GPR Monitoring System for Evaluation of Asphalt Pavement

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Abstract

To evaluate the condition of asphalt pavement road, two GPR systems with different frequency band were mounted in the trailer type vehicle. The GPR system with higher frequency band was used to measure the thickness of the asphalt layers and the other system with lower frequency band was used to detect the air cavity located beneath the asphalt pavement.

Keywords : GPR, Asphalt, Layer, Pavement, NDE

1. Introduction

The asphalt pavements are distressed by high volume of traffic, increase of heavy vehicle, and environmental effects. To prevent the disaster in high way or runway of airport due to the fatigue crack or settlement of asphalt pavement in advance, a number of non-destructive test methods are studied for long times [1]-[6]. Traditionally, the thickness of asphalt layers was evaluated by measuring the strain and pressure of road or by collecting the core samples directly [2][3]. Recently, it was reported that GPR systems were very useful for estimating the layer thickness of asphalt because of its high accuracy and operational simplicity [4][5]. In addition, it was well known that the ground settlement or sinkhole was caused by air cavities in deep area due to the ground water leakage and it can be also detected by GPR system easily.

To evaluate and monitor the asphalt road condition effectively, these two parameters have to be measured simultaneously. One is the thickness of the asphalt layer to evaluate the road fatigue crack and the other is some air cavities located beneath asphalt pavement to predict the ground settlement. In general, the pulse radar system with the bandwidth above 1GHz should be used to discriminate layers with thickness with about 10~20 centimetres. Unfortunately, it has low penetration capability because the electromagnetic wave with higher frequency band decayed exponentially because underground medium such as asphalt, soil and rocks are lossy and inhomogeneous. In contrast, the radar system for detection of air cavity at deep region should have the lower frequency band below 500 MHz.

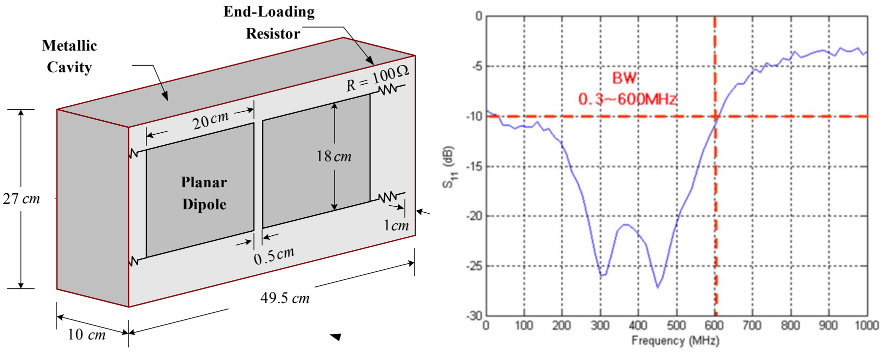
In this paper, our team combined two types of GPR having lower and higher frequency band to implement the vehicle mounted GPR system for evaluation of asphalt road. The capability of asphalt thickness measurement by using GPR was evaluated in newly constructed highway road. The combined GPR system was also demonstrated at parking area with asphalt pavement and underground structure in a few meter depths.

2. Implementation of GPR monitoring system

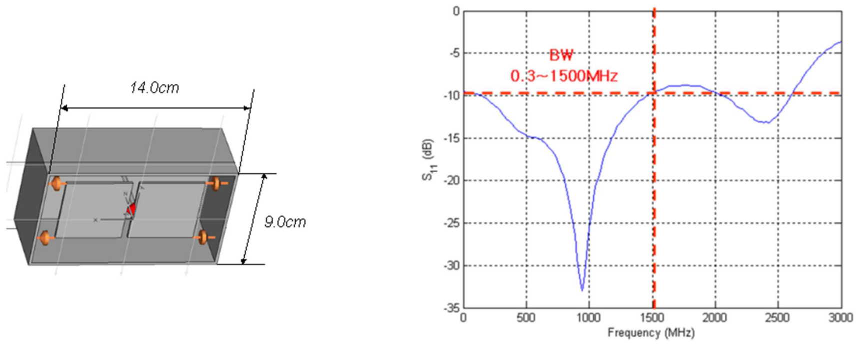
To implement asphalt evaluation system, we used two types of GPR system listed in Table 1. The lower band system is designed for detection of underground cavities with the diameter above 50cm in the depth of a few meters. In this system, pulse generator with 2ns pulse width and 100 V was used as transmitter. To acquire its response signal, the receiver has the bandwidth between 100 and 500 MHz and the sampling step of 0.3 ns. In contrast, for the measurement of asphalt layer thickness, the higher band system was implemented with the pulse generator of 0.6ns and 5 V and the digitizer of 0.075 ns sampling step and 0.5~1.5GHz bandwidth. As the antenna of both systems, two planar dipole antennas with cavity were used as shown in Figure 1. To get wide band characteristic, each antenna element had rectangular plate structure and the end loading resistors of 100 Ohm were attached between the end of element and metal cavity. The outer size of lower band antenna was about 50 x 10 cm and that of higher band antenna was scaled about a one third of lower band antenna size.

Table 1: Specification of Combined GPR system

GPR Type	Tx		Rx	
	Pulse width(ns)	Peak voltage(V)	Band width(MHz)	Sampling step (ns)
Lower band	2	100	100~500	0.3
Higher band	0.6	5	500~1500	0.075

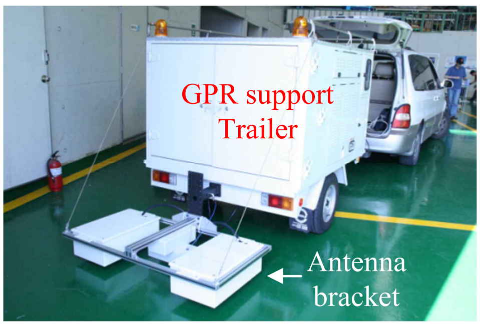


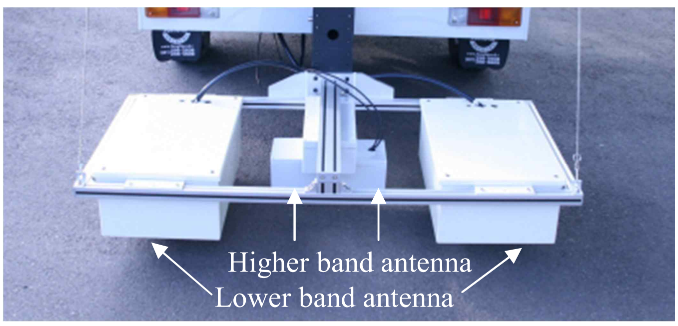
(a)



(b)

Figure 1: Structures and reflection coefficients of two planar dipole antennas.
(a) Lower band (b) Higher band.





(a) (b)

Figure 2. Implemented GPR Monitoring System for Road Evaluation
(a) GPR Support Trailer (b) Antenna bracket mounted dual band antenna

To get GPR data on the asphalt road at high speed, both systems were implemented in the GPR support trailer as shown in Figure 2. In this system, the power systems, such as electrical power generator and inverter, were equipped inside the trailer and an encoder was also applied to get travelling distance. The antenna bracket was attached the tail of the trailer to mount both GPR antennas. As you can see in Figure 2(b), the lower band antenna was separated about 70 cm. The higher band antenna with 20 cm separation was located in the middle of both lower band antennas. The elevation height from road surface of all antennas was about 10 cm.

3. Results

3.1 **Evaluation of newly asphalt pavement**

We tested the capability of GPR to measure the thickness of asphalt pavement layer in the newly constructed the 3rd Seoul-Inchon highway. This highway road was constructed with 3 layers listed in Table 2. In each layer, the maximum thickness is 5 cm, 7 cm and 25 cm, respectively. Because the maximum construction thickness of a vibrating roller vehicle is 9 cm, base layer with 25 cm thickness was constructed by 3 repetitions in the order of 9-9-7 cm. Because each layer has a different maximum aggregate size of as shown in Table 2, the relative permittivity of each layer is different from 6 to 12 [6]. In addition, the adhesive oil like RSC-3 or RSC-4 was also inserted between each layer as shown in Figure 3 (a). The electromagnetic pulses are reflected at the interface of each layer due to different permittivity and adhesive material. To assure the layer reflection of pulse signal clearly, a metal mesh plate was inserted between base 2 and 3 layers in asphalt pavement construction. Figure 3(b) shows the GPR measurement result. All layer interfaces are depicted with red. From the strong signal reflected at the metal mesh plate between base 2 and 3 layers, the other layer interfaces can be discriminated easily. However, the interface between surface and intermediate layers was relatively weak because the difference of the relative permittivity of both layers is small.

Table 2: Asphalt pavement Structures and Permittivity

Layer		Structures		Relative Permittivity [6]
		Thickness (cm)	Aggregate Size (mm)	
Surface		5	13	6
Intermediate		7	19	8
Base	1	7	25	12
	2	9		
	3	9		

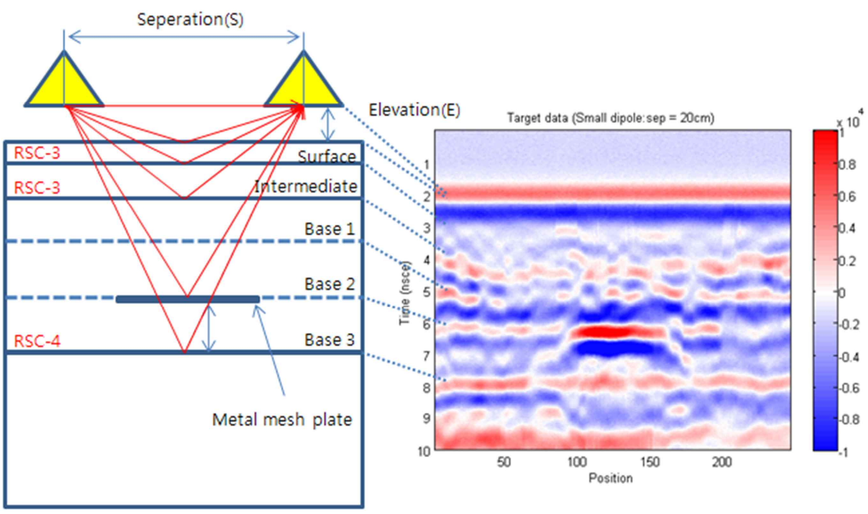
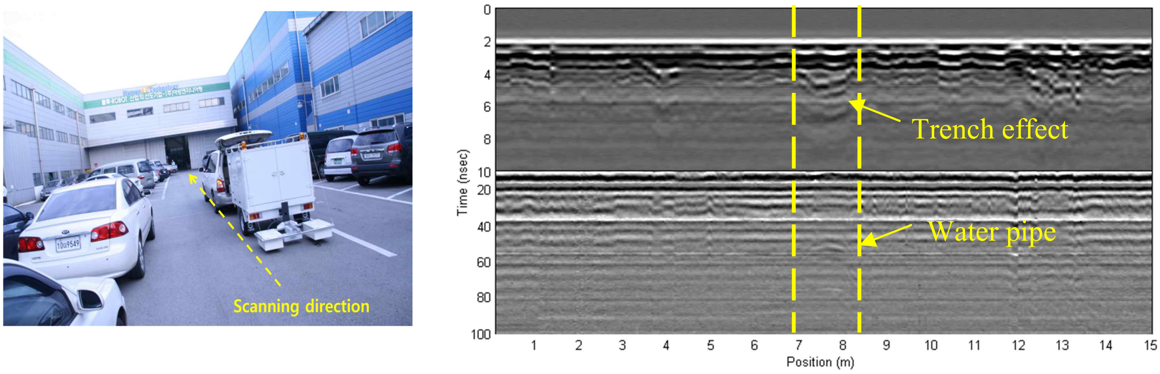


Figure 3. Measurement Result of Asphalt Layer Thickness
(a) Asphalt layer structure (b) GPR measurement result

3.2 **Combined monitoring of asphalt pavement**

Figure 4(a) shows the implemented GPR monitoring system demonstrated in the parking area. The total scan distance was 15 m. In Figure 4(b), the results of higher band GPR were depicted in early times between 0 and 10 ns and the profiles of lower band GPR were displayed after 10 ns. As shown in Figure 4(b), the trench effect was discovered in higher band signal to bury the new water pipe with diameter of 50 cm at the depth of 3 m and the hyperbola pattern of the water pipe was shown in lower band signal about 50 ns.



(a) (b)

Figure 4. Measurement result in parking area

(a) Field experiment (b) GPR result combined higher and lower band system

4. Conclusion

The GPR monitoring system was implemented to evaluate asphalt road by combining two GPR system operated in different frequency bands simultaneously. We can discriminate the layer of asphalt with higher band system and underground utilities like as pipe or air cavity in deep area with lower band system. If this system is operated periodically in the same location, the variation of the thickness of asphalt pavement and the air cavity due to underground water can be discovered. It will be very useful to predict the road defect area in advance.

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