IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Hardware Accelerator For Ground Penetrating Radar

**Dr. Cyril Prasannaraj P[1], Prof. Ravikumar M[2], Raghavendra P[3], Sachin C[4], Sachin P V[5], Sagar H P[6]**

[1]Director, CCCIR, Cambridge Institute of Technology(CITech), K R Puram, Bengaluru
[2]Assistant Professor, Department of Electronics and Communication Engineering, CITech, K R Puram, Bengaluru
[3,4,5,6]Students, Department of Electronics and Communication Engineering, CITech, K R Puram, Bengaluru

**Abstract:** Ground penetrating radar (GPR) image recognition accuracy and efficiency have been greatly enhanced by deep learning. A significant number of weight parameters must be specified, which requires lots of labeled GPR images. However, obtaining the ground-truth subsurface distress labels is challenging as they are invisible. The traditional data augmentation techniques, like rotating, scaling, cropping, and flipping, would change the GPR signals' real features and cause the model's poor generalization ability. When the annotated training GPR pictures are not enough, the datasets can be expanded using the suggested data augmentation techniques. When there are not enough annotated training GPR pictures, the datasets can be expanded using the suggested data augmentation techniques.

**Index Terms – GPR (Ground penetrating radar),GPR signal, GPR picture**

## I. INTRODUCTION

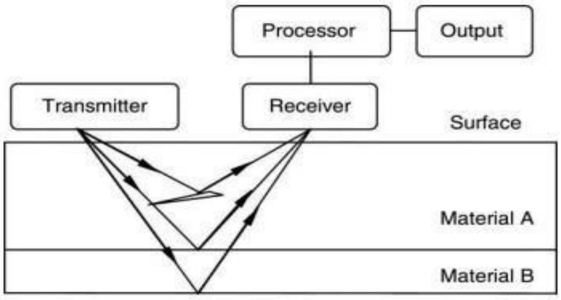
The geophysical method known as ground penetrating radar (GPR) is very recent. There have been significant advancements in technology over the past ten years. The various applications of GPR are closely linked to its history. Of all the geophysical techniques, GPR has the broadest range of applications, which results in a diverse range of instrument configurations and a broad range of application spatial scales.

Shallow geophysical detection with great efficiency can be achieved with ground penetrating radar (GPR). Through the use of high-frequency electromagnetic pulse waves, the GPR method analyzes and infers the physical characteristics and medium structure by utilizing differences in the electrical parameters of the subsurface medium based on kinematics and dynamics characteristics, suchas the amplitude, waveform, and frequency of the echo. Engineering geophysical exploration has given it a lot of attention because toits nondestructive, quick, easy, and highly precise benefits over traditional geophysical approaches. There are two types of GPR instrument systems: time domain and frequency domain. Engineering research frequently uses time domain GPR systems. Its primary benefit is that radar images can accurately depict a target's underlying structure. Domain of frequencies The Fourier transformation is the primary method used by GPR systems to obtain the frequency domain response of the medium for electromagnetic waves. Although the development of a stepped frequency GPR system is slower due to the need for specialized hardware and signal processing technologies, it offers superior resolution and accuracy. These days, GPR is used in a wide range of industries, including the military, engineering, geology, resources, and the environment.

GPR has a very broad range of potential applications in shallow geological surveys. Currently, employing foreign brands is prioritized in the majority of GPR in China. However, the software dongle is all that these GPR devices can perform. Users of GPR are unable to use the program or change the algorithms. This causes great inconvenience for GPR users.

## Basic Principles

The fundamental working concept, depicted in the picture below, illustrates the practical outcome of electromagnetic wave emission into the subsurface for GPR measurements[1]. When an electromagnetic wave is released from a transmitting antenna, it passes through a substance at a speed mostly dictated by the permittivity of the substance. The wave propagates and descends until it encounters an item whose electrical characteristics differ from those of the surrounding medium. It is then scattered off the object and picked up by a receiving antenna. A wavefront is the area that surrounds the wave that is moving forward. A ray is a line drawn straight from the transmitter to the wavefront's edge. The direction of the wavefront's movement in any direction away from the transmitting antenna is indicated by rays. A portion of the wave's energy is "reflected" back to the surface when it strikes a buried item, but some of it still travels underground. A receive antenna records the wave that is reflected back to the surface and stores it on a digital storage device for subsequent analysis. Antennas are essentially transducers that transfer electromagnetic waves into a substance by converting electric currents on their metallic components. When the acceleration of the current on an antenna changes, the antenna emits electromagnetic radiation.[2] Radiation can result from either an angular or a linear acceleration (such as an electromagnetic wave travelling on the antenna that changes over time). Radiation happens wherever the current changes direction, such as at the end of an antenna element, or along a curved channel.[3]



Antenna design aims to guide and control the radiation coming from an antenna. By absorbing a portion of the electromagnetic wave, antennas also serve as receivers of electromagnetic radiation, converting electromagnetic waves to currents on an antenna element. For antennas that are transmitting and receiving signals in the air, much above the surface of the ground, the reciprocity principle states that the transmit and receive antennas are interchangeable. Because of the attenuation effects of the ground near the transmit antenna, transmit and receive antennas are not always strictly interchangeable when positioned on the ground or a lossy material surface. The permittivity of the material largely dictates the particular velocity at which electromagnetic waves move. The basic idea behind employing GPR to explore below ground is the link between wave velocity and material qualities.[4]

LMX150 FINDAR

The LMX150™ FINDAR® is a cutting-edge technology developed by Leica Geosystems for utility locating applications. Here's a briefoverview of its key features and functionalities[5]:

Overview:
**Advanced Utility Locating:**
The LMX150™ FINDAR® offers advanced capabilities for accurately detecting and locating underground utilities.
**Ground-Penetrating Radar (GPR) Technology:**
It utilizes ground-penetrating radar (GPR) technology for providing non-destructive subsurface imaging.
**Real-time Data Collection:**
The system enables real-time data collection, allowing operators to quickly assess underground environments.
**High Resolution Imaging:**
Provides high-resolution imaging of underground structures, including pipes, cables, and other utilities.
**Three-dimensional Mapping:**
Offers three-dimensional mapping capabilities, permitting users to visualize underground assets in detail.
**User-friendly Interface:**
It has an easy-to-use design with controls that are intuitive, making it suitable for both inexperienced and seasoned users.
**Portable and Lightweight:**
Designed to be portable and lightweight for easy transportation and deployment in various field conditions.
**Versatile Applications:**
Suitable for a wide range of utility locating applications, including construction, infrastructure development, and maintenance projects.

Benefits:
**Improved Safety:**
Helps prevent damage to underground utilities, reducing the risk of accidents and injuries on construction sites.
**Time and Cost Savings:**
Enables efficient planning and execution of utility locating tasks, resulting in time and cost savings for project stakeholders.

**Enhanced Accuracy:**
Provides accurate and reliable data, minimizing the need for additional excavation and verification efforts.
**Environmental Protection:**
Minimizes environmental impact by reducing the likelihood of accidental damage to underground infrastructure.
**Compliance Assurance:**
It aids in making sure that the regulations governing the location of utilities and excavation operations are followed.
Overall, the LMX150™ FINDAR® represents a significant advancement in utility locating technology, offering enhanced efficiency, accuracy, and safety for various industries and applications.

### LMX150™ FINDAR® GPR complements traditional pipe and cable locators and allows you to locate targets below the surfacesuch as[6]:

Metal utilities, including pipes and cables Non-metallic pipes, including PVC and asbestos cement Concrete storm and sewer systems
Utilities where installed tracer wiring has failed Underground storage tanks and drainage tiles Septic system components optic cables Non-utility structures such as vaults, foundation walls and concrete pads

### LMX150™ FINDAR® uses ground penetrating radar (GPR) technology to enable law enforcement to quickly andeffectively look for evidence that is hidden beneath the surface[7].

GPR has the advantage of being able to detect both metallic and non-metallic items, which sets it apart from other popular subsurfacesearch technologies like metal detectors. LMX150TM FINDAR® is able to find:
Clandestine graves
Drugs or money buried in metal or plastic containers Buried weapons and ammunition stashes
Benefits of LMX150™ FINDAR® Locate evidence in actual time.
Convenient and intuitive to use with minimal training
Locate buried evidence on a variety of terrains and make decisions on-site.
The intuitive user interface guides investigators through a systematic grid search
Generate 3D images on-site in seconds pinpointing the position and depth of potential evidence Compact and portable system that fits into a single hand-carried shipping case.
Transfer screenshot images to a PC and integrate images into your reports.
Export GPR data to a PC to post process in the optional EKKO_Project™ Software to visualize, understand and report your findings.

## II. LITERATURE SURVEY

| YEAR | AUTHOR NAME | PAPER TITLE | KEY SOLUTON |
|---|---|---|---|
| 1994 | Alumbaugh.D.L. and Newman.G.A. | Fast Frequency-Domain Electromagnetic Modeling of a 3-D Earth | Lies in its exploration of efficient computational techniques for electromagnetic modeling in geophysics. Specifically, the paper likely discusses how employing fast frequency-domain methods and finite differences can enhance the speed and accuracy of electromagnetic simulations, thereby enabling more effective exploration and understanding of subsurface structures and properties. |
| 1974 | Annan.A.P | The Equivalent Source Method for Electromagnetic Scattering, Ph.D. Thesis, Memorial University. | Lies in its contribution to the understanding and development of the equivalent source method (ESM) for electromagnetic scattering problems. This thesis likely provides a comprehensive overview of the ESM technique, its theoretical foundations, computational algorithms, and |

| | | | |
|---|---|---|---|
| | | | applications in electromagnetic scattering analysis. |
| 1975 | Bevan, V. and Kenyon, J. | Ground-penetrating radar for historical archaeology | Its contribution to the application of ground-penetrating radar (GPR) in historical archaeology. This article likely discusses the methodology, findings, and implications of using GPR as a non-destructive tool for subsurface investigation in historical sites. |
| 1994 | Carcione, J.M. | Ground-penetrating radar: Wave theory and numerical simulation in lossy anisotropic media, Geophysics, Vol. 61, p. 1664-1677. | Comprehensive exploration of wave theory and numerical simulation techniques for ground-penetrating radar (GPR) in lossy anisotropic media. This paper likely provides detailed theoretical foundations and computational methods for understanding and modeling electromagnetic wave propagation in complex subsurface environments. |
| 2002 | Green, A., Holliger, K., Horstmeyer, H., Maurer, H., Tronicke, J., van der Kruk, J. | 3D acquisition, processing and imaging of Ground Penetrating Radar Data, GPR 2002 Tutorial 2 Notes, Proceedings of the Ninth International Conference on Ground Penetrating Radar (GPR 2002), Santa Barbara, C. | Its detailed guidance on acquiring, processing, and imaging three-dimensional (3D) ground-penetrating radar (GPR) data. This resource likely provides practical insights, techniques, and considerations for conducting comprehensive GPR surveys and effectively interpreting 3D subsurface structures. By citing this work, researchers and practitioners in the field of GPR can access valuable information and methodologies |

According to published research, GPR measurements are typically taken on peatlands using devices that have antennas that range in frequency from 100–200 MHz for large peat depths and 300–400 MHz for low peat depths. This range of frequencies offers a good balance between depth coverage and resolution (Comas et al., 2005a; Kettridge et al., 2008). There is a maximum 0.5 m maximum distance between traces (Comas et al., 2005a, 2005b; Kettridge et al., 2008). Depending on the antennae frequency and the assumption that the dielectric constant (k) is invariant with depth, the sample time window varies between 500 and 1000 ns in various investigations (Comas et al., 2005a, 2005b, 2011; De Oliveira et al., 2012). To achieve the particular objectives of the studies, GPR surveys are frequently combined with other available techniques. Peat cores can be extracted or manual sampling can be carried out along the transects recorded to aid in the interpretation and validation of the data received from GPR surveys (Kettridge et al., 2008; Plado et al., 2011; Rosa et al., 2009).[8]

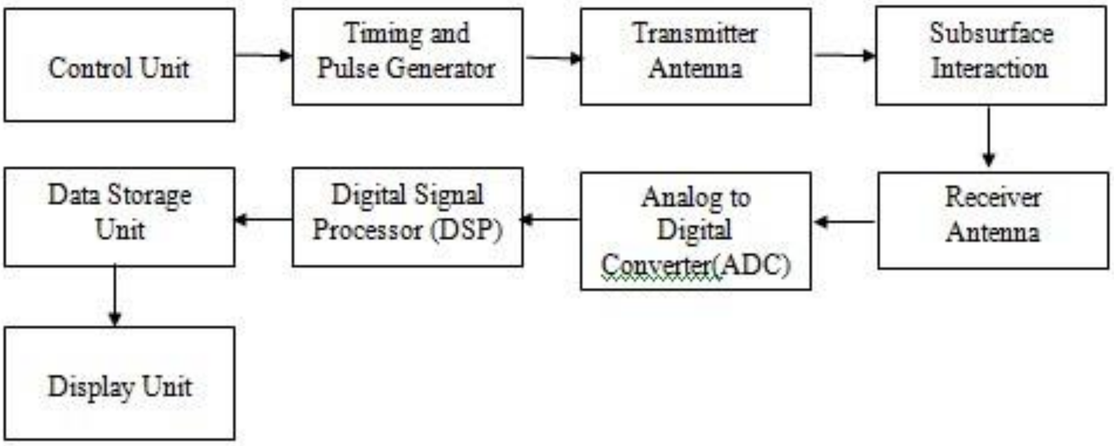
## III. METHODOLOGY

The methodology and block diagram for a Ground-Penetrating Radar (GPR) system involves outlining the steps taken to collect and process subsurface data. Below is a description of the methodology along with an accompanying block diagram:

This block diagram represents the main components and their relationships within a GPR system:

1. Control Unit: Manages overall system operation and user interaction.
2. Timing and Pulse Generator: Controls the timing of pulse transmission.
3. Transmitter Antenna: Emits electromagnetic pulses into the ground.
4. Subsurface Interaction: Represents the interaction of pulses with subsurface structures.
5. Receiver Antenna: Detects reflected signals.
6. Analog-to-Digital Converter (ADC): Digitally transforms analog signals.
7. Digital Signal Processor (DSP): Digital signals are processed in order to improve data.
8. Display Unit: Displays real-time or processed data.

Data Storage Unit: Records raw or processed data for later analysis.



Block diagram of a GPR system

This block diagram outlines the flow of data and signals through the various components of a GPR system during the process of subsurface data collection and analysis. Keep in mind that specific implementations may vary based on system design and requirements.[9] Image Brightness Transformation Based on Gain Compensation Image Resolution Transformations Based on Station Spacing.Space Transformations Based on Radar Signal Mapping Rules Deep Learning Model.

## IV. IMPLEMENTATION

The implementation and design of a Ground-Penetrating Radar (GPR) system involve a combination of hardware and software components, as well as specific algorithms tailored for subsurface imaging. Below is an overview of the key aspects of GPR implementation:[10]

**Hardware Components:**

**Antennas:**

Transmitter Antenna: Emits electromagnetic pulses into the ground. Receiver Antenna: Detects the reflected signals from subsurface structures.

**Control Unit:**

Timing and Pulse Generator: Controls the timing of pulse transmission.

Signal Processing Unit: Manages the overall system operation and processes signals.

**Data Acquisition Unit:**

Analog-to-Digital Converter (ADC): Transforms analog signals that the antenna receives into digital form so that they may be processed.

**Display Unit:**

Display Screen: Shows real-time or processed GPR data to the user.

**Positioning System:**

Global Positioning System (GPS): Provides accurate location information for georeferencing collected data.

**Power Supply:**

Battery or External Power Source: Supplies power to the GPR system, especially in portable applications.

**Software Components:**

**Control Software:**

User Interface: Allows users to configure the GPR system, set parameters, and control the data acquisition process.

**Data Processing Software:**

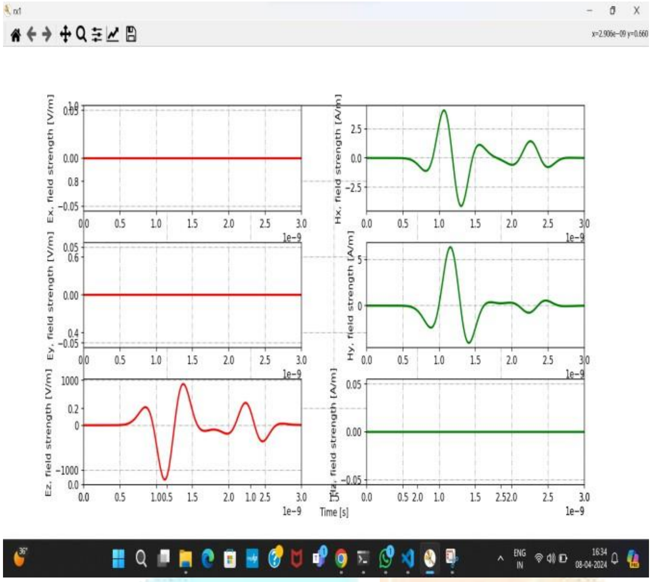
Digital Signal Processing (DSP) Algorithms: Improve the signal quality that is received, filter noise, and extract meaningful information.

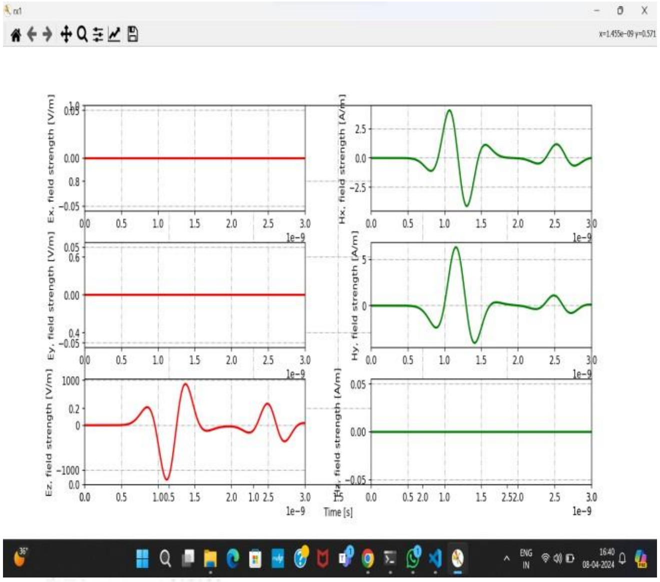
Imaging Algorithms: Generate subsurface images from the processed data.

**Post-Processing Software:**

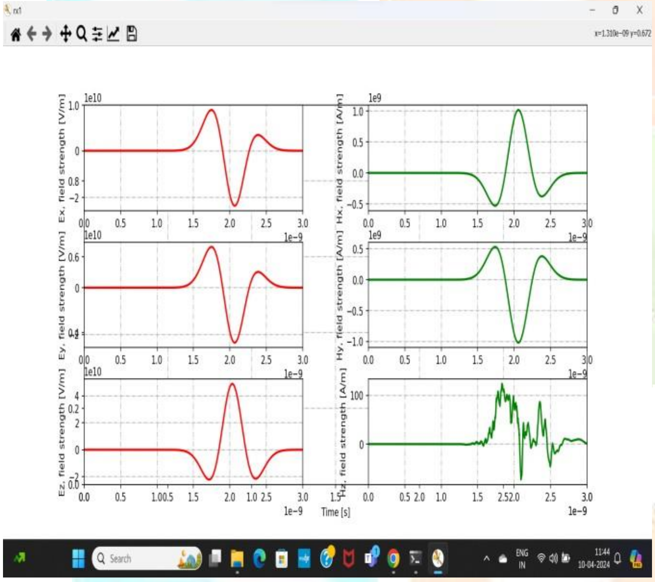
Analysis Tools: Enable further analysis of collected data, interpretation, and identification of subsurface features.

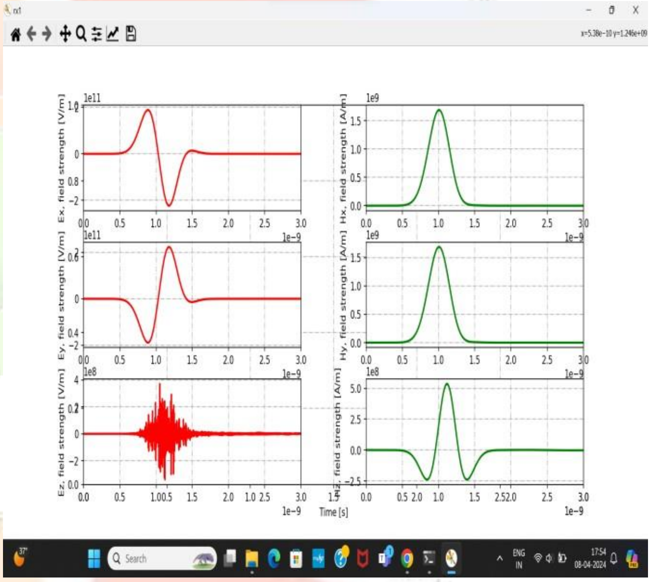
## V. GPR MAX EXAMPLE OUTPUTS





**CYLINDER_ASCAN_2D** **CYLINDER_BSCAN_2D**





**HERTZIAN_DIPOLE_DISPERSIVE** **MAGNETIC_DIPOLE_FS**

## VI. CONCLUSION

GPR is now a highly developed method that can produce finely detailed photographs of the nearby surface. The majority of GPR research has been carried out for engineering and environmental purposes. All of this development, though, has implications for engineering applications as well as the characterization of archeological sites. GPR is superior than the majority of other non-invasive geophysical methods in two ways:

1) GPR yields a three-dimensional pseudo-image that is readily transformed into precise depth measurements within a few centimeters, and

2) Both metallic and non-metallic objects can be detected by GPR. Any inhomogeneity dis the subsurface that is typified by a little variation in density, or porosity, can be well-mapped with GPR.

The primary GPR processing methods used in non-invasive inspections are the focus of this project's discussion. First, a brief overview of GPR procedures in road engineering is provided. After that, a summary of a GPR system's operation in the most popular configurations is given. However, the processing phase's performance may also be limited by the degree of noise and the appropriate frequency setting determined by the target's characteristics. Therefore, the primary and most crucial thing to focus on in order to highlight the efficacy of the data processing is the correct execution of a GPR survey on the site.[11]

## VII. OUTCOME

Gaining a thorough grasp of the state of research, methodology, difficulties, and applications in the field is the anticipated result of performing Ground Penetrating Radar (GPR). The review of the literature ought to broaden your understanding and serve as a starting point for any further study or work you perform in the field. The following are some particular results that you may obtain:

**Identification of Key Studies**:
Determine and examine the major research that have influenced GPR technology the most. Understand the methodologies employed in these studies and their impact on the quality of results.

**Methodological Insights**:
Gain insights into the various methodologies used in GPR, including frequency selection, antenna configurations, and hardware choices.
Understand how these methodological variations influence the outcomes and applications of GPR.

**Comparative Analysis**:
Conduct a comparative analysis of results across different studies.
Identify commonalities, discrepancies, and trends in the results obtained by various researchers.

**Challenges and Limitations:**
Identify challenges and limitations faced by researchers in GPR applications.
Understand how environmental conditions, interference, and other factors impact the performance of GPR systems.

**Application Insights**:
Learn about the various uses of GPR in environmental research, civil engineering, geophysics, and archaeology, among othertopics.Understand how GPR technology is adapted for specific tasks and environments.

**Future Research Opportunities:**
Identify gaps in the existing literature and potential areas for future research.
Recognize the problems that require more research and the chances for GPR technological innovation.

**Synthesis of Knowledge:**
Integrate the information from the literature review to create a comprehensive picture of the state of GPR research today.Formulate conclusions and insights that contribute to your more comprehensive knowledge of the area.

**Preparation for Research or Projects:**
Arm yourself with the information required to organize and carry out GPR-related tasks or research. Recognize optimal practices and factors to take into account based on other researchers' experiences and discoveries.

**Communication and Documentation:**
Communicate your findings effectively, both in writing and potentially in presentations or reports.
Document the key references, methodologies, and outcomes for future reference and citation in your own work. Overall, the outcome on GPR should empower you with a thorough comprehension of the subject, enabling you to make informed decisions and contributions to the ongoing advancements in Ground-Penetrating Radar technology.[12]

## REFERENCES

[1] Alumbaugh, D.L. and Newman, G.A., 1994, Fast Frequency-Domain Electromagnetic Modeling of a 3-D Earth Using Finite Differences: Extended Abstracts from the Society of Exploration Geophysicists 1994 Annual Meeting, Los Angeles, California, pp. 369-373.

[2] Annan, A.P., 1974, The Equivalent Source Method for Electromagnetic Scattering, Ph.D. Thesis, Memorial University.

[3] Bevan, V. and Kenyon, J., 1975, Ground-penetrating radar for historical archaeology: MASCA Newsletter, Vol. II, No. 2,of Pennsylvania Museum of Applied Science Center for Archaeology, Philadelphia, Pennsylvania.

[4] Carcione, J.M., 1996, Ground-penetrating radar: Wave theory and numerical simulation in lossy anisotropic media, Geophysics, Vol.61, p. 1664-1677.

[5] Green, A., Holliger, K., Horstmeyer, H., Maurer, H., Tronicke, J., van der Kruk, J., 2002, 3D acquisition, processing and imaging of Ground Penetrating Radar Data, GPR 2002 Tutorial 2 Notes, Proceedings of the Ninth International Conference on Ground Penetrating Radar (GPR 2002), Santa Barbara, C.