Accurate Sensing Model Simulation for Porang-Tuber Detection

Onny Setyawati
Electrical Engineering Dept.
Brawijaya University
Malang, Indonesia
osetyawati@ub.ac.id

A. Shidqy Aziz
Electrical Engineering Dept.
Wisnuwardhana University
Malang, Indonesia
asaziz19@wisnuwardhana.ac.id

Rodiyati Azrianingsih
Biology Dept.
Brawijaya University
Malang, Indonesia
rodiyati@ub.ac.id

Rahmadwati
Electrical Engineering Dept.
Brawijaya University
Malang, Indonesia
rahma@ub.ac.id

M. Fauzan Edy Purnomo
Electrical Engineering Dept.
Brawijaya University
Malang, Indonesia
mfauzanep@ub.ac.id

Axel Bangert
Microwave Electronics Lab.
Dept. of Electrical Engineering
& Computer Science
University of Kassel
Kassel, Germany
bangert@uni-kassel.de

***Abstract*— In this study, we present two scanning signals of GPRMax model simulation to sense Porang (Amorphophallus muelleri Blume) tuber underground. The need to detect tubers underground is emerged due to dormant period experienced by Porang plants in their third year which in turn caused difficulty to harvest the tubers. Measurement of tubers' water content is also presented. The higher the percentage of water content in tuber, the higher the dielectric constant of tuber. The model simulation tests were performed by varying the tubers diameter, the depths, and number of the tubers underground. Range frequencies used for estimating the depth of tubers were between 1 up to 2.3 GHz. At 1.1 GHz an error estimation of Porang underground was less than 1% at 10 cm in depth. However, at 1.7 GHz the smallest error of only 0.55% was achieved for 6 cm tuber depth detection. In these tests, using of high frequencies was very effective for detecting tubers at shallow depths.**

Keywords— Porang tuber, B-Scan, GPRMax, diameter tuber, depth estimation

I. Introduction

Electromagnetic waves are emitted into the ground by the transmitter antenna and their reflection will be recorded by the receiving antenna when it reaches the ground. Electromagnetic waves will be transmitted and reflected when Ground Penetrating Radar (GPR) system recognizes another object in the ground [1]. GPR research in agriculture has been carried out by Bassuk et al. for the detection of the location of tree roots under asphalt concrete with a thickness of 10 cm. The frequency used in their study was 900 MHz, and GPR could accurately detect the presence of roots in both dense soil and rocky soil [2]. Another study was conducted by Butnor et al. in 2003, where the GPR system was used to measure the biomass of pine tree roots using a frequency of 1.5 GHz. The results of the study with the help of signal processing showed that the estimated root biomass to a depth of 30 cm was correlated with root samples harvested using the soil core [3]. Ralston et al. in his research applied the application of GPR to measure the thickness of coal in the soil, and one of the objectives was to increase the productivity and quality of coal products by maintaining the mining process in the coal seam [4]. In 2014, Chlaib et al. used GPR to study its feasibility and ability to detect weapons buried in the ground [5].

An important parameter needed for detecting objects in the ground using GPR method is the permittivity of the objects. Permittivity describes the objects' ability to store and release electromagnetics energy in the form of electric charge [6]. Parallel plate method is one of methods that can be used to find the permittivity or dielectric constant. We had reported this method for the dielectric constant measurement of Porang (Amorphophallus muelleri Blume) tubers in detail in [7].

Porang is a plant that belongs to the iles - iles category, it usually grows in the forest and it has tuber underground. Porang tubers have high potential economic value because they contain glucomannan [8][9]. The position of the Porang tubers is unknown since the plants have a dormant or rest period during harvest in fourth year, or normally in the third year, and Porang leaves will wither so that they appear dead [10]. Thus, the harvesting process will be constrained to determine the location of the tubers especially in the forest. If the tubers get defects due to farms equipment during harvesting, they are getting rot very fast, thus, a proper technique to find tubers location is required.

The illustration of GPR system to detect Porang tuber using GPRMax software is shown in Fig. 1 [7], where A-scan signal to detect the depth of tuber underground was presented. The errors generated during the simulation using A-scan were

978-1-6654-0179-1/21/$31.00 @2021 IEEE

relatively high, especially for the depth of less than 9 cm, since A-scan only read signal at one point. In this paper, we focus on both processing signals B-scan and A-scan, wherein numbers and diameter of tubers were described, along with tuber depth detection.

We organize the paper as follows. The second section described the methods, i.e. validating Porang parameters by obtaining tuber's water content related to its dielectric constant, getting the Ez value and its return loss, and using two scan signals to detect tubers underground. The third section shows simulation results in finding diameter and depth of tubers, along with the discussion. The fourth section concludes this study.

II. Methods

The measurement step was taken place for processing signals using B-scan and A-scan to detect number of tubers, to estimate their diameters and depths underground. In addition, the water content of tubers, Ez and their return loss are also presented.

A. *Two Scanning Techniques*

There are two scanning techniques that can be performed on GPRMax, i.e. A-scan and B-scan. A-scan is a scanning technique that can only perform a single trace, meanwhile B-scan can perform several traces or multi traces [11]. Fig. 2 shows the scanning signals visualization, thus determining the location and calculating the depth of Porang can be evaluated more accurately.

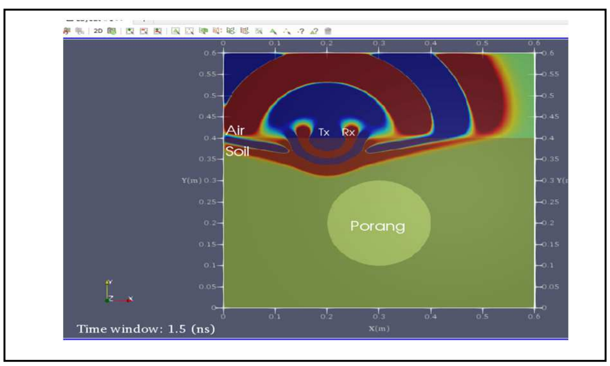


Fig. 1. Depth detection model simulation by GPRMax [7].

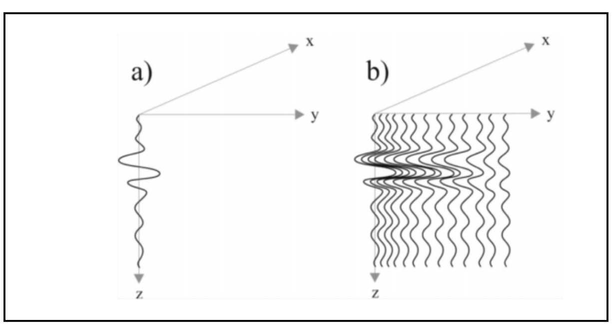


Fig. 2. Visualization of signal model in GPR : a) A-scan, b) B-scan [11].

After scanning using B-scan, we determined the peak point in the B-scan signal results. The peak point of the signal was the upper side of the detected object and the values of t_0 and t_1 would be obtained. Then estimated values of the tuber depth can be calculated. Value of t_2 is required for estimation of the tuber diameter.

Before processing B-scan signal, we need to determine the source step and rx step first. The rx component is a name of output receiver to be plotted. Source step and rx step are the displacement steps from the source, and rx if making B-scan towards the scan line. Determination of the source step and rx step is used to obtain the number of signal sampling performed when scanning on B-scan. The equation for calculating the number of samplings carried out using B-scan can be seen in (1). For instance, the distance was 20 cm and moving steps during sampling was 0.2 cm, thus the sampling signal would be 100, or numbers of sampling for A-scan should be equal to 100 times to form B-scan signal.

$$number\ of\ sampling\ \frac{scanning\ distance}{moving\ steps\ (of\ source\ or\ receiver)} \quad (1)$$

Simulating the position of Tx (transmitter) and Rx (receiver) aimed to see the difference in the B-scan signal generated, when the position of transmitter and receiver was different as it started to detect Porang tubers. The simulated Tx and Rx positions had three positions, i.e. first, the Rx was on the top side of the tuber; second, Tx and Rx were right above the tuber; and third, the Tx was on the top side of the tuber.

The resulting B-scan signal would experience a shift, due to the shift of the tuber side being detected. The shift was represented by the resulting t_1, where t_1 was the time required for the receiver to detect Porang tubers. For the test using 1 GHz and the given depth of 10 cm, when the position of the Rx and the Tx were right on the top side of the Porang tuber, the resulting t_1 value was 4.6 ns, and 5 ns, respectively, and when the tuber was right between the Tx and Rx, t_1 was equal to 4.9 ns.

B. *Water Content in Porang Tubers*

Measurement of water content or moisture in Porang tubers was carried out on four samples of tubers used in this study. It aimed to determine the effect of water content on their dielectric constant obtained at the time of measurement. We had measured and examined Porang dielectric constant using the parallel plate method [7].

The water content measurement was taken place in the Biological Plant Taxonomy Laboratory. The measurement was performed by taking 10 grams sample of each tuber. Samples of each tuber were dried in an oven for 24 hours. Dried Porang samples were then weighed to obtain the dry weight. The water content can be measured using (2).

$$\%\ water\ content = \frac{gross\ weight - dry\ weight}{gross\ weight} \times 100\ \% \quad (2)$$

TABLE I. PERCENTAGE OF WATER CONTENT IN PORANG TUBER

Porang tuber	*Dielectric constant*	*Gross weight (gram)*	*Dry weight (gram)*	*Water content (%)*
1	8.64	10	1.89	81.12
2	8.71	10	1.69	83.01
3	8.63	10	2.00	79.96
4	8.78	10	1.65	83.50

This water content affected the value of the tuber dielectric constant. Where the greater the water content in the Porang tubers, the greater the dielectric constant in the measured tubers. And if the water content contained in the Porang tubers is less, the dielectric constant obtained is also lower. This measurement was summarized in Table I. Therefore, dielectric constant of 8.67 was sufficient to represent the Porang tuber in the GPRMax model simulation.

C. Return Loss and Reflected Power

To validate the Porang parameters, we checked value of Ez and return loss of the Porang tuber compared to Suweg tuber, as function of the response frequencies. Another factor which can strengthen the effect of dieletric constant to Ez value is the calculated return loss. Equation (3) shows the reflection coefficient value |Γ| which is the ratio of reflected potential/voltage and transmitted voltage [12].

$$\Gamma = \frac{V_0^-}{V_0^+} \quad (3)$$

with a voltage reflection coefficient Γ, a reflected voltage V_0^-, and a transmitted voltage V_0^+.

Return loss value would be considered better if it has a value of less than -10 dB. Equation (4) in the following is used to calculate it.

$$\textit{Return Loss} = 20 \log_{10} |\Gamma| \quad (4)$$

According to [13] the power reflectivity can be found using (5).

$$P_r = \Gamma^2 \quad (5)$$

For 6 cm to 10 cm in depth, and frequency of 1.5 up to 2 GHz, range of Ez values of -53,403 V/m up to -105,905 V/m, and -149, 011 V/m up to -320,45 V/m were achieved for Suweg, and Porang tuber, respectively. The return loss value of Suweg tuber was bigger than Porang, since we measured that the dielectric constant of Suweg (ε = 14.89) was higher than Porang (ε = 8.67). Therefore, the energy that can be absorbed by Suweg would be higher than the one absorbed by Porang tuber.

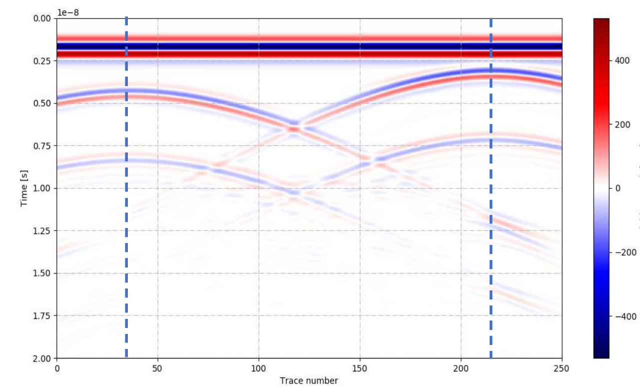
III. RESULTS AND DISCUSSION

The results in the following show the ability of GPRMax model simulation to detect more than one tuber underground, to obtain the tuber diameters and to find the tuber depths.

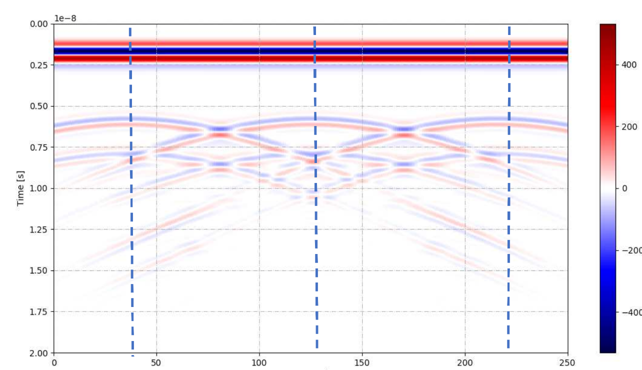
A. Scanning for Two and Three Tubers

To detect whether we got more than one tuber underground or not, could be determined by the following tests. For the first test we used two Porang tubers. The first tuber was set for 10 cm depth and the second one was for 6 cm underground. Frequency of 1 GHz was used.

Based on B-scan results in Fig. 3(a) for simulation of two tubers the peak of B-scan was influenced by numbers of Porang detected underground. The first and second tuber were detected at trace of 40 and trace of 220, respectively. Trace determination was used to estimate depth of the first and second tuber by means of A-scan. Estimation depths of the first tuber, and the second one was 10.06 cm, and 7.44 cm, respectively. This difference could be explained after seeing the test using range frequencies of 1.0 - 2.3 GHz to estimate the tuber depth.



(a)



(b)

Fig. 3. B-scan signal at 1 GHz for a) two tubers, and b) three tubers

Number of signal peaks resulted from B-scan was three peaks, Fig. 3(b), accordingly to number of tubers detected. Peak or upper side of the first tuber was traced at 40, meanwhile the second and the third tuber were sensed at trace number of 130 and 220. All of tubers had the depth of 10 cm, thus, for the depth estimation only one sample of A-scan signals of three samples was taken. From the sample we estimated the depth of the second tuber was 10.39 cm.

B. Estimation of Porang Tuber Diameter

Samples used for these simulation tests were Porang tuber with diameter between 10 cm to 30 cm, and frequency of 1.7 GHz with 10 cm in depth from the surface.

Table II shows the estimation results and Fig. 4 shows the signal at 30 cm diameter. Time t_1 is the time required by a receiver to detect an object. If the diameter was 10 cm and 20 cm, the time between t_2 and t_1 would be less than the value obtained for a diameter of 30 cm, thus around 2 s and 4 s, respectively. Not only able to detect the tuber location, but the GPR system also can be used to distinguished tuber sizes being detected, by means of t_2 value obtained from the reflected electromagnetic signal, which got reflected back after reaching the bottom side of tuber. Equation (6) is used to calculate the diameter *d* with a speed of light *c* and dielectric constant of Porang ε_r.

$$d = \frac{(t_2 - t_1).c}{2\sqrt{\varepsilon_r}} \quad (6)$$

TABLE II. ESTIMATION PORANG TUBER DIAMETER

Porang diameter (cm)	*t_1 (ns)*	*t_2 (ns)*	*Estimation Porang diameter (cm)*	*Error*
10	3.28	5.13	9.42	6.12 %
15	3.25	6.13	14.67	2.25 %
20	3.26	7.14	19.76	1.20 %
25	3.25	8.15	24.96	0.16 %
30	3.42	9	29.14	2.97 %

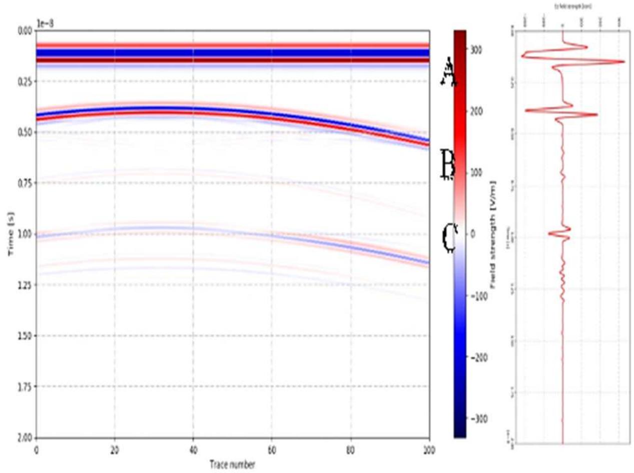


Fig. 4. Estimation of porang diameter at 1.7 GHz (30 cm). A signal showed a time receiver needed to read signal directly from transmitter t_0, B signal showed t_1 and C signal showed t_2.

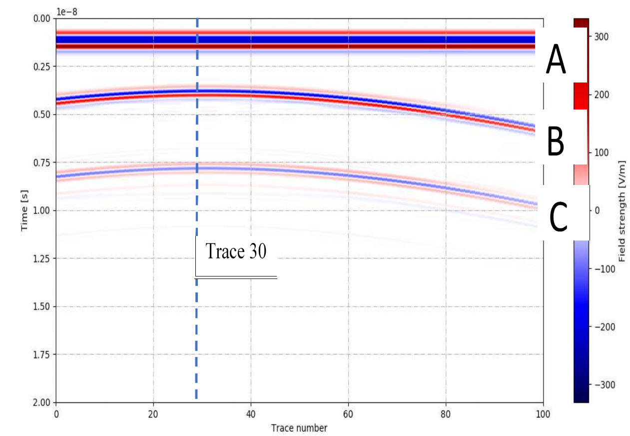


Fig. 5. B-scan signal at frequency of 1.7 GHz at 10 cm in depth.

TABLE III. ESTIMATION PORANG TUBER DEPTH AT 1.7 GHZ

Distance of Porang from surface (cm)	*t_0 (ns)*	*t_1 (ns)*	*Estimation Porang depth (cm)*	*Error*
6	0.4	2.2	6.03	0.55%
7	0.4	2.46	6.89	1.58%
8	0.4	2.7	7.71	3.77%
9	0.4	2.98	8.63	4.28%
10	0.4	3.26	9.58	4.32%

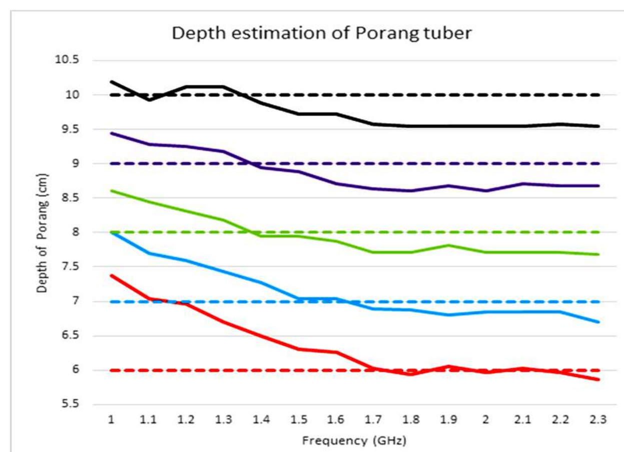


Fig. 6. Estimation of Porang depth at 1.0 – 2.3 GHz, with reference depth (dash line), and estimated depth (straight line) using GPRMax.

C. Estimation of Porang Tuber Depth Using Two Scan Signals

Previously in [7] we used only A-scan signal to estimate tuber depth. In this study, we present the advantage of B-scan to minimize errors. Frequencies of 1.7 to 1.9 GHz were evaluated; those are the Porang response frequencies. In this model simulation, the soil and the dielectric constant of Porang tuber used were 20 and 8.66, respectively. The diameter tuber was 20 cm.

Fig. 5 show one of the B-scan results at 1.7 GHz at 10 cm in depth, with a center point of signal at trace 30. The next step was performing A-scan at trace 30 to get two travel time values, to obtain the tuber depth. A was a direct signal from GPR transmitter to receiver, B was reflected signal from Porang tuber read by receiver, and C was a signal absorbed by Porang tuber then reflected back to receiver due to difference in dielectric constants of Porang and the soil underneath the tuber.

Table III shows estimated depth of tuber having the smallest error of 0.55% at 6 cm depth detection using 1.7 GHz. Meanwhile, the highest error of 4.32% recorded during detection at 10 cm in depth. However, error values obtained by means of B- and A-scan signals were much less than the ones estimated using A-scan only. Maximum error reached was still less than 5% for depth estimation at 1.7 – 1.9 GHz. For other range frequencies, we present the results in Fig. 6. Equation (7) is applied to estimate the depth *d* with the dielectric constant of soil i.e. $\varepsilon_r = 20$.

$$d = \frac{(t_1 - t_0).c}{2\sqrt{\varepsilon_r}} \quad (7)$$

From the simulation test using 1.8 GHz, we found at 6 cm in depth the error was 1.14%. While the highest error was 4.68% at 10 cm where estimated depth of 9.55 cm was obtained. At 1.9 GHz the estimated depth was 6.07 cm, thus, an error of 1.10% was recorded at the reference depth detection of 6 cm.

Based on Fig. 6, we evaluated that the depth of 6 cm would be very adequate to use high frequency of 1.7 GHz up to 2.3 GHz, as well as 7 cm in depth since an error of 1.58% was obtained at 1.7 GHz. Meanwhile, to estimate depth of 8 or 9 cm, and 10 cm, the frequencies of 1.4 GHz and 1.1 GHz were required, respectively. For 10 cm depth detection, at 1 GHz and 1.2 GHz, we had errors of 1.86% and 1.21%, respectively. At a frequency of 1.1 GHz, an error of approximately 15% was found for depth detection of 6 cm, however, the smallest error of 0.79% was revealed for the detection of 10 cm in depth.

IV. CONCLUSION

The differences in the magnitude of the dielectric constant in each Porang tuber, with a range between 8.64 to 8.78, were influenced by the water content. The greater the water content contained in the Porang tuber, the greater the dielectric constant value of the tuber.

Simulation tests using GPRMax were able to sense two or three number of tubers underground. In addition, the results showed tubers diameter were accurately examined at 1.7 GHz with relatively small errors of 1.2% and 0.16%, for 20 cm and 25 cm in diameter, respectively.

Model simulation with B- and A-scan could detect the depth of 6 or 7 cm at frequency of 1.7 – 2.3 GHz, at which the error obtained was relatively small (less than 2%). For instance, when detecting Porang depth of 6 cm, and 7 cm at 1.7 GHz, the error obtained was only 0.55%, and 1.58%, respectively. At 1.1 GHz, for the tuber detection at 10 cm underground, the smallest error of approximately 0.8% was achieved. Therefore, the high frequencies in GPRMax were very effective to sense shallow depth of tubers, or tubers having position near to soil surfaces. However, frequencies of 1.0 to 1.2 GHz would be sufficient for detecting tubers of approximately 10 cm in depth.

ACKNOWLEDGMENT

Authors thank Porang Research Center Brawijaya University for the supports during the measurements.

REFERENCES

[1] Elfarabi. (2017). *Pengolahan data Ground Penetrating Radar (GPR) dengan menggunakan software MATGPR R-3.5.* Jurnal Teknik ITS vol. 6, no. 1, (2017) ISSN: 2337-3539.

[2] Bassuk N, Jason Grabosky, Anthony Mucciardi, and Gary Raffel. (2011). *Ground-penetrating Radar Accurately Locates Tree Roots in Two Soil Media Under Pavement.* Arboriculture & Urban Forestry 2011. 37(4): 160–166.

[3] Butnor J.R, J. A. Doolittle, K. H. Johnsen, L. Samuelson, T. Stokes, and L. Kress. (2003). *Utility of Ground-Penetrating Radar as a Root Biomass Survey Tool in Forest Systems*. SOIL SCI. SOC. AM. J., Vol. 67, September – October 2003.

[4] Ralston, J. C., D. W. Hainsworth and R. J. McPhee. (1997). *Application of Ground Penetrating Radar for Coal Thickness Measurement*. Proceedings of IEEE, Brisbane, Qld., 1997, pp. 835-838 vol.2.

[5] Chlaib Hussein Khalefa, W. Abdulnaby, Najah Abd. (2014). *Application of the ground penetrating radar to detect weapons caches and unexploded ordnance: laboratory experiments.* OSR Journal of Applied Geology and Geophysics (IOSR-JAGG) e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 2, Issue 5 (Jul-Aug. 2014), PP 41-50.

[6] Jol, Harry M. (2009). Ground Penetraing Radar : Theory and Applications. Oxford : Elsevier Sience.

[7] A. Aziz, O. Setyawati, R. Rahmadwati and A. Bangert. (2018). *Model Simulation of Ground Penetrating Radar using GPRMax to Detect Porang Tuber.* 2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS). pp. 136-141. doi: 10.1109/EECCIS.2018.8692906.

[8] Anturida Z, R.Azriningsih dan D.Wahyudi. (2015). *Pengaruh Jarak Tanam Terhadap Pertumbuhan Porang (Amorphophallus muelleri Blume). Pada Fase Pertumbuhan Kedua.* Jurnal Biotropika Vol. 3 No. 3, 2015.

[9] Koswara, Sutrisno. (2013). *Teknologi Pengolahan Umbi - Umbian, Bagian 2: Pengolahan Umbi Porang.* Southeast Asian Food And Agricultural Science and Technology (SEAFAST) Center IPB : Bogor.

[10] Porang Research Center (P4I) Universitas Brawijaya. (2013). *Budidaya dan Pengembangan Porang (Amorphophallus Muelleri Blume) Sebagai Salah Satu Potensi Bahan Baku Lokal*. Pusat Penelitian dan Pengembangan Porang Indonesia, Universitas Brawijaya. Malang.

[11] Benedetto, A., Tosti, F., Bianchini Ciampoli, L., & D'Amico, F. (2017). *An overview of ground-penetrating radar signal processing techniques for road inspections*. ScienceDirect : Signal Processing, 132, 201–209.

[12] Surjati, Indra. (2010). Antena Mikrostrip: Konsep dan Aplikasinya. Publisher: Universitas Trisakti. Jakarta.

[13] Annan, A.P. (2003). *Ground Penetrating Radar: Principles, procedures & applications*. Sensors &Software Inc. Technical Paper.