MAPPING TOP SOIL WATER CONTENT USING GROUND PENETRATING RADAR IMAGING

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Abstract

Measurement of water content in materials is needed in various fields, one of which is agriculture. Water content in top soil layer plays an essential role for success rate of agricultural. A method is needed to localization the water content in the top soil for a large area, Gravimetry is one of the method that require a lot of time and expensive to find information of water content in large area. Detection of top soil water content by remote sensing is the method of choice for mapping soil conditions over a large area. Ground Penetrating Radar (GPR) is a method that can be used in the process of Soil water Content. GPR works by transmitting electromagnetic waves into the ground and receiving reflected signals by an objects under the ground level.

This thesis proposes to imaging top soil water content information using B-Scan methods. Information the top soil water get form post-processing method proposed the Least Square extraction model, then to imaging in B-scan method for two-dimensional data processing will developed using MATLAB. The GPR system consists of a transmit antenna connected to a signal generator and receive antenna connected to the Low Noise Amplifier that connected to the signal processing unit. In this experiment, GPR system is modelled using Vector Network Analyzer.

Through processing B-Scan images will imaging of the area soil water content So that post processing using B-scan imaging on Ground Penetrating Radar will obtain information and mapping soil water content in a more efficient time.The 80 percent experiment was carried out by proving the success of previous studies in detecting top soil water content of 97 percent for scenarios with the distance between the ground and antenna R 35 mc, while for R 30 cm the accuracy in detecting top soil water content was 19.5 percent.The experimental results are not clear for the reconstruction of the B-scan signal because the device used during the experiment is unstable and soil type, setup settings in data collection due to signal transmission and the coupling between the two antennas must be prepared.

Keywords: Ground Penetrating Radar, Soil of Water Content, Post-Processing, B-Scan, MATLAB.

1. Introduction

1.1 Background

Soil moisture is difficult to determine because it has different things in different disciplines, including in agriculture [1]. Soil is very supportive of plant life that provides nutrients and water on earth, but not all soils in Indonesia have soil types with good and stable water content. Sub-surface water content to the root zone is very important for the development of crops, which affects the quality and quantity. Generally, the problem that occurs is the determination of physical and mechanical properties of the soil, not all soils are suitable for plants because the texture of the soil is different, this is very important because the water content in the soil serves as a medium for nutrient transport to plant roots, water content in excessive soils can limit the movement of air in the soil resulting in dead plants [2] .

Spatial knowledge of groundwater content is also important for precision agriculture programs, and the costs of crop irrigation can be very large, especially in arid and semi-arid regions [3]. There are several methods to identify soil moisture, including the gravimetric method [4]. For wide area observations, the gravimetric method will certainly require a lot of time and money to detect. Remote sensing method for estimating characteristics

Soil has also been studied in soil mapping, such as satellite imaging [5], Radiometrics [6], Synthetic Aperture Radar (SAR) [7] and Ground Penetrating Radar. The data that are obtained from the GPR experiment will not directly show information of soil water content, thus advanced post-processing of the data will be needed for extracting the soil water content information from the GPR output. The performance of the post-processing method to mapping soail water content using B-scan technique that are proposed also needed to be analysed.

1.2 Problems Formulation

Mapping and detection of water content at top soil in large areas using GPR, process the measurement data from the measurement survey with the GPR device in order to obtain information on water content on soil top level on the B-Scan image. The B-scan method is expected to be able to increase the time, easy to identify the state of the soil, and the cost efficiency in mapping top soil content over a large area.

1.3 Objective

mapping of the top soil water content on the ground, which then performs the test of the implementation of detection with actual measurement conditions. The method used is expected to improve time and cost efficiency in mapping groundwater content in large areas.

1.4 Scope and Limitations

The scope and limitations of problem that this final project is:

1. The research focus on process process signal until B-scan.
2. Imaging of underground objects using a time domain GPR device with a frequency of 1 GHz.
3. Electromagnetic wave propagation media with unspecific sand.
4. Does not discuss the GPR device subsystem in depth.
5. Not analysing the detection of soil types.

1.5 Research Methodology

The research method that conducted are experimental with steps such as:

1. Study of Literature
   The purposes of this step are to collecting and identify some journals, paper, books, and the previous research about Ground Penetrating Radar (GPR) system, signal processing in GPR, the method to mapping and determine the water conten on base soil using GPR to support the preparing this undergraduate thesis.
2. Experiment
   Collect data from experiments using VNA. Before that, preparations were made for tools used for the experiment, one of which was a sandbox with sand that was not specified specifically, VNA, bistatic antenna and water at the bottom of the soil. Then sand with water at the bottom of the soil will be mapped, by collecting data on the VNA which will then be analyzed.
3. Analysis
   The analysis process is the result of an experiment in the form of a GPR

output signal that has been taken subsequently processed into an image or image using a matrix laboratory.

4. Conclusion
This step is the final stage to be done as a report of the results and conclusions of the experiments and analyzes that have been carried out.

2. Basic Concepts

2.1 Ground Penetrating Radar

GPR is a geophysical surveying technique based on transmitting pulsed electromagnetic (EM) and measuring the strength of the reflected energy under the soil surface and receiving electromagnetic wave,usually in the frequency range of 10-1000 Mhz.

The main benefit of using this GPR technology is knowing all the information that is below the surface of the land (for example about the characteristics / patterns under the surface and the existence and location of an object in the soil) that can be known without the need to damage the ground surface, because the GPR detects differences from the permittivity, permeability and resistivity of what is detected[9].

Ground Penetrating Radar (GPR) is a radar system that emits electromagnetic waves for the detection of structures or objects that are underground with a certain distance without having to damage the ground. Basically GPR works by emitting a signal into the ground and the signal will experience scattering or return and returned to the receiving antenna with this form of signal which will then be processed into an image [3].

Based on the block diagram above, each block has a function related to each other. At first the waves generated at the transmitter are emitted by the transmitter antenna. If a wave hits an object, it is a wave it is reflected back to the receiver antenna and into the receiver and signal processing where the waves obtained will be processed into data what we want. The factors that influence in determining the characteristics of the transmitted signal, the type of antenna used and the processing method signal that is the type of object detected, the depth of the object and the characteristics of the medium passed by it [5].

2.2 Conventional Method

The received signal in the GPR are usually formulated in the frequency domain.

The received signal model can be expressed as:

$$\hat{S}_r(t) = S_2(t) + S_3(t) + S_4(t)$$
$$= S_2(t) + \Gamma_a S_1(t - Ta) + \alpha S_1(t - T_b) \quad (2.1)$$

Γ is the area of the coefficient of reflection between the transmitted wave and the reflected wave. This parameter will be used as a parameter for extracting soil water content in the top soil section. In GPR the reflected waves arriving at the RX antenna are influenced by the electrical properties of the ground. The ground water content greatly affects the electrical properties of the soil, so that an increase in water content in the soil will cause an increase in permittivity and conductivity of the soil [11].

Stage A-Scan processes cleaning the reflected signal from the desired object

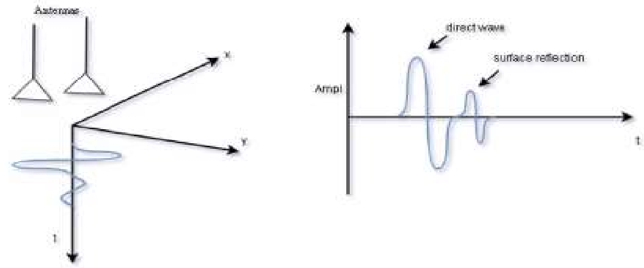

Figure 2.2 Configuration and representation of an A-scan.

$$S(x,y) = [S_r(y,x_1)\, S_r(y,x_2) \ldots S_r(y,x_n)] \quad (2.16)$$

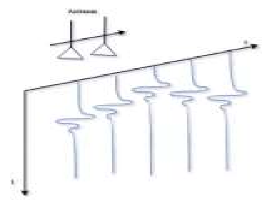

Figure 2.3 Configuration and representation of an B-scan.

against the reflected signal from clutter. A single waveform is recorded by a GPR b (x, y, z), with the antennas at a given fixed position (x, y) is referred to an A-scan Figure below. The only variable is the time, which is related to the propagation velocity of the EM waves in the medium [1].

If the A-Scan data gets the optimal signal, then the B-scan that is processed will produce an optimal signal that is clean also because at the B-Scan stage, the data input is the data obtained from processing the A-Scan signal. When moving the GPR antenna on the X axis by stacking the signal A-scans which form a two dimensional data set [1].The B-scan waveform can be defined from the following equation, B-Scan will get optimal results if the A-Scan process also gets optimal results, because the B-Scan signal used as input is a signal that has undergone cleaning on the A-Scan.

2.1 System Design

Scanning of water content in the soil is carried out as shown in Figure 3.2.In the first process until the end as in the block diagram, the specification determination refers to the parameters that have been determined in the experiment in the thesis before which became are ference for process development algorithm in these thesis. Development of algorithm that mean will be the process of processing data from experiments to get reflected data it is

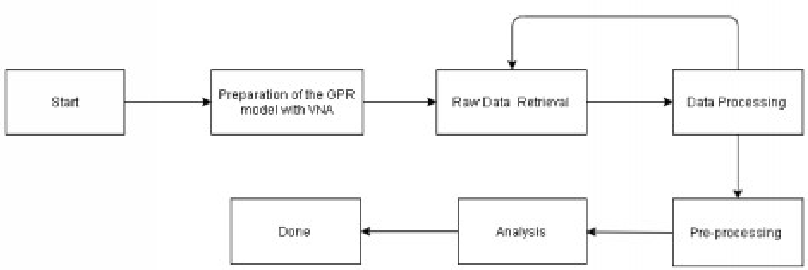

Figure 3.2 Model and scanning of Project.

processed into an image of information that includes A-Scan and B-Scan. As in block diagram Figure 3.3 The process starts from the stage of connecting the VNA with power supply then connects the TX and RX antennas to each port. Electromagnetic waves emitted from TX antennas by a pulse generator with timing circuit as a frequency width controller. TX and RX antennas will be placed above the ground. The process of receiving the s21 signal received from port 2 will be forwarded to LNA to obtain signal gain without reducing the signal-to-noise ratio. then collect the A-scan information data which will be processed into information in the form of B-SCAN. Furthermore the signal goes into sequential fast analog digital sampler which signals that arrive will the be

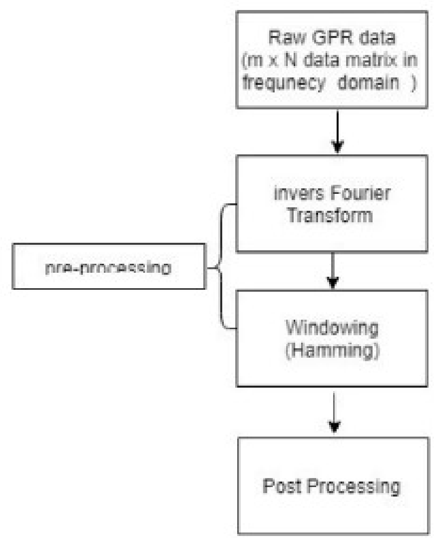

Figure 3.4 Diagram of GPR signal processing to process of data B-Scan.

in frequency domain which will be converted in to the time domain using IFFT (Inverse Fast-Fourier Transform) of this process will be the parameters needed to find the volumetric soil water content used [7].

The next stage will be developed with 2-dimensional IFFT processing,the output in discrete sequence the will be used to calculate to find the volumetric soil water content. When processing b scan starts from the range A-Scan data collection stage from GPR which provides information related to the parameters, specifications and rough estimation of soil water content. Amount from A-Scan collected in GPR data processing, which will form a 2D called B-Scan. Where GPR raw data collected in the B-scan frequency domain with the matrix data M x N using IFFT.M is the frequency or time sample point and N is the position of the cross range in Figure 2.2 At this stage the data obtained from the survey results using an existing GPR device will experience preprocessing first so that the resulting image will be obtained which will be used for object detection and determination

3. Result and Analysis

Laboratory experiment using VNA is performed for obtaining estimated volumetric soilwater content that processed usingMATLAB(R). The Ground Penetrating Radar system generetes and transmits narrow pulse with the frequency between 1-6 GHz.

Experiments carried out in 2 scenarios namely the distance of the R antenna with a value of 30 cm and 35 cm. The signal transmitted from the VNA is obtained by configuring the antenna as shown in Figure 3.1. signals that are in the frequency domain will be converted into the time domain using IFFT logarithm.

Transmitted signals are obtained with the antenna configuration shown in Figure 3.2. Transmitted signals are interpreted as S1 (n − Na) and Received signals are interpreted as Sr (n). Received signal and Transmitted signal from VNA which are in frequency domain then converted into time doas shown in Figure 4.2 and 4.3 show experiments conducted with R values of 30 and 35 cm were carried out to analyze experiments to find receiver signals on dry land.

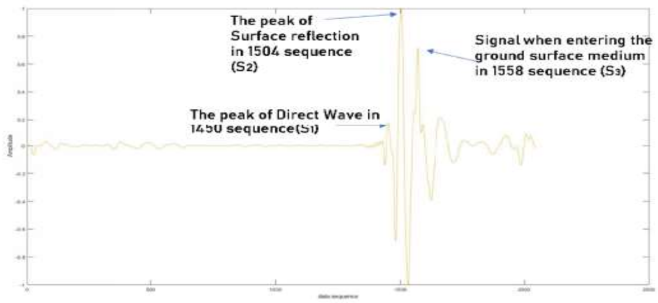

Figure 4.2 A-Scan measurement in a Dry soil with R 30 cm in sequence

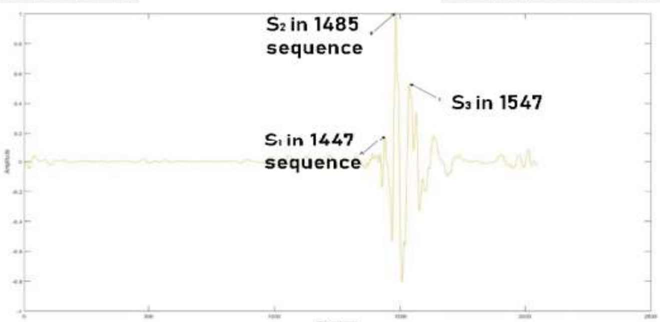

Figure 4.3 A-Scan measurement in Dry soil with R 35 cm in sequence

The results of the signal response on the s-parameter test data collection on dry soil in the experiment in the form of sample sequences are seen in Figures 4.2 and 4.3. Graph Y represents the received signal as signal strength and graph x represents the number of sequences. Point "A" indicates the signal begins processing to be emitted, point "B" shows the coupling signal from the Tx antenna received by Rx antenna, point indicates, the signal when entering the ground surface medium.

Experiments were carried out to get a reference signal from sand with water content in it. S-parameters obtained in experiments using VNA will then be converted into the time domain using IFFT logarithms with discrete sequence samples. Experiments carried out in finding the received signal by doing a few steps, namely receiving signals in dry sand with R 30cm and R 35 cm with 500 ml humidity.

Experiments on the received signal are sandy dried with an optimal R value obtained from previous experiments o lower the mixing of transmitted signals and coupling signals into the received signal. In Figure 4.5 shows taking data on R measurement of 30 cm with 500 ml water content, measurements in experiments shown on the graph with the x-axis value is time in seconds while the y-axis shows the received signal in volts.

In this experiment 40 data points were collected with a distance between points of 2 cm with a distance of R 30 cm and R 35 cm which will be attached to appendix A. Reconstruction of the B-Scan signal is obtained by combining the entire A-scan data into one image using MATLAB using the matrix method. The matrix is converted into two-dimensional images. In figure 4.6 and figure 4.7 are the reconstruction of the b-scan signal which consists of 49 columns.

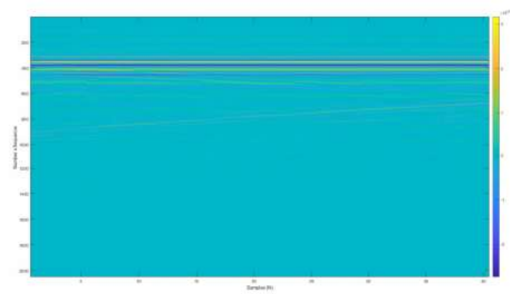

Figure 4.7 B-Scan measurement in top soil water content in time domain with R 30cm

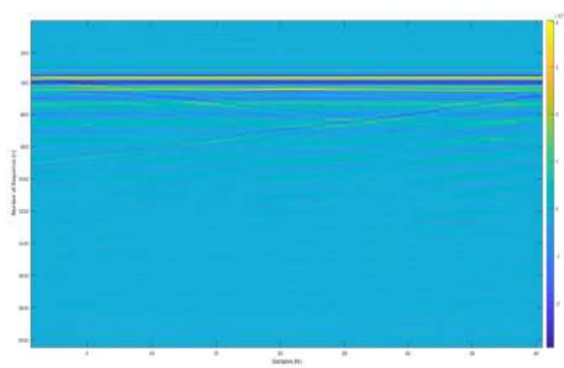

Figure 4.8 A-Scan measurement in top soil water content in time domain with R 35cm

In this experiment carried out using flat ground conditions and given as much as 500ml of water spray and using antenna distances R 30 cm and R 35 cm.

Sand with Different R	**Estimated Volumetric Soil Water Content (ml/cm^f3g)**	**True Volumetric Soil Water Content (ml/cm^f3g)**	**Accuracy (Percentage)**
R 30 cm with 500ml	0.0960	0.0803	-19.5
R 35 cm with 500 ml	0.0782	0.0803	97.38
B-Scan R 30 cm with 500 ml	Error	499.8675 ml/m^3	0
B-Scan R35 cm with 500 ml	Error	499.8675 ml/m^3	0

Table 4.1 Analysis of Estimated Volumetric Soil Water Content

many possibilities that occur such as human error, cable loss can also affect the results by reducing the signals sent and received, because the data retrieval is done manually. While at one of the scan points at R 35 cm accuracy estimate obtained water content can be accepted.

Besides, in determining the volume information of topsoil water content in the form of b-scan, it cannot be found because at each measurement point the estimation obtained is different, this is caused by human error, cable loss and also the characteristics of the soil ensure tested at each different point. - so that it is very difficult to detect volumetric topsoil water content information in mapping topsoil water content. There must be continued development in making measurements such as the process of drying sand with certain temperatures and humidity, the process of sand filtering to separate sand from rocks is also very influential in the process of scanning of mapping topsoil water content

4. Conclusion

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From the experiments conducted on the estimation of Volumetric Groundwater Content ˆmv (ml / cm3), the b-scan method proposed in the process of mapping top soil water content is unacceptable because on the b-scan display it cannot be seen and detected because of homogeneous mixed soil properties with water so that it cannot detect in its entirety subsequently the experiments carried out by the methods carried out previously can be properly proven because accuracy is still within the permitted values. The B-scan method used to find the top soil water content mapping was unsuccessful and there must be continued development with this method because there are several things that must be considered in measurements such as moisture elements in the soil, soil type, setup settings in data collection due to signal transmission and the coupling between the two antennas must be prepared and the R value which is the range between the antenna and the ground must be adjusted so that the direct wave and the coupling signal are not so close to the reflected surface wave. This experiment has many shortcomings and limitations due to limitations in the current data collection due to the Covid-19 pandemic. However, the method in previous studies can be proven to be successful. The Least-Square method uses IFFT algorithm to convert proven data to be used to find volumetric estimates of soil water content.

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