A STUDY ON DETECTING WATER-LEAK OF WATER PIPES USING LABORATORY SMALL-SCALE GPR SYSTEM

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1. Introduction

In Korea, about 26.7 percent of the total water production is lost. Main cause of water loss is water-leak from water pipes. According to the Office of Waterworks Seoul Metropolitan Government, systematic leak detection and fast leak repairs are necessary to reduce the loss. Leak detection mainly used acoustic method is very sensitive to surrounding noise. Recently, non acoustic methods such as tracer gas, infrared thermography, and ground-penetrating radar(GPR) for detecting water-leak are experimentally investigated at specially constructed field site[1]. However, because of large background effects, the feasibility of GPR for leak detection is not presented[2]. Therefore, we introduced laboratory experiment under well-controlled condition. Dry sandbox is installed as background medium in our laboratory. Within significant frequency band of the transmitting signal, the electrical properties of the material under test(MUT), such as dry sand and wet sand used in experiment, are measured by using an open-ended coaxial probe method[3]. The electrical property of the dry sand is similar to that of acryl. Therefore, support for maintaining position of the buried targets is made of acryl filled with dry sand. It is very difficult to maintain moisture content and distribution of wet sand. The electrical property of the wet sand under saturation is very alike that of methanol. Therefore, acryl box with methanol-filling is equivalently considered as water leakage model. The size and buried depth of real water pipe are scaled down. B-scan surveys for several cases of leaky pipes are performed. And we presented that target image such as the pipe and the leakage is obtained by simple signal processing.

2. Laboratory GPR System

As shown in Fig. 1(a), the experimental GPR system is installed by using bistatic antennas above PVC tank filled with dry sand. The antennas are designed by using the finite-difference time-domain (FDTD) method[4]. The antennas are parallel to each other above air-sand interface and perpendicular to the survey line. The transmitter and receiver are connected to the feeds of transmitting and receiving antennas through coaxial cables with 50 Ω, respectively. For triggering, the trigger output of the transmitter is connected to trigger input of the receiver. Because of imperfect impedance matching among transmitter-feeder-transmitting antenna, the multiple reflections may be transmitted through the transmitting antenna. Therefore, the reflected signals are delayed by using feeder line with sufficient length and are windowed out in time domain. To perform accurate acquisition, the receiver is operated by using personal computer(PC) through general purpose interface bus(GPIB) cable. And the antennas are mounted on Cartesian positioning system, which are precisely moved by step-motor connected to motor driver. The driver is automatically controlled by PC through serial cable.

The complex permittivity of material under test(MUT) used in GPR experiment is measured by using our open-ended coaxial probe method[3], as shown in Fig. 1(b). The probe method is very

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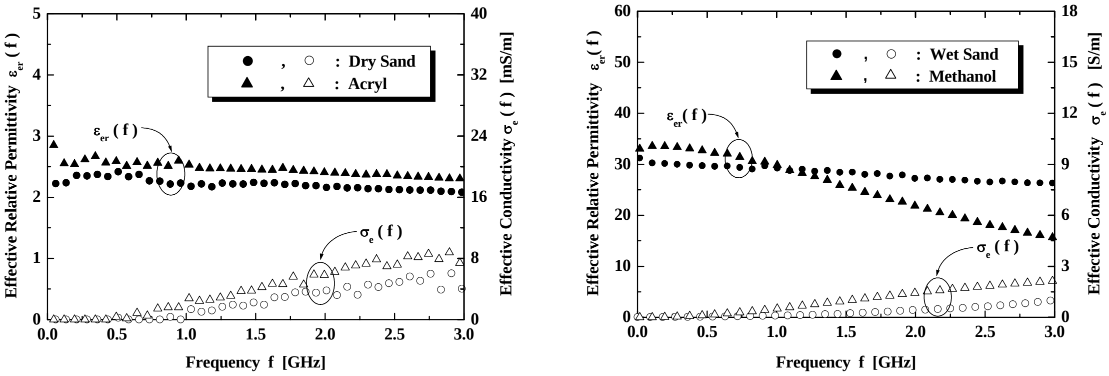
sensitive to contact between the probe and MUT. Therefore, to obtain the stable data, the measured data(Fig. 2) are repeated nine times under perfect contact and the results are averaged. As shown in Fig. 2(a), the electrical properties of the dry sand(circle symbol) and acryl(triangle symbol) are measured. The parameters of the acryl are very similar to that of the dry sand. Target support is necessary to maintain precise location of targets. Therefore, support is made of thin acryl plates and pipes, as shown in Fig. 3(a). To minimize the effects of the support, the support is filled with the dry sand and we bore holes through the upper plate of the support. Generally, the saturation of soil and voids around leaky pipes are created. As shown in Fig. 2(b), the electrical properties of saturated sand(circle symbol) and methanol(triangle symbol) are measured. Because of changing moisture content and distribution of wet sand as times go, it is difficult to maintain the condition of wet sand. Fortunately, as shown in Fig. 2(b), the property of methanol is alike to that of wet sand. Therefore, acryl box filled with methanol is used as water leakage model, as shown in Fig. 3(b).

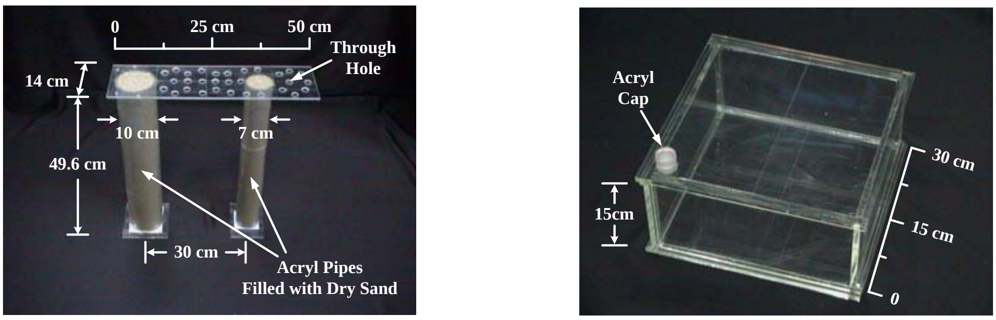
(a) (b)

Fig. 1. Experimental setup. (a) laboratory GPR system, (b) open-ended coaxial probe system.



(a) (b)

Fig. 2. Measured electrical properties of the MUTs. (a) dry sand and acryl, (b) wet sand and methanol.



(a) (b)

Fig. 3. Geometry of (a) target support and (b) leakage model.

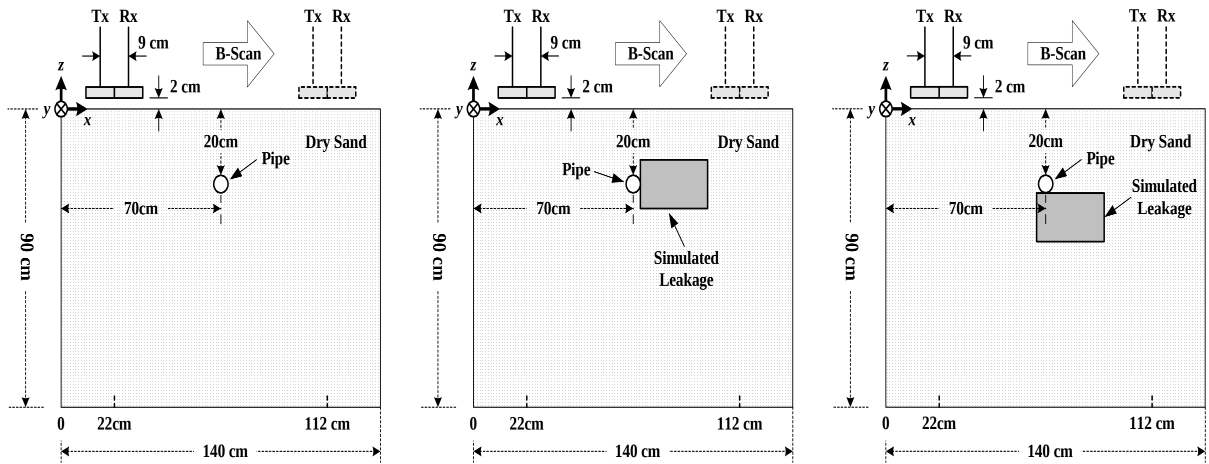
3. B-Scan Surveys and Results

First, we performed B-scan in case of no target and confirmed that reflections of side and bottom of the tank as well as target support are negligible. According to the Office of Waterworks Seoul Metropolitan Government, a number of water-leaks are occurred at the pipe with about 200 mm in diameter. The pipe is buried at a depth of above 1.2 m. Thus, the size and buried depth of the pipe are scaled by the factor 1/5.88.

B-scan surveys are performed as shown in Fig. 4. Fig. 4(a) showed that single pipe with 3.4 cm in diameter is buried only at a depth of 20 cm. As shown in Fig. 4(b) and 4(c), leakages presented at the right side and under side of water pipe, respectively. All B-scan surveys are conducted along the survey line under the conditions that separation between transmitting and receiving antennas is 9 cm and the antennas is located at a height of 2 cm from the air-sand interface. Measured B-scan data are displayed by using gray-scaled image. And then target images are simply extracted by employing signal processing as shown in Fig. 5 and Fig. 6. The target image is extracted by subtraction between the raw image and partially averaged B-scan image with spatial-window, as shown in Fig. 5. This processing is background removal and approximately spatial low-pass filtering of the target image. In Fig. 5, stripe at 2 ns represented direct-coupling and ground surface reflection. Fig. 5(a) showed that hyperbolic pattern is caused by the pipe. As shown in Fig 5(b) and Fig. 5(c), the images are superposed by pipe and leakage. Therefore, we could detect the leakages as well as the pipe itself. Fig. 6 showed difference image between neighboring A-scan data. And it may be considered as background removal and approximately spatial high-pass filtering. Fig. 6(a) showed that neighboring difference at apex of the hyperbolic pattern is near to zero. This point is equal to the position of the pipe. Fig. 6(b) and 6(c) show the edges of the leakage as well as pipe image itself. Therefore, we can estimate the location of the pipe and the leakage.

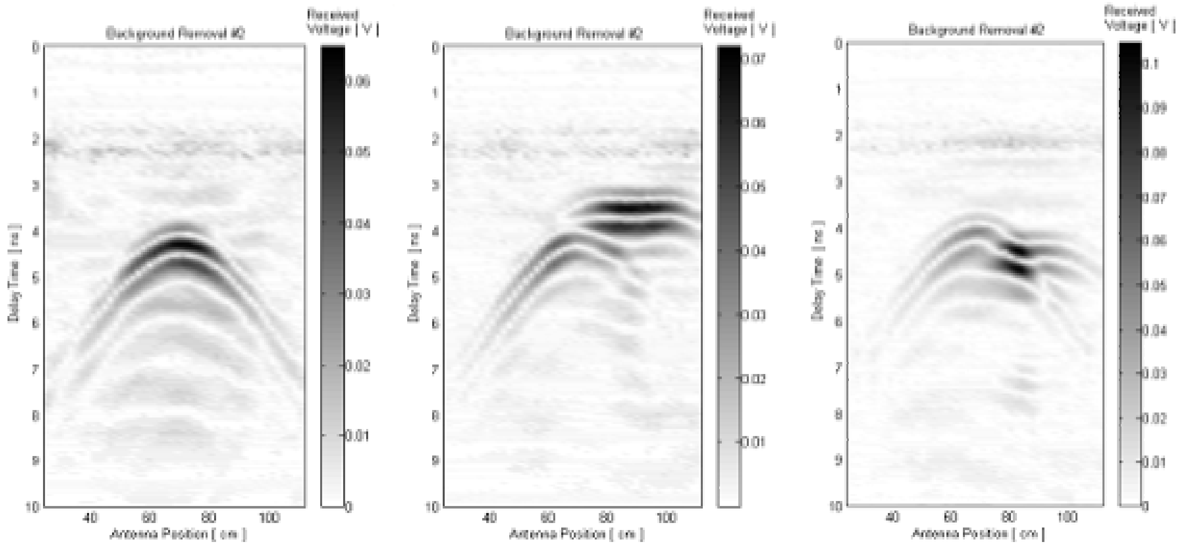
4. Conclusions

We have experimentally investigated the possibility of GPR for detection of water pipes. Experimental GPR system under well-controlled condition is installed in our laboratory. We selected dry sand as background medium. Small-scale models of water pipe and leakage are buried in sandbox. The leakage model is made of acryl box filled with methanol, which is alike to electrical properties of saturated sand. Target images are extracted by using simple signal processing such as subtraction technique using spatial window and neighboring difference. We presented that leaky pipes under low-loss and clutter-free background such as dry sand can be easily detectable using GPR. Due to high contrast between saturated soil and background or clutter, GPR probing technique might be applicable to detect the leakage of leaking pipes in real soil. In the future, we will investigate more realistic condition such as background clutter and noise.



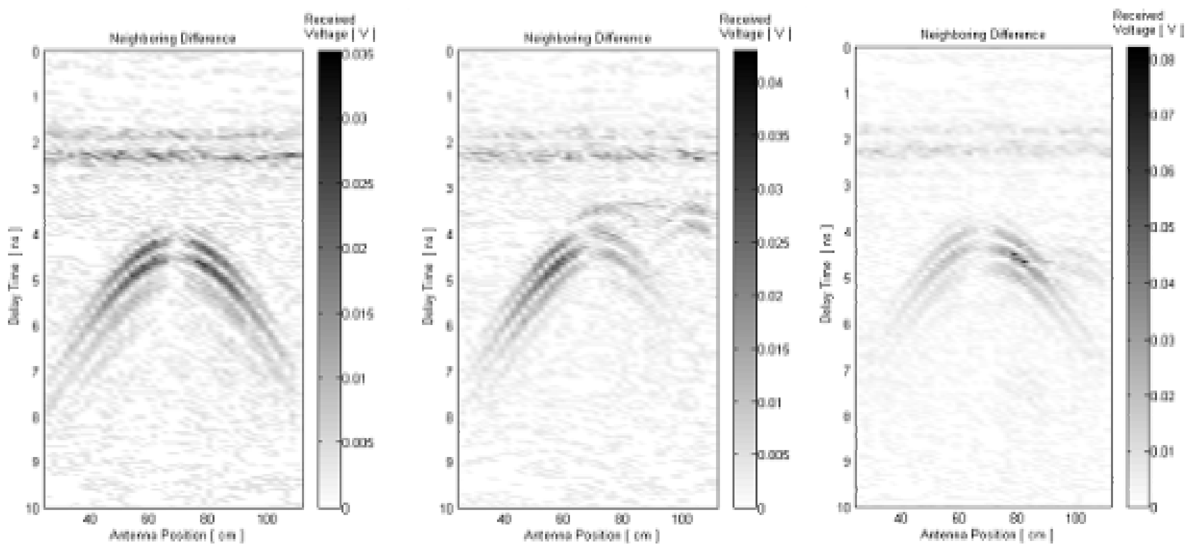
(a) (b) (c)

Fig. 4. B-scan surveys. (a) case #0, (b) case #1 , (c) case #2.



(a) (b) (c)

Fig. 5. Subtraction images. (a) case #0, (b) case #1 , (c) case #2.



(a) (b) (c)

Fig. 6. Neighboring difference images of (a) case #0, (b) case #1 , (c) case #2.

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