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To cite this article: Mohamad Syafiq Mohd Amin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **555** 012023

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A study on surface contact effect using ground penetrating radar

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Abstract. In this paper, the effect of contact and non-contact antenna system of ground penetrating radar (GPR) for buried pipes are presented. The frequency for GPR antenna used in this project is 400MHz which is suitable for GPR system to detect buried pipes for the tested surfaces, since the soil involved is sand which has low electrical conductivity. The results of the radargram obtained from this experiment and the limitations occurred are discussed.

1. Introduction

Ground penetrating radar (GPR) is one of Non-Destructive Testing (NDT) method which uses geological method radar pulses to image the subsurface. This NDT method uses electromagnetic radiation in the microwave band of radio spectrum, and detects the reflected signal from subsurface structures. GPR can have application in a variety of field such as geological and hydro-geological investigations, engineering investigations, location and evaluation of buried structures, site inspection and subsurface mapping for underground substructures including pipes. GPR is easily moved to inspection area since the equipment is portable and on-site interpretation due to instant graphic display. The basic GPR technology had aided the development of NDT methods. This can be proved by the growth of GPR since 1970's (Conyers, 1997) and GPR application in various fields.

This project's objectives are to operate basic working principle of GPR and to detect the location of pipes with different sizes, depth and separation by using GPR and the project is attempted at Block 60, Malaysian Nuclear Agency. For this project, antenna with frequency of 400MHz is used since the pipe is below 2 meter from the ground surface and the data obtained is clearer than antenna with higher frequency used. Furthermore, from the data obtained, the limitation of GPR is discovered.

Underground piping is commonly used for utilities in civil engineering. To monitor the exact location and condition of the utilities pipe, engineers normally map the underground layer using various methods, especially GPR. Unfortunately, due to location of the new un-developed site or developed site, most civil site is not smooth and prevent GPR antenna to make a full contact with ground surface.



2. Experimental works

2.1. Pre-data collection

To conduct the GPR, firstly, we need to know the target characteristic which is either the target is metal lines, plastic pipes, a concrete culvert or bedrock. In this project, the objective is to determine the location of pipes with 3 different conditions – depth, separation and size. Besides knowing the target characteristics, the electrical properties of and the pipes and soils should we understand since the GPR's antenna emits electromagnetic impulses. It is related to dielectric constant and conductivity of materials. Then, we should know the capability of antenna used by predicting the survey area such as depth of the pipes and types of soil involved in the survey. In this project, the depth is about 2 meter from the ground surface and type of soil involved is sand. After that, we need to choose the survey design either in 2D or 3D. Since the target is utility line and they are in a known direction, it may to do in 2D transect.



Figure 1. Location of pipes.

2.2. During data collection

When collecting the data, the antenna is dragged along the survey line to identify pipe positions, depths and sizes on the surface. While conducting this project, two different condition of antenna that is the level of air gap between the antenna and the ground. The radargram will appear on the screen at SIR 4000. Also, the depth and position of pipes measured by using cross-hairs cursor. The corresponding X (distance) and Y (depth), coordinates are shown in the bottom right corner.

2.3. Post-data collection

Then, the data is transferred to PC and analysed using the computer monitor for data interpretation. A postprocessing software called RADAN (Figure 2) is used so that the data analysis is more accurate and precise. Some filtrations are done to achieve the objectives of this project.

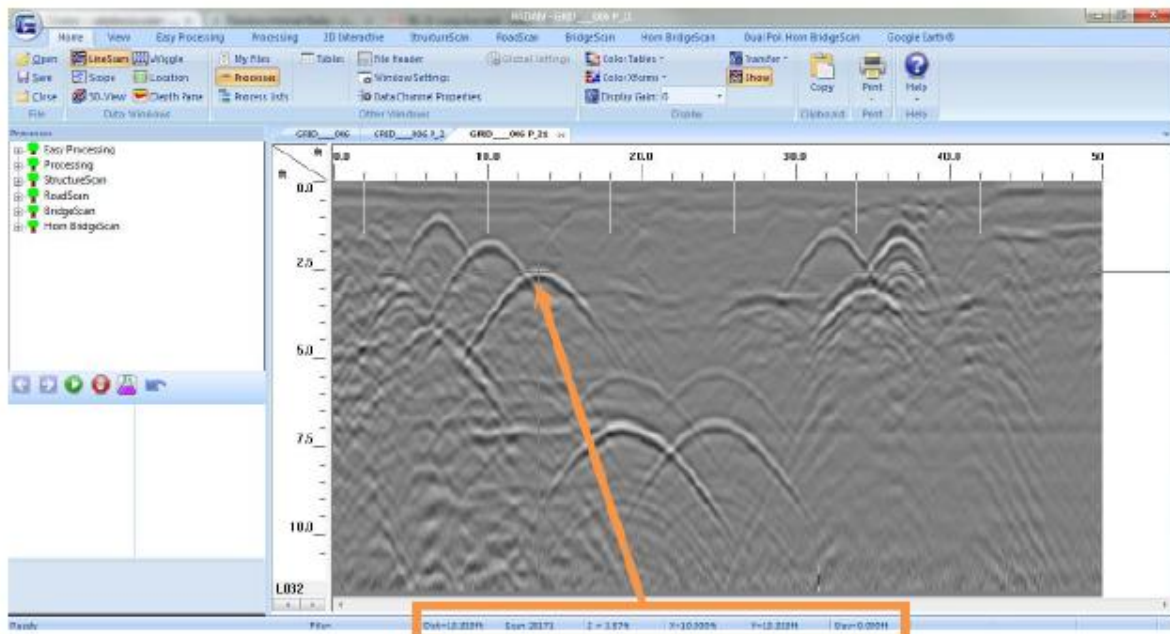


Figure 2. RADAN software.

The test site was filled with dry sand. The metal (iron) pipe was buried into the test area in three conditions. First with different pipe separation gap. Second, pipe with different depth, and the third pipe with different size. The antenna setting for 400 MHz.

3. Result and analysis

The purposes of this project are to demonstrate the basic working principle of GPR and to use this technique to detect the location of pipe with different sizes, depths and separations. The project was done with two conditions of antenna which was attached and detached on the ground. From the Figures 4, 6 and 8 (where the antenna was attached on ground), the hyperbolic shape on radar profile is more complete compared to the Figure 3, 5 and 7 (where the antenna detached on the ground). This changing pattern is due to the electromagnetic impulses are able to penetrate within the soils until the buried pipes. When the antenna is in contact to the ground, there is no gap between them. The air gap contains particles that would absorb the energy from the electromagnetic waves. The energy is not lost when the electromagnetic waves reach the ground surface, which then is able to detect the buried pipes with fewer obstacles. Thus, the hyperbolic shape obtained is more complete and clearer than when the antenna is not in contact with the ground surface.

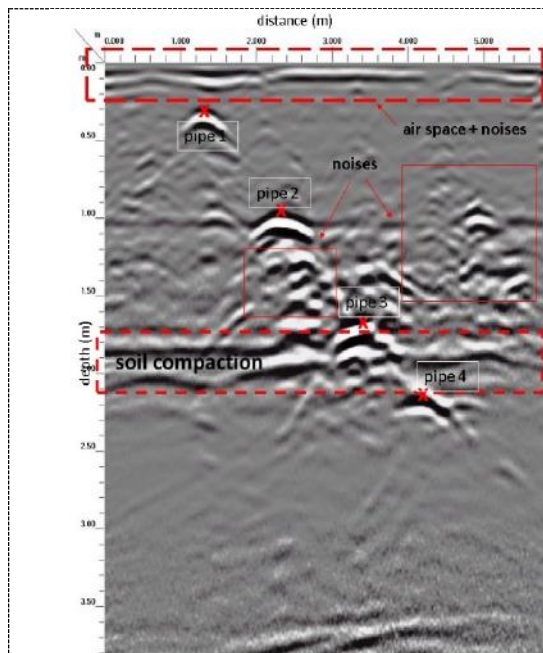


Figure 3. Pipes with different depth: radar profile for antenna detached on ground.

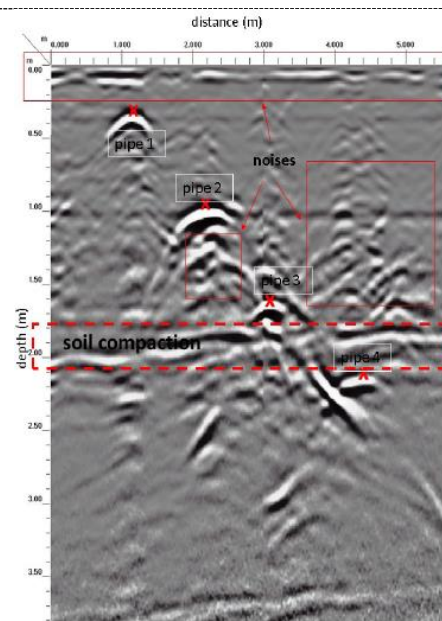


Figure 4. Pipes with different depth: radar profile for antenna attached on ground.

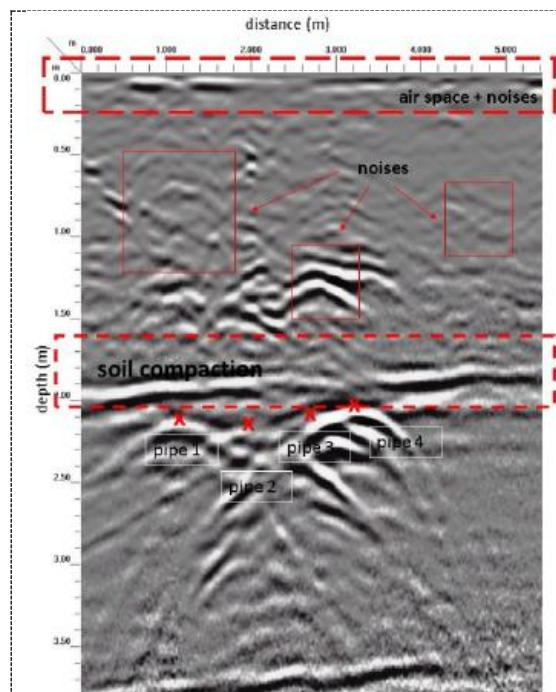


Figure 5. Pipes with different separation: radar profile for antenna detached on ground.

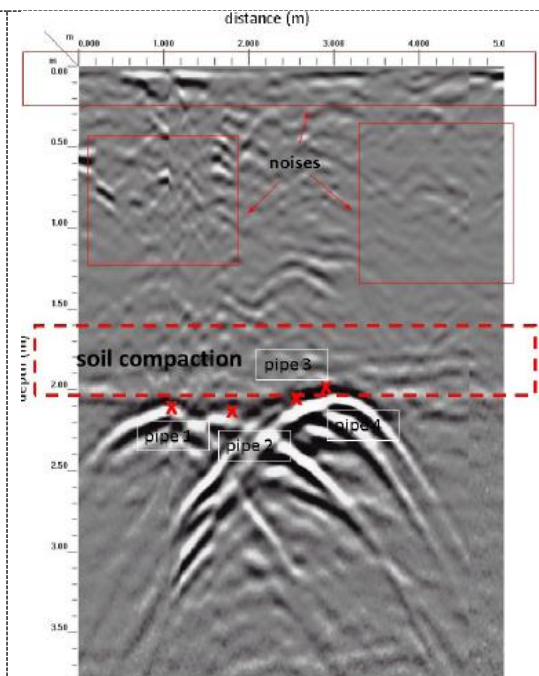


Figure 6. Pipes with different separation: radar profile for antenna attached on ground.

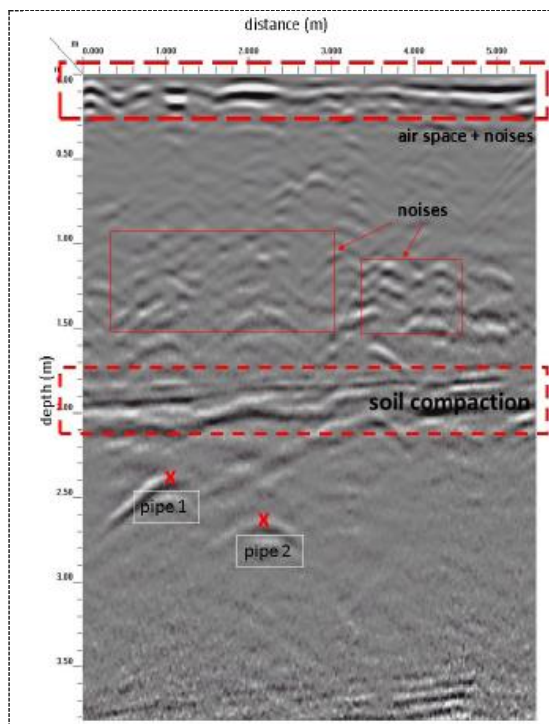


Figure 7. Pipes with different size: radar profile for antenna detached on ground.

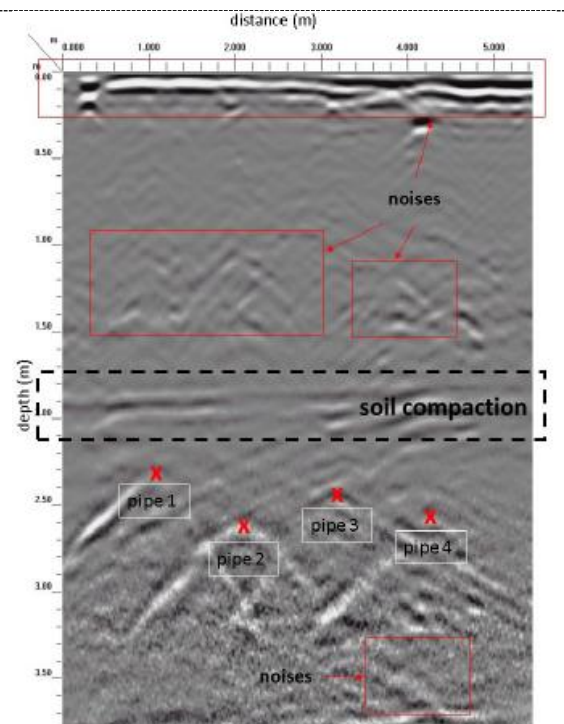


Figure 8. Pipes with different size: radar profile for antenna attached on ground.

The results obtained from all radargrams are in hyperbolic form. This is due to the distance of the antenna and the detected buried pipes. As the GPR was placed far from the buried pipe, the incident electromagnetic waves need to travel with a long path to reach the pipe. Then the reflected waves from the buried pipes received by the antenna travel with a long path as well. From here, it is reasonable to conclude that there was significant energy loss before it reached the antenna. When the GPR was moved closer towards the pipes, the distance travelled by the electromagnetic waves to reach the buried pipes and reflected to the antenna was shorter. Due to these differences in distance and energy loss, the density of the reflected waves received by the antenna was different as well.

The noises from all figures were detected due to the sensitivity of GPR. GPR is sensitive and has a high resolution coverage of the survey area. Therefore it is able to detect small material, including particles of soil and air. However, the noises showed in the radargram were not significant. To overcome this problem, some filtrations can be done during data interpretation by using a software called RADAN. We only focused on the perfect hyperbolic shape that shows the location of buried pipe, and then filtered all the unwanted noises.

The continuous lines on all radar profiles indicate soil compaction. The GPR is also able to detect soil compaction. Compaction of soil contains dense and many particles, so some of the energy from the electromagnetic waves were captured before the waves reached the target. If there is no soil compaction, we can assume that the hyperbolic shape from the radargram is clearer than the results obtained.

There was a limitation of GPR. If the target is too deep and small, the signals would not go through the target because the energy is lost before the signals reach the target. Figure 7 (radar profile of pipes with different sizes with antenna detached on the ground) illustrate this point; the third and fourth pipes were not detected by GPR. To overcome this problem, antenna with high frequency should be used. According to the relation between frequency, wavelength and energy, higher frequency of antenna result in shorter signal wavelength, thus the greater the energy, the higher the penetrating

power so that the signals will be able to penetrate deeper into the soil. The signals emitted by the transmitter antenna are also limited in materials with high electrical conductivity such as clays.

4. Conclusion

In conclusion, there are possible techniques to detect all pipes with both conditions - antenna attached and detached on ground. However, the hyperbolic structure of radar profile is more complete when the antenna is attached to the ground.

5. References

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Acknowledgments

The authors would like to acknowledge the financial support from MESTECC and Malaysian Nuclear Agency as well as the Material and Structure Integrity Group (NDT-MSI) for the support.