment's list.

No.	Name of equipment
1	Rope
2	Optical cable
3	MALA ProEx Control Unit
4	MALA Monitor XV11 with the battery
5	MALA 250 MHz shielded antenna
6	50 m measuring tape
7	Wheel

3. THEORY OF GPR

GPR is a subsurface imaging method that provides high-resolution information to a depth of typically 0 – 10 m. Using the wave propagation characteristics of electromagnetic fields, GPR provides a very high resolution subsurface mapping method. In many ways, GPR is the electromagnetic counterpart of seismic reflection. GPR has a limited exploration depth, so it is not a tool for all applications. The most detailed information can be obtained using GPR in electrically resistive where it is the most effective [1].

A GPR system consists of a few components, as shown in Figure 2, which emit an EM wave into the ground and receive the response. A part of the EM wave is reflected back to the receiver antenna if there is a change in electric properties in the ground or if there is an anomaly that has different electrical properties than the surrounding medium or an object. The system scans the ground to collect the data at various locations. Then a GPR profile can be constructed by plotting the amplitude of the received signals as a function of time and position, representing a vertical slice of the subsurface. The time axis can be converted to depth by assuming a velocity for the EM wave in the subsurface soil [3].

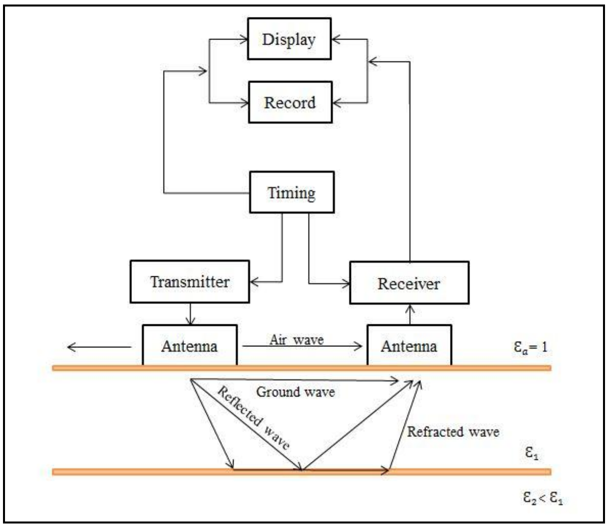

Figure 2: Block diagram of a GPR system [3].

4. STUDY AREA

The study area is located in USM, Pulau Pinang. The line has a total length of 13 m which consists of different media like asphalt, air and concrete. The line is divided into three sections with asphalt from 0 m to 6.7 m, air from 6.7 m to 7.2 m and concrete from 7.2 m to 13 m. The area is on top of a hill with a flat top which cover the whole line. Figure 3 shows the study area for this survey.

Figure 3: The study area in USM, Pulau Pinang [4].

Figure 4 shows the exact location where GPR is conducted. GPR is moving from 0 m to 13 m.

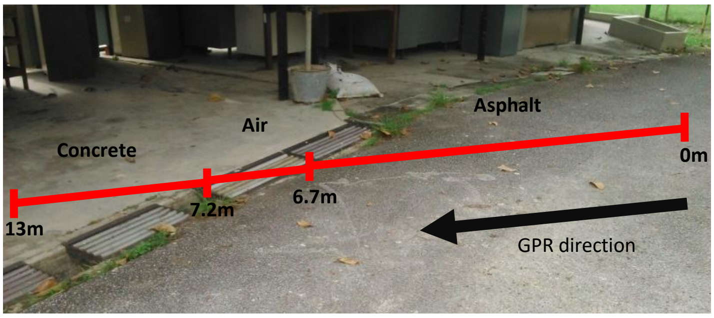

Figure 4: Different medium for conducting GPR.

5. METHODOLOGY

GPR survey is based on measuring the EM pulse that is being transmitted by a transmitter. The wave travels downward eventually refracted and reflected as it travels through the subsurface layer or boundary with different electrical properties and dielectric constant. The wave that is reflected back to the surface is then captured by the receiving antenna and recorded on a digital storage device for later interpretation.

This survey used 250 MHz shielded antenna with sampling frequency of 2450 MHz. The point interval used is 0.02 m and antenna separation is 0.31 m. The total length of the survey line is 13 m, which is measured by a measuring tape. The shielded antenna is pulled slowly to make sure there is no wave distortion in display unit. The recorded data is processed using RAMAC GroundVision and Microsoft Excel. In RAMAC GroundVision software, the data is filtered using 3 types of filter which are DC Removal, Time Varying Gain and Band Pass to remove the noise. The filtered data is exported to ASCII format and is opened in Microsoft Excel. The different medium amplitude is chosen to plot graphs of Amplitude vs Time (ns).

6. RESULTS AND DISCUSSION

There were 3 different types of media which are asphalt (0 – 6.7 m), air (6.7 – 7.2 m) and concrete (7.2 – 13 m). Figure 5 shows the data display from RAMAC GroundVision for the study area in USM. From Figure 5, trace 122 indicate asphalt anomaly, trace 389 indicate air anomaly and trace 659 indicate concrete anomaly. Figure 6 shows understanding of the radargram

The results show the most distinct anomaly at the distance between 6.7 m to 7.2 m. The anomaly indicates air due to its difference in dielectric constant (ε = 1) from concrete (ε = 6 to 8) and asphalt (ε = 3 to 5) as shown in Table 2. Based on Figure 7 that shows the graph of amplitude vs time (ns) for asphalt, the period which can be measured from the graph is 69.36 ns. Figure 8 shows that the period for air is 53.04 ns and Figure 9 shows the period for concrete is 65.28 ns. Figure 10 shows the combined results for air, asphalt and concrete in one graph of amplitude vs time (ns). The three mediums show similar graph pattern of amplitude.

The graph from Figure 10 starts to show fluctuation at the time of 90.42 ns. Based on the previous calculation, the results state that EM wave for air medium having the shortest period which tells EM wave for air travelled with the highest velocity compared to asphalt and concrete. Both asphalt and concrete have longer period, hence having a lower velocity than air.

Table 2: Electrical properties of materials [2].

Material	Dielectric	Velocity (m/μs)
Air	1	300
Concrete	6-8	55-112
Asphalt	3-5	134-173

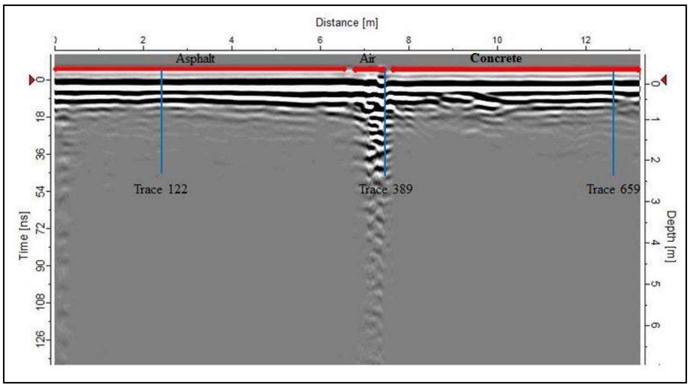

Figure 5: Data display from RAMAC GroundVision.

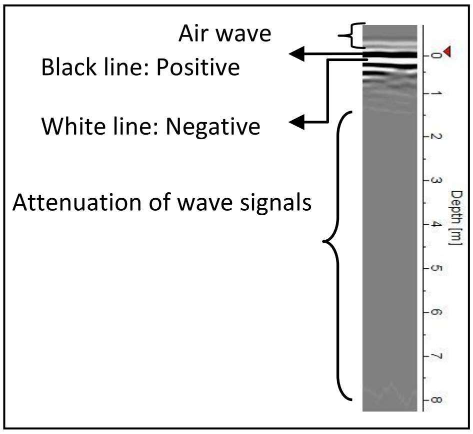

Figure 6: Understanding radargram.

Figure 7 shows the EM wave for asphalt medium, from time 0 ns to approximately 97.92 ns, the amplitude is zero due to the air wave layer. The maximum amplitude starts at positive. The wave starts to lose its signal at time 244.8 ns.

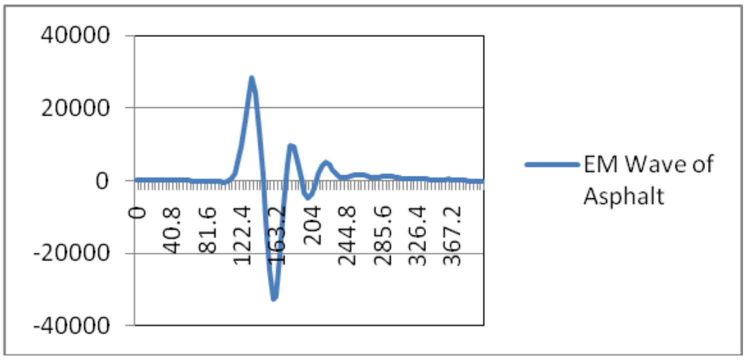

Figure 7: Graph of Amplitude vs Time (ns) for asphalt.

Figure 8 shows the EM wave for air medium, from time 0 ns to approximately 102 ns, the amplitude is zero due to the air wave layer. The amplitude starts to reflect at negative amplitude. Anomalies where the first reflections were negative were determined as cavities [5]. In this case, air is considered as voids. The wave starts to lose its signal at time 387.6 ns due to loss of energy.

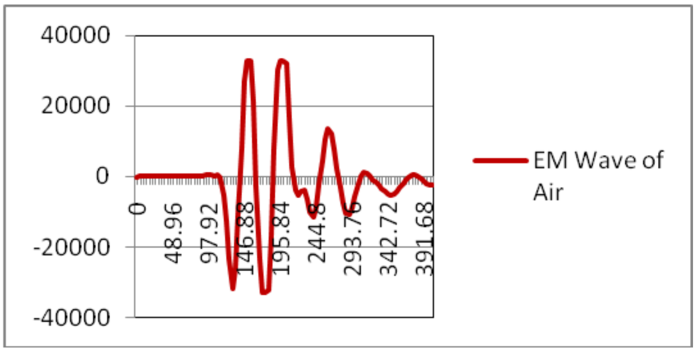

Figure 8: Graph of Amplitude vs Time (ns) for air.

Figure 9 shows the EM wave for concrete medium, from time 0 ns to approximately 97.92 ns, the amplitude is zero due to air wave layer. The maximum amplitude starts at positive. The wave starts to lose its signal at time 244.8 ns because of energy loss.

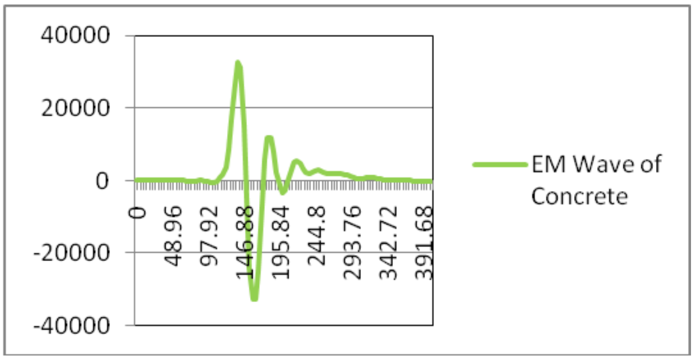

Figure 9: Graph of Amplitude vs Time (ns) for concrete.

Generally, Figure 10 shows the entire EM wave for the 3 different types of media. From previous analysis of each EM wave based on both parameter of period and signal amplitude, the EM wave for air medium travelled much farther than the other media, it also start to attenuate the slowest compared to others. Both asphalt and concrete nearly shows the same EM wave pattern, concrete medium shows slightly high amplitude than asphalt.

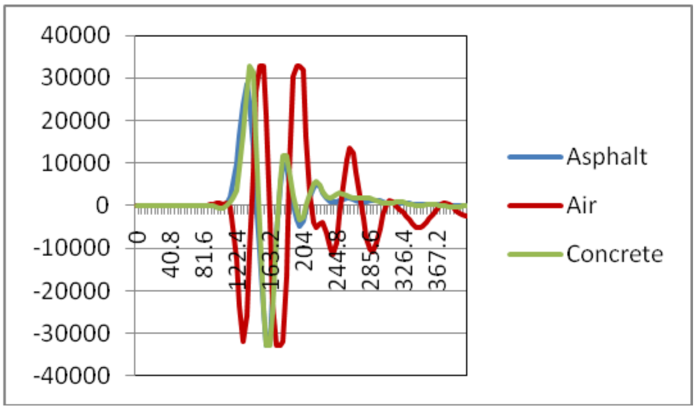

Figure 10: Graph of Amplitude vs Time (ns) for the three different media.

7. CONCLUSIONS

GPR is a powerful diagnostic method for the identification of signal for different types of media. While GPR is a great tool, it does not come without its downfalls. Ground composition, electromagnetic noise in the area, depth of a feature, and resolution are all factors determining the effectiveness of GPR profiling. The resultant data should be interpreted carefully, combining the relevant information of above ground and subsurface features. This survey identifies that the air has the shortest value of period compared to asphalt and concrete indicating that air has higher velocity than both asphalt and concrete.

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