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Full Length Research Paper

Implementation of High-Frequency Ground Penetrating Radar (GPR) for the Detection of Guns and Ammunition in Walls.

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ARTICLE DETAILS

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ABSTRACT

We tested the accuracy of high-frequency GPR to detect ammunition and guns inside walls of different materials. Using different approaches and hardware set-ups we tried to define the optimal methodology for this type of application. In this research note, we present promising results of a novel approach that provides quick and reliable answers on the field, without the need for major post-processing.

1. Introduction

Ground Penetrating Radar (GPR) has emerged in the last years as an important tool in forensic investigations, offering insights into subsurface structures without the need for invasive techniques. With its ability to penetrate various materials, including soil, concrete, asphalt, and more, GPR used to serve as a tool for locating buried objects, clandestine graves, and concealed evidence. GPR operates on the principles of electromagnetic wave propagation. An electromagnetic wave is emitted into the ground or a wall, it travels at a constant speed until it encounters a material with different electromagnetic properties, such as dielectric permittivity and conductivity. The difference of the host material and the object in terms of dielectric permittivity must be greater or equal to 1 in order GPR to record a difference. By measuring the two way traveltime between the transmitted pulse and the received signal, GPR determines the depth of subsurface features. The amplitude and phase of the reflected signals provide information about the properties of the materials encountered, enabling GPR to differentiate between various structures, such as soil layers, buried objects, or voids. Mathematical algorithms, including Fourier transform techniques and migration algorithms, are then employed to process the raw data collected by GPR antennas, generating two-dimensional or three-dimensional images of the subsurface. These images depict the spatial distribution of subsurface features, allowing forensic investigators to interpret and analyse the data to reconstruct crime scenes, locate buried objects, and gather critical evidence. The majority of the works that involve GPR in forensics are about clandestine graves [1] and only a handful about detecting guns or ammunition [2]. We test different GPR hardware devices, all of high frequency, >1GHz, and we employ a new methodology for the optimal detection of guns and ammunition with minimal post-processing.

2. Methodology

Materials with high conductivity will attenuate the signal rapidly. Metals are considered to be a complete reflector and do not allow any amount of signal to pass through. Materials beneath a metal sheet, fine metal mesh, or pan decking will not be visible. Based on that, a hidden gun will show better in the radargram than excavated earth or a wooden box with ammunition.

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We test two different devices, one with a single antenna of 1,5GHz and the other with an array of antennas of 2,5GHz. Hardware based, the two radars have different antenna architecture, meaning that one is a pulse-based, while the other is a stepped frequency antenna. Pulsed systems are limited by the central frequency of the antenna, so they have specific limitations in terms of depth and resolution [3]. On the other hand, stepped frequency antennas face some resolution constraints especially with shallow targets. Data was collected on 2D and 3D mode and the conclusion made is that for finding hidden guns, 3D data collection provides more accurate and easy to interpret information, while in the case of ammunition 3D adds confusion compared to 2D data. During data acquisition background removal filter and automatic gain applied on data, in order to increase our S/N ratio. For the post-processing procedure we followed a new algorithm that is being displayed in Figure 1.

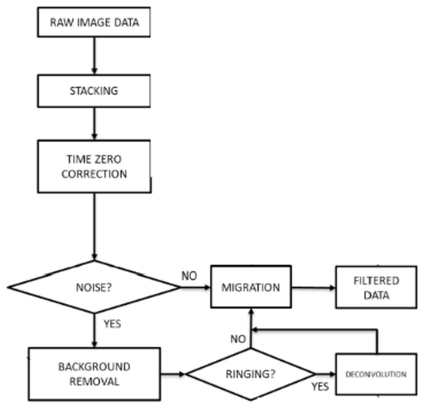


Fig 1 Algorithm Procedure for the detection of guns and explosives with GPR.

We automated the post-processing procedure and reduced the time needed to process the data by 1/3 compared to manual procedure. For reference the processing of 55MB of files takes less than 5 seconds on a typical computer system of today.

3. Results

3.1 Hidden Guns

We tested GPR in different host materials, including concrete, reinforced concrete, plaster and wood, with guns directly placed into polyfoam boxes. The thickness of the host material was 10cm, selected based on the experience of real cases.

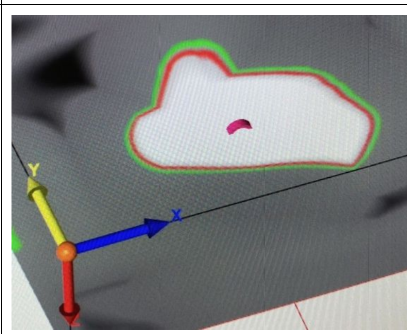
Reality	GPR Display
	

Fig 2 Gun in polyfoam before hiding it in different host materials (left). 3D visualization after collecting and processing GPR data (right).

Using the algorithm in Fig 1, data was displayed on 3D with satisfactory resolution as can be displayed in Fig 2. The white colour in the GPR data corresponds to high reflective materials, while darker colours correspond to less reflective materials. The detection rate of guns with this method is 100% accurate, when the host material is concrete, reinforced concrete (one to two maximum rebar layers), wood, plastic, plaster and other non-reflective materials. Complexity arises when guns are hidden under heavily reinforced concrete with three rebar layers, or more, resulting in a very congested area of high amplitude signals, making the distinction between guns and other metals impossible.

3.2 Hidden Ammunition

Hidden ammunition detection is far more complicated and small deviations on the dielectric constant of the host material may lead to different results. We hid ammunition inside concrete, reinforced and non-reinforced walls. The ammunition was hidden at a depth of 3-5cm from the concrete surface. The detection rate was 100% for reinforced walls with one rebar mesh and for non-reinforced walls, including those made of concrete, plaster, wood. Since ammunition is of higher diameter and thus thicker from rebar it shows a stronger positive reflection in the GPR data, as shown in Fig 3. When there is no rebar, ammunition appears as the only positive reflection as shown in Fig 4.

The dielectric of the host material in all cases was in the range of 5-10. The detection rate drops for approximately 1% for every single digit the dielectric gets higher. We tested dielectrics as high as 30 and we were still able to reconstruct the ammunition in the radargram. Of course, this number will get worse if we plug ammunition deeper in concrete, but it is very rare, in real life, someone to hide ammunition in depths deeper than 5cm.

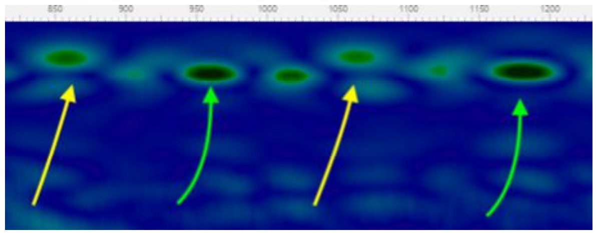


Fig 3 Radargram of ammunition revealed with GPR inside reinforced concrete. Yellow arrows show the rebars, while green arrows show the stronger reflection from ammunition.

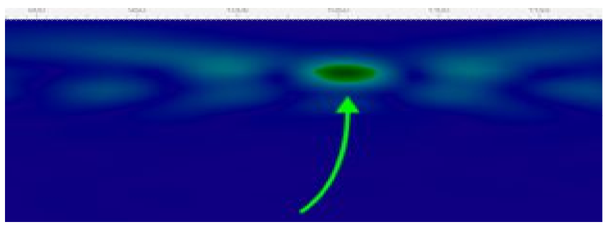


Fig 4 Radargram of ammunition revealed with GPR inside non-reinforced concrete. Green arrow shows the positive reflection from ammunition, with no interference from metallic rebars.

4. Discussion

This note shows the importance of GPR in revealing clandestine ammunition and firearms, in short time and without the need of destructive testing. Further study will associate the exact dielectric values with the maximum resolution a user can get during a survey.

5. Conclusions

In conclusion, the use of GPR technology in locating firearms and ammunition marks a significant advancement in forensic investigation and law enforcement efforts. As demonstrated here, GPR can be a useful and reliable tool in forensics studies.

6. References

Journal Article

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