INFLUENCE OF ANTENNA POLARIZATION AND DIELECTRIC CONTRAST ON GROUND PENETRATING RADAR SIGNALS FROM NON-METAL PIPE

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No not today

Someday, the flowers will wither

But no, not today

No no not today

If you can't fly, run

Today we will survive

If you can't run, walk

Today we will survive

If you can't walk, crawl

Even if you have to crawl, gear up

Point, aim, shoot!

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ABSTRACT

Ground penetrating radar (GPR) usage in detecting subsurface non-metal objects is investigated as there are many factors which can affect the strength of GPR signals such as the frequency of GPR antenna, the size, shape and the dielectric properties of the objects as well as the dielectric properties of the soil. This study involves the detection of GPR signal from a polyvinyl chloride (PVC) pipe of 0.15m in diameter and buried at a fixed depth of 0.5m from the soil surface in a testbed. Data collections were made using 500MHz and 800MHz GPR antennas which were placed directly above the soil surface, and in perpendicular or parallel orientation to the buried PVC pipe. Dielectric properties of the soil and the pipe content were varied by changing the amount of water added to them respectively. The results were shown by graphs of peak to peak amplitude of the detected GPR signals versus the soil conditions characterizing the soil-pipe dielectric contrast. Regardless of the antenna orientations, it was found that stronger GPR signals were obtained using the 500MHz antenna compared to those obtained using the 800MHz antenna. In addition, no significant difference is observed in signal strength collected using the 500MHz antenna in both perpendicular and parallel orientations. The results also show that there is a gradual increase in signal strength with increasing soil-pipe dielectric contrast irrespective of the orientations of the antenna. As a conclusion, depending on the level of the dielectric contrast, it is always more favourable to use the 500MHz GPR antenna to detect the PVC pipe.

ABSTRAK

Penggunaan radar penembus tanah (GPR) bagi mengesan objek bukan logam di bawah permukaan dikaji kerana terdapat banyak faktor yang boleh mempengaruhi kekuatan isyarat GPR seperti frekuensi antena GPR, saiz, bentuk serta sifat dielektrik objek dan juga sifat dielektrik tanah. Kajian ini melibatkan pengesanan isyarat GPR daripada paip polivinil klorida (PVC) berdiameter 0.15m yang ditanam pada kedudukan tetap sedalam 0.5m dari permukaan tanah dalam kotak ujian. Pengumpulan data dibuat menggunakan antena berfrekuensi 500MHz dan 800MHz yang diletakkan betul-betul di atas permukaaan tanah dan berorientasi serenjang atau selari dengan paip PVC yang tertanam. Sifat dielektrik tanah dan kandungan paip diubah dengan mengubah kandungan air yang ditambah pada kedua-duanya. Hasil kajian ditunjukkan sebagai graf amplitud puncak ke puncak isyarat GPR melawan keadaan tanah yang mencirikan kontras dielektrik tanah-paip. Tanpa mengira orientasi antena, didapati isyarat GPR yang lebih kuat diperolehi dengan antena 500MHz berbanding dengan isyarat yang diperolehi dengan antena 800MHz. Tambahan pula, tiada perbezaan yang signifikan tercerap daripada kekuatan isyarat yang diperolehi dengan antena 500MHz bagi kedua-dua orientasi serenjang dan selari. Keputusan juga menunjukkan peningkatan kekuatan isyarat secara beransur-ansur dengan peningkatan kontras dielektrik tanah-paip tanpa mengira orientasi antena. Sebagai kesimpulan, bergantung kepada aras kontras dielektrik, didapati adalah lebih sesuai menggunakan GPR antena 500MHz untuk mengesan paip PVC.

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LIST OF ABBREVIATIONS

GPR	Ground Penetrating Radar
PVC	Polyvinyl Chloride
EM	Electromagnetic
TE	Transverse electric
TM	Transverse magnetic
NDT	Non-destructive Testing
NDE	Non-destructive Evaluation
NDI	Non-destructive Inspection
TDR	Time-domain Reflectometer
RAMAC	Random Access Method of Accounting and Control

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discusses importance of the challenges studies for getting signals on ground penetrating radar of non-metal pipe. The challenges start from the generation of signals from the non-metal pipe which is weaker compare to metal pipe.

1.2 Background

Generally, Ground Penetrating Radar (GPR) is a subsurface sensing which involves detecting, locating and identifying object underneath a surface. For example, it locates underground mines or victims in rubble, detect cracks in bridges, detection of pipe leakage, detect and identifying improvised explosive device and through-wall imaging. GPR method usually deals mostly with generation, propagation, reflection, transmission and reception of a broadband electromagnetic or radiation. Throughout history, to determine any certain targets at the subsurface area, radio echo sounding was derived from the development of GPR (Milsom, 2003). Besides that, GPR has spread its function in different environmental conditions and its ability to detect small and shallow buried targets had been proven (Grasmueck et al., 2016). Now it is widely used to study the shallow subsurface anywhere at construction (Saharudin et al., 2016), landfill (Solla et al., 2015), archaeological sites (Oliva et al., 2015; Damiata et al., 2017) and many other survey sites. The use of GPR for shallow subsurface mapping studies also increase tremendously because it can detect shallow underground heterogeneity and discontinuity (da Silva et al., 2004; Rashed et al., 2003).

GPR is an advent of another technology that allows for non-invasive study of subsurface and underground phenomena. GPR system is used worldwide in radar surveys to find information about the underground bodies and structure. Some of the radar wave energy will leaks out above the surface due to unwanted reflections cause by surrounding features at the survey area. These unwanted reflections may misguide the analyst during interpretation phase (Hameed et al., 2003).

The radar survey employs short electromagnetic pulses from the antenna which propagate towards the target in a medium. Next, the electromagnetic pulses are reflected to the antenna for signals interpretation. During the transmission and reflection, electromagnetic pulses can be affected by many parameters. Amplitude of the detected signal usually is related to the target size and the electrical conductivity of the medium while depth of the target and the dielectric constant of the medium give effects to the traveling time. The dielectric properties of the medium depend on the conditions of the soil and this may affect the GPR signals. Accurate GPR signals can be obtained when the role of antenna-target polarization and target size are secured. When a wave encounters a material with different permittivity then the electromagnetic energy will change direction and character. This transformation at a boundary is called scattering. When a wave impinges on interface, it scatters the energy according to the shape and roughness of the interface and the contrast of electrical properties the host material and the object. Part of the energy scattered back into the host material and the other portion of the energy may travel into and through the object. Resonant scattering occurs when a wave impinges on a closed object such as cylinder and the wave bounces back and forth between different points of the boundary of the object (Daniels et al., 2008). Every time the wave hits a boundary, part of the energy is refracted back into the host material and some is reflected back into the object.

Polarization plays important role in designing of GPR. This is because most antennas of GPR are dipoles which radiate linearly polarized waves. Furthermore, the receiving antennas are quite sensitive to polarization of waves scattered by any object buried under a surface. The scattered electromagnetic waves from the buried object depends on the polarization of the incident wave (Roberts et al., 1996). A receive antenna oriented perpendicular to the transmit antenna is sensitive to cross-polarized components parallel to its long axis in the portion of the scattered field it receives. Polarization has its own sensitivity. The sensitivity of GPR antenna configurations depend on the positions of transmitter and receiver of antennas, antenna's field patterns and depolarization properties of target. Pipes and other targets scatter energy depending on the incident polarization (Radzevicius et al., 2000).

In previous research, they studied on the shielded bowtie antenna that merge the presence of paving structure for improvement of GPR pipe detection (Seyfried et al., 2014), a circular survey for 3D GPR to map hidden cylinders (Zhu et al., 2013), application of GPR in detecting target of interest (Saharuddin et al., 2016), velocity effect over GPR signal (Syukri et al., 2015), permittivity measurement of different types of soil for GPR applications (Karim et al., 2014), effect air pollution on GPR (Hameed, 2003), GPR for high-resolution mapping of soil and rock stratigraphy (Davis et al., 1989) and many more. Thus, in this thesis, the effect of antenna polarization and dielectric contrast on GPR signals from non-metal pipe were investigated experimentally. This thesis may enhance the usage of GPR signals from non-metal pipe, the possible correct orientation of antenna for generation good signals from GPR of non-metal, the effect of dielectric contrast for different medium of sand for detection of signals and many more.

1.3 Problem Statement

GPR is a well-known in technique for its near subsurface sensing. The previous studies concluded are in wave physics, agricultural engineering, sensor engineering, geophysics and image processing area. The problem faced in using GPR is that it has difficulty of interpreting radar signals. Some studies stated that the positions of antenna may affect the signals generation which depend on the materials, size of buried object and medium they penetrate. Some conflicts arise as to obtain accurate GPR signals, important roles to be noted were the nature of target size and antenna-target polarization (Shaari et al., 2010). Besides, by using linearly polarized dipole antenna, metallic pipes are best imaged with long axes of the dipoles oriented parallel to the long axis of the pipe (Reppert et al., 2000). While circular survey for 3D GPR can deviate to the optimal measuring condition which long axis of the bow-tie antenna oriented is parallel to the long axis of the cylinders, it always obtain the strongest reflected signals from the cylinders (Zhu et al., 2013). The aim of this project is more on experimental studies compared to previous research (Shaari et al.,2010) which using FDTD approached to determine effect of antenna polarization and dielectric contrast from GPR signals of non-metal pipe.

1.4 Objectives of Thesis

This study was using 500MHz and 800MHz shielded antenna of GPR to detect a buried non-metal pipe.

(i) To determine the strength of signals based on orientation of antenna

(ii) To analyze the GPR signals due to different dielectric contrast based on different moisture of soil inside and outside the pipe

(iii) To identify the optimum set up for better signals generation from different antenna polarizations and dielectric constant of medium

1.5 Scope of Thesis

The scope of study involved is from the experimental step to determine antenna polarization and dielectric contrast's effect on GPR signals from PVC pipe. As known, the signals from the non-metal pipe which is the PVC is weaker. The pipe was buried into the soil and the signals generation were detected by using GPR antenna. Certain enhancement been made to improve the signals generation from the non-metal pipe. The frequencies of shielded GPR's antennas used in the studies were 500 and 800 MHz respectively to detect the PVC pipe buried in soil of different moisture content.

1.6 Significance of Thesis

From this study, the signals generated from GPR of non-metal pipe was investigated. The 500MHz and 800MHz antenna were used and some signals generated have amplitudes where they were sometimes high and low based on certain moisture conditions of the soil. From the results obtained, the effectiveness of ground penetrating radar signals influence on antenna polarization of non-metal pipe can be known, also its advantages and limitations. The advantage of this thesis is that the signals from the non-metal pipe discovered were strong when the moisture of soil has high water content. But the limitation arose when the signals fluctuate and the non-metal pipe cannot be seen clearly. Besides, the study may also optimize the dielectric properties contrast medium of the different moisture of soil. With further research about GPR signals from non-metal pipe, it can improve GPR usage in numerous fields. The knowledge in experimenting GPR is believed to be beneficial for improving in further studies.

1.7 Thesis Outline

This thesis contains five chapters. Chapter 1 tells about the introduction of ground penetrating radar, the background and the planning of this research performances. Chapter 2 presents the literature review of ground penetrating radar, non-destructive method, dielectric properties, target and the approach taken which used in the analysis. Chapter 3 elaborates the methodology used for the design of the experiments. Chapter 4 presents the obtained experimental results and discussions. Lastly, Chapter 5 summarizes the conclusions and also suggests an outlook for future studies.

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