Effects of Intermediate Frequency Bandwidth on Stepped Frequency Ground Penetrating Radar

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***Abstract*—A stepped frequency ground penetrating radar (GPR) system is used for detecting objects buried under high permittivity soil. Different intermediate frequency bandwidth （IFBW） of the mixing receiver is used and measurement results are compared. It is shown that the IFBW can affect the system's signal-to-noise ratio (SNR). Experimental results show that objects of different materials can clearly be detected when the appropriate IFBW is used.**

Keywords*— *stepped-frequency GPR; vector network analyzer (VNA); high permittivity; intermediate frequency bandwidth (IFBW)

I. Introduction

The humidity in a tropical country is generally high, especially during the rainy season. This high humidity in the environment may result in high soil moisture content. Soil moisture content is one of the major factors affecting the performance of the ground penetrating radar (GPR). The high permittivity of high moisture soil generally degrades the performance of the GPR [1]. Therefore, to improve the detection capability of the GPR in such an environment, suitable system parameter settings will be necessary become an interesting topic.

There has been several research performed on time-domain pulse GPR. In [2], a time-domain pulse GPR is reported to have low detection resolution due to the hardware capability that limits its pulse width. Compared to the time-domain pulsed GPR, the stepped frequency GPR is more suitable for this research for several reasons. Firstly, it is easy to set the desired frequency components with equal power levels. Secondly, the frequency bandwidth of the system adapts the signal bandwidth to match the antenna well; finally, it is convenient for signal processing since the transmitted and received signals are both in the frequency domain [3].

In this research, two objects with different materials are buried under the high moisture soils. These objects are a tree trunk that has been soaked in water for more than a week and an empty aluminum water container. Intermediate frequency bandwidth (IFBW) can be used to control the signal-to-noise ratio of the received signal, the smaller the IFBW, the better the signal-to-noise ratio (SNR) [4]. In the experiment, we study the effect of using different values of IFBW for underground object detection. From the experiment results, the most suitable IFBW value is obtained.

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II. Measurement of Dielectric Parameters

The soil in the testbed is prepared based on the soil composition ratio of urban parks provided by National Parks Board, Singapore. It is comprised of a mixture of 3: 1: 1 ratio of topsoil, sand, and organic matter. The testbed is then placed in the natural environment.

Since a wideband measurement is performed, it is important to know the permittivity and conductivity of the soil over the broad frequency range. The soil measurements were carried out using the Agilent 85070D Dielectric Probe [5] that allows for the measurement of the real and imaginary parts of the soil complex relative permittivity over the operating frequency band. The measured results are shown in Fig. 1. The average relative permittivity is found to be ε_c=27.5+j2.5.

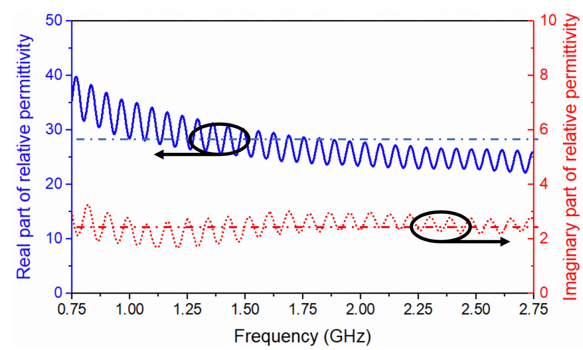

Fig. 1 Measured real and imaginary parts of the relative permittivity of ASM.

When measuring the soil in the testbed, the entire testbed was divided into 12 equal parts, and 3 points were tested in each part. We found that the permittivity value of the soil near the edge of the testbed is significantly different from that in the middle, which is affected by the walls of the testbed. The results shown in Fig. 1 are the averaged value of 18 points that are collected in the middle of the testbed.

One of the tested objects is a wet V-shape tree branch, as shown in Fig. 2(a). In order to imitate a tree trunk, the dry tree brunch was soaked in water for more than one week to increase its water content and then buried in the soil. By doing so, its permittivity will be similar to the value of the soil and the detection capability will be reduced. The other test object is an aluminum bottle similar in size as the trunk, as shown in Fig.

2(b). This provides a reference as an object that is relatively easy to be detected.

The characteristics of the wet trunk and aluminum bottle are tested in a similar way as the soil, and the averaged results of the test results are shown in Table I.

III. Laboratory Experiments

Two similarly shaped objects of different materials are tested by a bi-static GPR system with two different IFBW values: 50 kHz and 500 kHz. The experimental results are made as B-Scan charts for analysis and comparison.

A. *GPR system setup*

The GPR system is made of two identical (EMCO/ETS-Lindgren 3115) double-ridged waveguide horn antennas operating from 0.75 GHz to 18 GHz. The antennas are placed parallel to each other with a center-to-center distance of 30 cm and are placed above the soil surface with a distance of 5 cm. They are connected to ports 1 and 2 of a Rohde & Schwarz ZVL6 Vector Network Analyzer (VNA) respectively as the transmitter and receiver. The key set-up parameters of the VNA are listed in Table II. The objects are buried at a depth of 30 cm. The S-parameters (S_{21}) are acquired at a space interval of 2 cm along the testbed. Each test point generates an A-scan. Fig. 3 shows B-scan images of the target which combines 25 A-scans along a measurement line.

(a) (b)

Fig. 2 (a) water-soaked tree brunch, (b) aluminum bottle.

TABLE I. Measured Characteristics Of Buried Objects

Object	ε_{real}	$\varepsilon_{imaginary}$
Wet trunk	26.01	5.73
Aluminum bottle	7.12	1.13

TABLE II. Summary Of Setup of Rohde & Schwarz ZVL6 VNA

Parameters	Value
Number of steps	4001
Start frequency (GHz)	0.75
Stop frequency (GHz)	2.75
Tx Power (dBm)	-10
I.F. bandwidth (kHz)	50
	500

B. *Experimental results*

Fig. 3 shows the B-scans after background removal operation. Since the placement of the antenna is completely symmetrical with respect to the testbed, after the background removal operation, the effect of the side walls of the testbed on the experimental results can be ignored. The highlighted points that indicate the objects are clear, from which we can estimate the location and the shape of the objects. From Fig. 3(a), a V-shape can be observed, which is similar to the shape of the tree brunch. Also, it can be found that the V-shape is clearer and the highlighted area representing the branch is more concentrated with an IFBW of 50 kHz. This is because a smaller IFBW leads to a higher SNR. In Fig. 3(b), the advantage of low noise interference with IFBW of 50 kHz is more obvious. In this case, the shape of the B-Scan is closer to the actual shape of the bottle. The size of the highlighted part in the B-scan is almost the same as the size of real object.

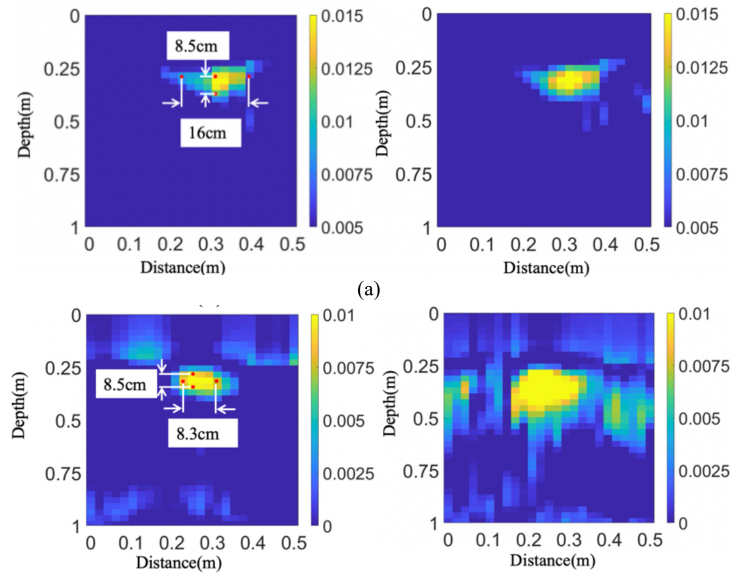

Fig. 3 Experimental results: IFBW = 50 kHz (left) and IFBW = 500 kHz (right). (a) water-soaked trunk, and (b) Aluminum bottle.

IV. Conclusion and Perspectives

The paper presents an evaluation of the impact of IFBW on the detection capability of buried objects using GPR. To complete our study, a bi-static GPR system has been successfully used to collect B-scans of two test objects. From the results, the stepped frequency GPR using lower IFBW yields better results detection capability with less noise and higher resolution, and it also indicates the actual size of the objects. Further investigation into the IFBW for better resolution will be performed.

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