ESTIMATION OF DEPTH & EXISTENCE OF UNDERGROUND WATER USING GROUND PENETRATION RADAR

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Abstract: The main aim of this research work is to save the cost/efforts of failed attempt of drilling the borehole for an unidentified water level or water existence. In this research paper we will discuss the proposed method, which is based both on hardware and software components. Before drilling a borehole in the ground for the water, we will measure the depth and the existence of the underground water. We have designed some electrical hardware namely Ground-penetrating radar (GPR), is a geophysical method, which uses radar waves to find out the hidden underground materials. This nondestructive method of GPR injects electromagnetic rays in the microwave band of the radio spectrum, and catches the reflected signals from subsurface structures. The fundamental principle of operation is the same as that used to detect aircraft overhead, but with GPR that antennas are moved over the surface rather than rotating about a fixed point. In this work we have designed GPR hardware, which sends electromagnetic waves using transmitter antenna to earth and records the reflected received signals via receiver antenna and sends to the computer for further processing. Additionally we have developed an application software, which assist us to understand and distinguish the nature of reflected signals. Further we have applied advance signal processing methods on the received signals using MATLAB to analyze the reaction to the signal behavior of underground material. Using different signal processing method such as Fourier transform methods we have investigate the reflected signals from different materials such as iron rod, soil, water and concrete.

Keywords: GPR, Water detection, Different materials, Signal processing

I. INTRODUCTION

One of the most versatile underground locating tools available is Ground-Penetrating Radar, or GPR. GPR uses high-frequency radar waves to create a detailed image of what lies under the earth. Ground-penetrating radar works well in some soil types than in others: GPR works best in gravelly or sandy soil, and less well in heavy clay materials [6]. Available GPR hardware are much costly because of their hardware but we have designed our GPR system using very cheap components, where the estimated cost is around 30 to 40 dollar. Instead of a dedicated computer for signal processing, which often used in existing GPR, we have processed our received signal of GPR using a personal computer. Existing GPR hardware and software are embedded and difficult to modify but our system is an open source system.

The efficiency of GPR is strongly affected by the target soil's conductivity (the soil's ability to carry a charge) and dielectric permittivity (the soil's capacity to hold a charge). Since different soils have different electrical characteristics, the effectiveness and scan depth of GPR is highly dependent on the particular target site. Clay soils, along with subsurface brackish or salt water, greatly attenuate (absorb) the radar signal used by the GPR unit to "paint" a picture of the subterranean environment. So, in certain soils, the GPR's scan depth is limited. Especially salty or clayey soils can block the signal completely, although we don't often encounter that [6].

The transmitter coils of the GPR generated the electromagnetic waves to penetrate through the ground, which generated several reflected signals depending on the contents of soil (e.g. soft soil, hard soil, rock, water etc.) as illustrated in figure-1.

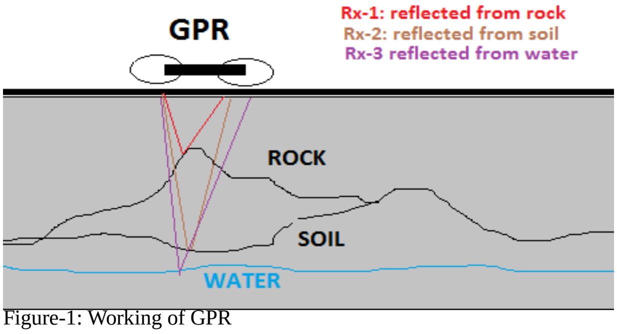

Figure-1: Working of GPR

GPR system design and methods of testing will be discussed in section-II. Signal processing methods, testing for different materials and observations using application software will be discussed in section-III.

II. MATERIALS AND METHODS

HARDWARE: GPR hardware depends on the application of geophysical exploration you need. However the basic and the common components are transmitter circuit, receiver circuit, transmitter antenna, receiver antenna and other components required to convert the received signal to the computer. Following figure-2 and figure-3 illustrates the block diagram and snapshot of GPR hardware.

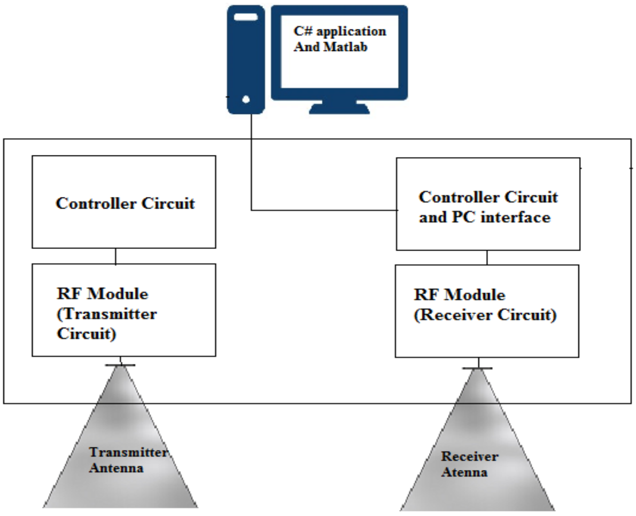

Figure-2: Hardware and Software component of GPR

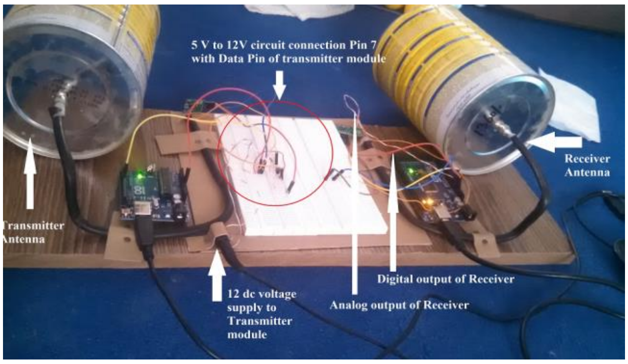

Figure-3: Hardware components of GPR

SOFTWARE: For the processing and analyzing the received signal, researchers uses different DSP software such as LabView, SignalView, MATLAB ete. We have used both MATLAB and our own application, our application performs some basic operations on the received signal. The applications retrieves 100 samples per second and store to a temporary buffer and that buffer is further used for the operations. At each clock tick the applications perform averaging of 100 samples and also calculates the frequencies of different amplitude levels. It also tells the maximum and minimum value of the last 100 samples. Following figure-4 shows the screenshot of the application.

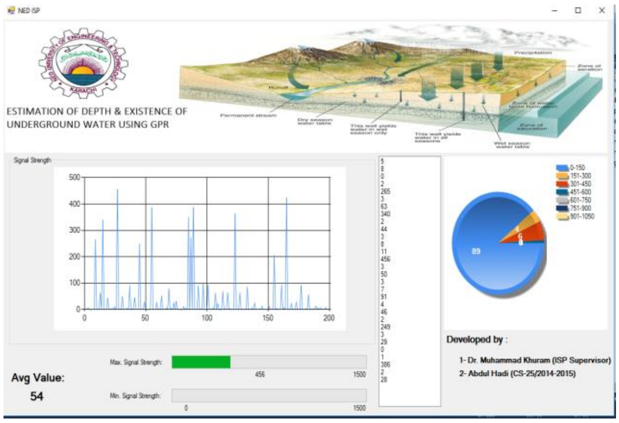

Figure-4: Software for signal analysis (C# application)

III. RESULTS AND DISCUSSION

Electric properties of materials are determined by electrical conductivity, permittivity and permeability. The permittivity is the most important parameter for GPR, because at a high frequency any material behaves as dielectric. The electromagnetic wave behavior in subsurface material is strongly dependent on its electrical conductivity, and the electrical conductivity is normally controlled by water. When a material is conductive, the electromagnetic field is diffusive and cannot propagate as an electromagnetic wave. When it is resistive, or dielectric, an electromagnetic field can propagate as an electromagnetic wave [5].

The reflection from materials occurs, when the electromagnetic wave of GPR encounters any electrically inhomogeneous. The travel time is defined as the time from the being transmitted to signal and the time signal is received, which corresponds to the propagation time from the reflecting object [5].

In our research work we uses both our proposed software and MATLAB to analyze reflected signal of different materials such as soil, water, concrete, and metals. Using phase and magnitude response components of FFT (Fast Fourier Transform) in MATLAB we have analyze the signal strength and delay caused by several materials. Following are the observations of these reflected signals.

Observation-1) Received Signal when the transmitter doesn't transmitting

Transmitter : **OFF**
Height of Antennas from the surface of the earth : **3 Inch**
Material : **Earth surface**

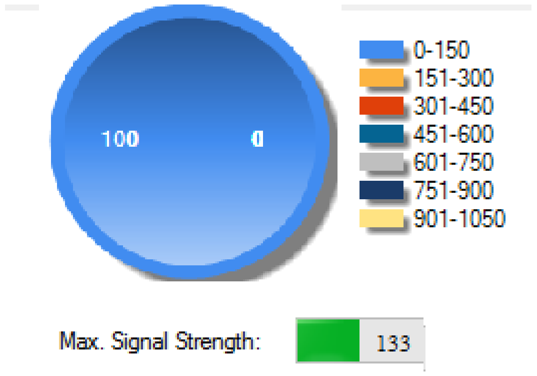

Figure 5 : Application View

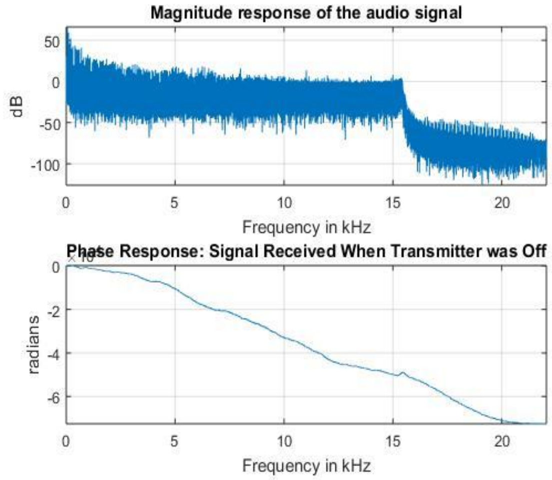

Figure 6 : MATLAB signal view

Observation-2) Received Signal when the transmitter is 'On' but no material on the earth surface (Concrete)

Transmitter : **On**
Height of Antennas from the surface of the earth : **3 Inch**
Material : **Earth surface (concrete)**

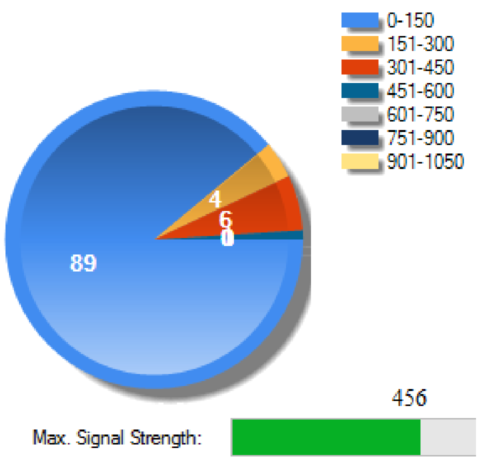

Figure 7: Application View

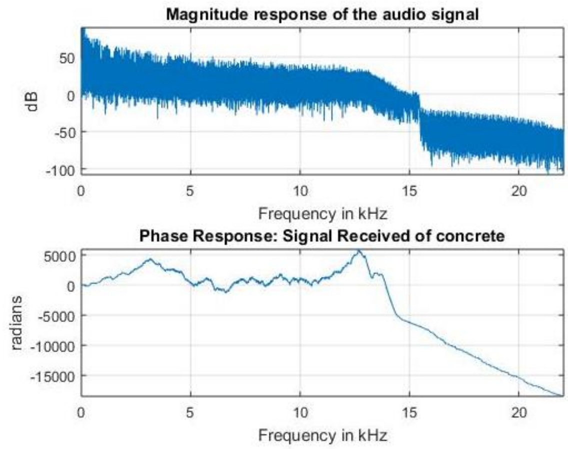

Figure 8 : MATLAB signal view

Observation-3) Received Signal when the transmitter is 'On' and iron/metal rod located on the surface of the earth

Transmitter : **On**
Height of Antennas from the surface of the earth : **3 Inch**
Material : **Iron rod**

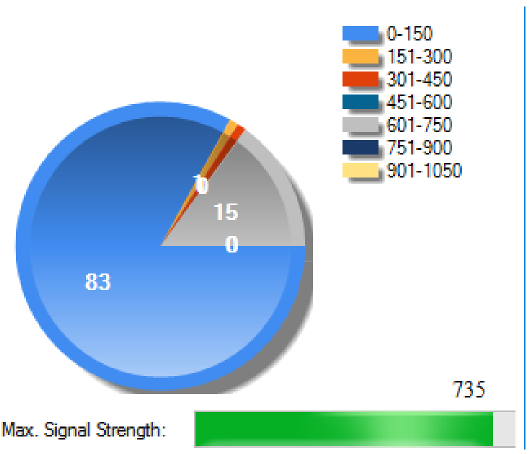

Figure 9 : Application View

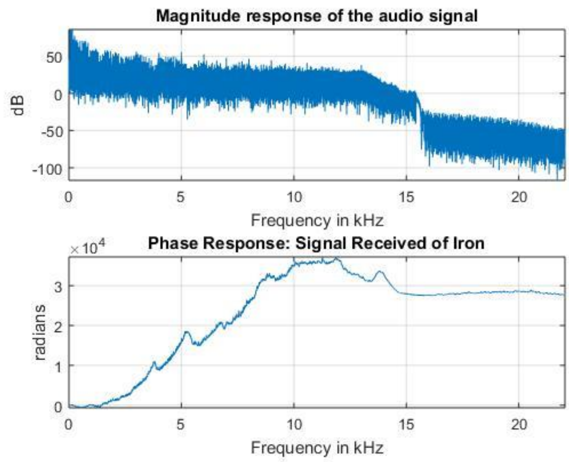

Figure 10 : MATLAB signal view

Observation-4) Received Signal when the transmitter is 'On' antennas are far from the surface of the earth and transmitting into the water tub

Transmitter : **On**
Height of Antennas from the surface of the earth : **12 Inch**
Material : **Water**

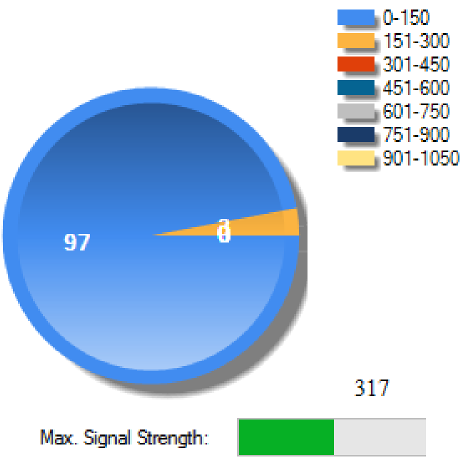

Figure 11 : Application View

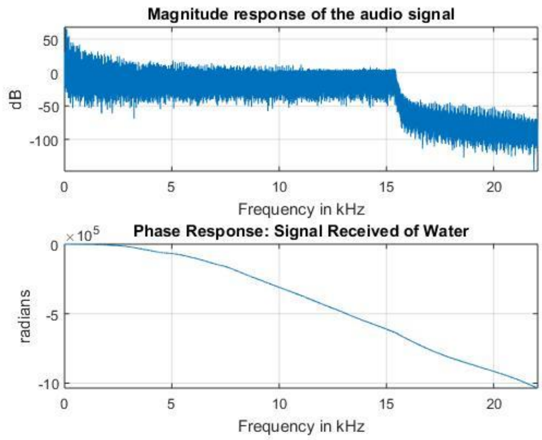

Figure 12 : MATLAB signal view

Observation-5) Received Signal when the transmitter is 'On' antennas are located towards the Soil.

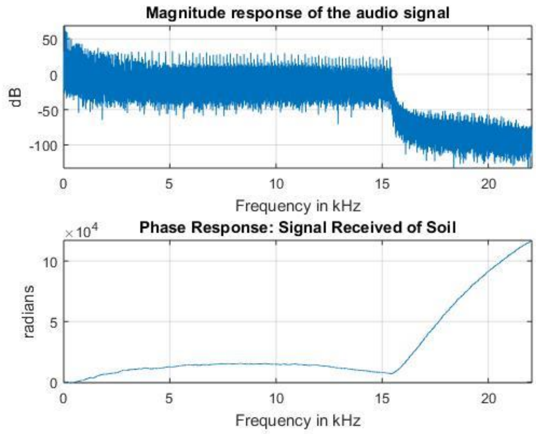

Figure 13 : MATLAB signal view

As we have discussed in section-III, the conductivity, real dielectric, signal velocity and wavelength properties of each underground materials is different, considering these fundamentals, the Following table-1 is the summary of all observations with their estimated signal velocity and wavelength.

Observation No	Figure	Max. Value	Signal AVG	Description
1	Figure-5	133	0-25	In this observation the transmitter is off but the "received signal strength" is because of incoming noise.
	Figure-6	-	-	Figure shows two responses one magnitude response of DFT and second is phase response of DFT. We will concentrate in phase response of different materials.
2	Figure-7	456	57.2 – 57.4	The observing materials is earth surface where the distance between GPR hardware and earth is 3 inch. The received signal is strong

				because of some reflection from earth surface.
	Figure-8	-	-	There is no much difference in magnitude response of all but has different phase responses. For the reason that each material has different velocity and different wavelength in their electrical behavior. For the concrete the estimated velocity is 11.34 and wavelength is 28.35. [7]
3	Figure-9	735	189.34 – 189.68	Since reflection from iron/metal is stronger, the receiver antenna receives strong signal strength.
	Figure-10	-	-	For the iron the typical (estimated) velocity is 0.01 and wavelength is 0.02 [7]
4	Figure-11	317	9.06 – 9.12	In this observation the distance between GPR and earth surface is 12 inch and the observing material is water. This give less reflections.
	Figure-12	-	-	Water has different categories such as salty water, pure water etc. the observing material is pure water which has estimated velocity around 3.33 and wavelength 8.33 [7]
5	Figure-13	-	-	The observing materials is clayey wet soil, which has estimated velocity around 7.72 and wavelength around 19.31 [7]

Table-1 : Observations Summary

IV. CONCLUSIONS

Based on physical and mechanical analysis of underground water, GPR is also useful for other applications such as detecting buried objects. GPR is a useful tool because of its ability to locate several type of materials. The application and GPR hardware that we has developed for our research work, could be useful for other researchers who wish to work in similar field.

V. REFERENCES

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