A small GPR for horizontal directional drilling system

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1. Background

HDD (Horizontal Directional Drilling) technique shows very preferable feature than conventional open-cut method, not only for shortening of the construction period, but also decreasing the quantity of waste soils. But underground installations are congested in the urban area and it is important to prevent damaging them. There is a problem that the location of the underground installation does not always agree with the underground map. In order to locate the underground objects, we often use a GPR to reduce the total working cost and time. But the pavement and traffic situation often prevents from using a GPR from the groundsurface.

There are the examples of conventional shield machine for tunnels with a diameter of a few meters or more, which has third party utilities detection system using acoustic method.

The drill head of HDD is too small to mount an acoustic system. Moreover, reflection caused by the heterogeneity of the ground is strong, and it is difficult to distinguish the reflection of object utility. We have applied to miniaturize the GPR system to mount in the small tip of drilling head. A GPR can detect not only the metal material but also the non-metal one.

2. Aims

Our development is to install a small GPR to the drill head, which can detect buried pipe in the vicinity of the drill head. Data measured by a GPR are transmitted using a wireless communication system. And finally, the operator of the HDD machine can check the GPR image in the monitor.

3. Method

1) High frequency circuit of GPR

Firstly, we selected the step recovery diode system as a pulse generator in order to transmit sharp pulse wave form. The center frequency of the pulse wave is approximately 1GHz and the peak amplitude of the pulse wave is 2.9V. This pulse is transmitted 400 times as frequent as a conventional GPR, since averaging the received signal is effective to reduce the random noise.

2) Small antenna

The size of the drill head of HDD is very small. Then, we experimentally produced small antenna (5 cm(D)$*$7.5 cm(W)$*$1.5 cm(H)) shown in figure and installed the antenna in the slope of the drill head.

We selected the shape of the antenna elements are bow-tie type.

Special features of the antenna compared with conventional GPR are;

- The rubber material of the low dielectric constant was filled in the antenna case for absorbing vibration while HDD machine is drilling.
- As the protection board of a GPR antenna element, we adopted special ceramics board (relative dielectric constant is approximately 20) to avoid the mismatch to the soil.

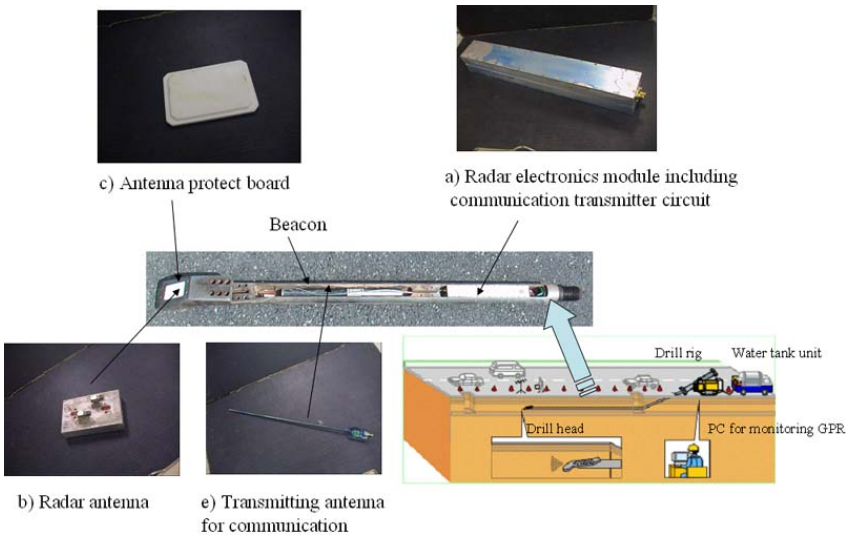
4. Results

The small GPR and the wireless communication system were set on the HDD machine, and we started to evaluate the performance of the small GPR system. We tested in the test field and actual piping job site. And we caught the reflective wave from the buried metal and non-metal pipe in some cases. Crossing and parallel buried pipes were detectable and the detective distance was 30 to 50 cm, but it depends on the soil attenuation of the transmitting pulse wave.

Checking the GPR monitor in real-time, we sometimes stopped moving the drill head and prevented to damage the third party pipe.

5. CONCLUSION

We developed a small GPR system including wireless communication system in order to prevent damaging installation when we use HDD while the piping work in the urban area. As a result, it is shown that the object buried ahead of the drill head in the ground. Both metal and non-metal pipe are detected before hitting them. Especially, we could detect the actual water pipe without damaging in this case.


c) Antenna protect board
a) Radar electronics module including communication transmitter circuit
Beacon
Drill rig
Water tank unit
Drill head
PC for monitoring GPR
b) Radar antenna
e) Transmitting antenna for communication