Ground Penetrating Radar (GPR)

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Abstract: GPR is the most modern equipment used for underground surveying. GPR has wide applications in different fields like archeological, mining, utility detection, road investigation and many more. GPR works on electromagnetic waves. The depth of penetration depends upon dielectric constant of material.

Key words: GPR, dielectric constant, antenna

1 Introduction

Quite often, non-metallic, inaccessible, unknown or abandoned utilities cannot be located with traditional cable and pipe locators. When this occurs, Ground Penetrating Radar (GPR) must be used in conjunction. GPR is a non-invasive, non-destructive geophysical surveying technique that is used to produce a cross-sectional view of objects embedded within the subsurface.

All GPR units consist of three main components: a power supply, control unit and antenna.

Fig No.3 GPR

2 Principles and Methodology

To understand how GPR works, we must first understand the performance of a scan is. A scan is performed by moving the antenna across the surface linearly to create a series of electromagnetic pulses over a given area. During a scan, the control unit produces and regulates a pulse of radar energy, which is amplified and transmitted into the subsurface at a specific frequency by the antenna. Antenna frequency is inversely proportional to penetration depth, which makes antenna selection the most important step in the survey design process. Below is a list of antenna frequencies, their application and maximum penetration depth.

Table No.1 table showing frequency and penetration according to application

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Sample application</th>
<th>Maximum penetration depth(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2600</td>
<td>Concrete, roadways, bridge decks</td>
<td>1</td>
</tr>
<tr>
<td>1600</td>
<td>Concrete, roadways, bridge decks</td>
<td>1.5</td>
</tr>
<tr>
<td>900</td>
<td>Concrete, shallow soil, archeology</td>
<td>3</td>
</tr>
<tr>
<td>400</td>
<td>Shallow geology, utility locating, environmental, archeology</td>
<td>9</td>
</tr>
<tr>
<td>200</td>
<td>Geology, environmental</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>Geology, environmental</td>
<td>60</td>
</tr>
</tbody>
</table>

Fig No.4 Principle of GPR
During a scan, the control unit records the strength and time required for the return of any reflected energy. Reflections are produced in the data screen profile (on the control unit) whenever the energy pulse enters and exits contrasting subsurface materials. The way it responds to each material is determined by two physical properties: dielectric constant and electrical conductivity.

The **dielectric constant** is a descriptive number that indicates how fast electromagnetic energy travels through a material. Energy always moves through a material as quickly as possible, but certain materials slow down the energy more than others. The higher the dielectric, the slower the energy will move through the material, and vice versa. Below is a list of some common materials with their corresponding dielectric constants and velocity values.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Dielectric constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
</tr>
<tr>
<td>Fresh water</td>
<td>81</td>
</tr>
<tr>
<td>Ice</td>
<td>3</td>
</tr>
<tr>
<td>Dry sand</td>
<td>3-6</td>
</tr>
<tr>
<td>Wet sand</td>
<td>25-30</td>
</tr>
<tr>
<td>Silt</td>
<td>10</td>
</tr>
<tr>
<td>Wet clay</td>
<td>8-15</td>
</tr>
<tr>
<td>Dry clay</td>
<td>3</td>
</tr>
<tr>
<td>Marsh</td>
<td>12</td>
</tr>
<tr>
<td>Average soil</td>
<td>16</td>
</tr>
<tr>
<td>Granite</td>
<td>5-8</td>
</tr>
<tr>
<td>Limestone</td>
<td>7-9</td>
</tr>
<tr>
<td>Concrete</td>
<td>5-8</td>
</tr>
<tr>
<td>Asphalt</td>
<td>3-5</td>
</tr>
<tr>
<td>PVC</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table No.2** Materials and Its Dielectric Constants

To determine the location of a subsurface target in the data screen profile, there must be a contrast between the dielectric values of the material one is scanning through and the target one is searching for. For example, a pulse moving from dry sand (dielectric of 5) to wet sand (dielectric of 30) will produce a strong, highly visible reflection, while moving from dry sand (5) to limestone (8) will produce a weak one. In addition, if one knows the dielectric value of the subsurface material one is scanning through, the control unit can measure the amount of time required to receive the reflected signal and convert this to depth.

Since the GPR emits electromagnetic energy, it is subject to attenuation (natural absorption) as it moves through a material. Energy moving through resistive (less conductive) materials such as dry sand, ice or dry concrete will penetrate much further than energy moving through absorptive (more conductive) materials such as salt water or wet concrete. As a result, the greater the contrast in electrical conductivity between the material one is scanning through and the target one is searching for, the brighter the reflection; high conductive materials such as metals produce the brightest reflections.

To understand how dielectric and electrical conductivity differences translate into visual data requires an understanding of how the antenna emits energy. Imagine the antenna scanning perpendicular to a pipe. Energy emits from the antenna in a 3-dimensional cone shape, not in a straight line as one might think. The two-way travel time for energy at the leading edge of the cone is longer than for energy directly below the antenna. Because it will take longer for energy at the leading edge to be captured, when the antenna first approaches the pipe, it will appear low in the data screen profile. As the antenna moves closer to the pipe and the distance between them decreases, the reflections will appear higher in the profile. At the point where the antenna is located directly above the pipe, the minimum distance of separation is reached and the reflections reach their zenith. As the antenna moves away from the pipe and the distance between them increases, the reflections appear lower in the profile once again. After the scan is completed, the center of the pipe will appear in the data screen profile as an upside down U, which is referred to as a hyperbola.
To gather, organize and present the data, a series of scans are performed within an orthogonal survey grid. At the end of each scan, the data screen profile is reviewed for the presence of hyperbolic targets. If present, the antenna is moved backward to place a cursor (which depicts the center of the antenna) on the center of the targets. The location and depth of the targets are then marked on the surface with chalk, paint and/or flags. Once the entire survey grid has been scanned, the marks are reviewed to search for patterns similar to that of the desired targets, in this case a pipe. Any marks that run in straight line and whose hyperbolas appear to be highly conductive metal targets are then connected, thereby displaying the location and depth of the pipe.

3 Application areas of GPR technology
1. Detection of underground utilities
2. Mining development
3. Water table determination
4. Geology
5. Archeology and forensic
6. Environment
7. Road investigations

4 Advantages
1. Rapid ground coverage afforded by towing the antenna either by hand or from a vehicle.
2. High lateral resolution of targets even for larger surveys
3. The instant graphic display offered by most GPR system allows on site interpretation
4. Along with locating pipe there are many other advantages of GPR as discussed earlier

5 Limitations
1. Data acquisition may be slow over difficult terrain
2. Depth of penetration is limited in materials with high electrical conductivity like clays
3. Energy may reflected and recorded from above ground features like walls, canopies etc, unless antenna are well shielded
4. Artifacts in the near surface may scatter the transmitted energy and complicate the received signal and/or reduced depth of penetration
5. Frequent handling of GPR machine can be hazards to workers as transmitted signal can affect the health of worker.

6 Benefits of GPR
1. Locate non traceable utilities and water lines in real time
2. Unsurpassed accuracy
3. User friendly system
4. Instant 3D data collection
5. Locate and mark utilities with the innovation backup curser feature
6. Easy data transfer to flash card
7. GPS integration
8. High definition, full colour screen that is easy to read even in bright daylight
9. Durable components
7 Conclusions
GPR is the most advanced and widely used for underground surveys. There is a huge effect of water table or saturated soil on underground detection. GPR fails to give results even when there is presence of water over surface. post processing of GPR data is very tedious job. the accuracy of results depends upon the skill of the surveyor. onsite data interpretation of data is possible but requires very deep knowledge of the same. GPR is widely used in archeological works, pavement studies and utility detection. surveying with GPR is costly work because the cost of the instrument is more and also skill person required for surveys.

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