International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 24 (2017) pp. 14026-14032

A Study on the Effective Maintenance of Water-Facilities using RF Method

Moon, Jeom Hwan[1] and Choi, Seung Pil[2]*

Department of Civil Engineering, Catholic Kwandong University, Gangneung, Gangwon, Republic of Korea.
**Corresponding Author*

ORCID: 0000-0002-1646-6361[1] and 0000-0003-0247-4376[2]

Abstract

Underground facilities have rapidly increased due to urban concentration. And there has been the high risk of accidents inherent in excavation work according to that. And the main agents for maintaining waterworks, communications, electricity, and gas by underground facilities are different from one another. And if facilities are closely or overlappingly buried, it is not easy to be distinguished from one another. So there have been the increasing factors that cause many accidents in excavation works. The metal detectors that have usually been used in detecting the existing underground conduit facilities have caused the accidents which damage other facilities due to errors of doing facilities while excavation works are done around underground facilities. Especially in case of nonmetallic pipe conduits, it is difficult to locate them only with the drawings because it is difficult to be detected. Therefore, the detection rate of nonmetallic pipe conduits needs to increase and development and verification of exact and effective detection technique are required. This study compared and analyzed location values of RF detection based on the detection rate of 100% and the results of location surveying before water pipes are buried in two places by using the RF detection method that underground detection by band. As the result, the applicability of RF was checked when water pipes are buried as RMSE of plane position is ±0.12m, ±0.12m and RMSE of the depth is ±0.14m, ±0.12m.

Keywords : RF, water-facilities

INTRODUCTION

For underground facilities, infrastructure, the number has explosively increased due to urban concentration. And the importance of underground facilities has been better emphasized than ever by the public safety and necessity (Lee, Yong-wuk et al., 2007).

Especially, there is high probability of accidents as there are many deteriorated water pipes in underground facilities. So the security of plans to obtain exact location information of buried pipes is urgent. However, the result that analyzed the result of the public surveying result evaluation from 2004 to 2009 has found that the average detection rate of water pipes is very low as 52.4% (Lee, Won-jong et al., 2015). It announced that the more nonmetallic pipe circuits are, the lower entire detection rate is because the rate of nonmetallic pipe circuits in water pipes is in inverse proportion to the detection rate of water pipes (Kim, Jae-myeong, 2010). And pipe conduit signs and stone markers have been arranged for maintaining underground facilities after underground works were completed. However, burying and washout have often happened.

For the metal detection method as the auxiliary measure, it is difficult to detect water pipes, gas pipes, telecommunication conduits, and electricity conduits that are mutually closed to one another or overlapped exactly because they are not separated from one another. For nonmetallic water pipes, the conduits have been maintained by the method that buries lead wire under the upper part of nonmetallic pipes. However, it has been less effective because lead wire is cut and lost when the water leak of water pipes is restored or saddle branched pipes or conduits are excavated.

Due to these various problems, plans to be able to respond to all kinds of accidents including the urgent restoration of the water leak by finding the location of facilities as soon as possible when they happen recently got to be required.

Therefore, this study tried to verify if RF detection method for underground buried pipes which can be distinguished by frequency band can be applied to improve these problems. Information on the location and depth was obtained through location surveying of conduits before water pipes are buried. And information on the location and depth was obtained by using the RF detection method after back filling. Based on these, it tries to suggest the applicability of the RF detection method by comparing and analyzing accuracy.

THE LIMIT OF THE TRADITIONAL TECHNOLOGIES RELATED TO UNDERGROUND FACILITIES

For the methods to detect underground objects being buried underground and made of metallic and nonmetallic materials, there are the method that uses ground penetrating radar to detect locations and standards more exactly and equipment that combines the two characteristics of metal detectors and ground penetrating radar with each other except the method to use metal detectors. However, equipment of the method that combines multiple sensors with one another is impossible to be applied to sites because it is too big and complicate to carry it and detect conduits.

Therefore, in the study the method that combines multiple sensors is excluded from comparison because they are rarely used. And it suggested an improvement plan by comparing the accuracy of the method that uses metal detectors which are generally being used now.

Detection method with a metal detector

A metal detector consists of two coils and the electronic circuit that controls magnetic field. And metal detectors' performance has gradually been improved as they were developed to detect locations of mines usually for military purposes.

However, the principle of metal detectors is to grasp locations of metal materials by detecting change of magnetic field between metal and detectors. So it is difficult to grasp metal types and size and the depth exactly.

Figure 1 – General shapes of metal detectors

Dozens of detection were conducted by burying metallic water pipes made of cast iron and steel to grasp the detection accuracy of metal detectors. It made a skilled personnel who has been responsible for maintenance of conduits in the waterworks field to improve the accuracy of detection.

The results that detected underground facilities by using a metal detector are shown in the following table. And it was possible to measure the depth. For estimating the depth, there was no any method except estimating the depth as the person who detected estimated it roughly by doing the sounds from the metal detector. So it is judged that the variance error and accuracy of the depth cannot be utilized as the standard.

The excitation method can be utilized as the method introduced to supplement this. The excitation method is to grasp locations or physical characteristics of subject facilities by analyzing wavelength reflected by applying vibration to them. It is usually being utilized in detection of the water leak.

Electrical prospecting method

This method is also called the electrical magnetic prospecting method or the magnetic prospecting method. It grasps locations of underground facilities as the method to measure physical phenomena by underground electrical material property. This method can be conducted as the indirect method (The inductive method) and the direct method.

(1) Indirect method (The inductive method)

How to use it is simple as the method to detect a lot of metallic facilities at a time but the types or characteristics of facilities cannot be reflected. It is scarcely used because the specific facilities cannot be detected. But, it can simply and promptly detect only one facility in an area if there is only one in it.

(2) Direct method

This method is now and usually used in detection specific facilities buried underground. This is the general method. It is one of the method that is widely being used as the most reliable method except the RF detection method arranged by the study. However, for this method, the location of one point must exactly be grasped among locations of underground facilities. Therefore, detection must start to be done around manholes for maintaining underground facilities and there were errors in detection when there are a lot of facilities that are crossed.

Table 1:. Comparison of variance errors by detection method (Unit: m)

Detection method	Time	Variance errors			Remarks
		X	Y	Z	
Metal detector		Cannot be evaluated because there is no reproducibility			
Electrical prospecting method (Indirect method)	1	0.27	0.33	0.5	
	2	0.31	0.29	0.5	
	3	0.30	0.36	0.6	
	4	0.29	0.28	0.5	
	5	0.39	0.36	0.5	
Electrical prospecting method(Direct method)	1	0.15	0.20	0.4	
	2	0.21	0.17	0.3	
	3	0.18	0.23	0.4	
	4	0.16	0.19	0.3	
	5	0.23	0.25	0.4	

For the type of metallic conduits, it was DCIP (D=150mm) that is usually being used by waterworks licensees. It made the skilled personnel who has been engaged in maintenance of water supply facilities for more than 20 years to secure professionalism of detection measure facilities several times. It is thought that it is not proper to judge the accuracy of the cm unit because it detects locations of conduits with the method that represents the dynamics of sound waves. However, the locations of the conduits were shown in the cm unit by

experience of the persons who detects them to compare the accuracy with the RF detector.

Institutional supplementation and political solutions

In order to solve these problems, drawing underground facilities exactly by measuring locations of conduits before back filling when they are newly established or replaced got to be compulsory according to the revision of the laws related to it in 2010.

However, according to the characteristics of the installation of water supply pipelines, the works must be carried out supplying tap water. So it was investigated that it is very difficult to apply it to the existing towns except the housing sites that are newly built. It is judged that making technicians who acquired qualification of measurement stay at sites is very unreasonable in an aspect of expenses and efficiency. It is judged to be few cases that locations of buried conduits are measured during waterworks are being arranged except large scale works because of this reason.

For maintenance of underground facilities, it is very difficult to find locations of objects promptly and exactly by using GIS drawings and coordinates built because it is being carried out by general managers of the applicable institutions (Kim, In-seop, 2010). And it is difficult to find the locations that the conduits are actually buried with GIS materials (Coordinates and topography) if the topography was changed.

Therefore, management of the exact locations of underground facilities through the RF exploration method suggested by the study is more urgent. The RF facilities are the simple method that does not require special functions. It is okay just when it is placed on the upper part of conduits. It is the simple method that can be done with conduit work. So it is judged to be the method that is easy to indicate exact locations of conduit facilities and maintain conduits after being buried.

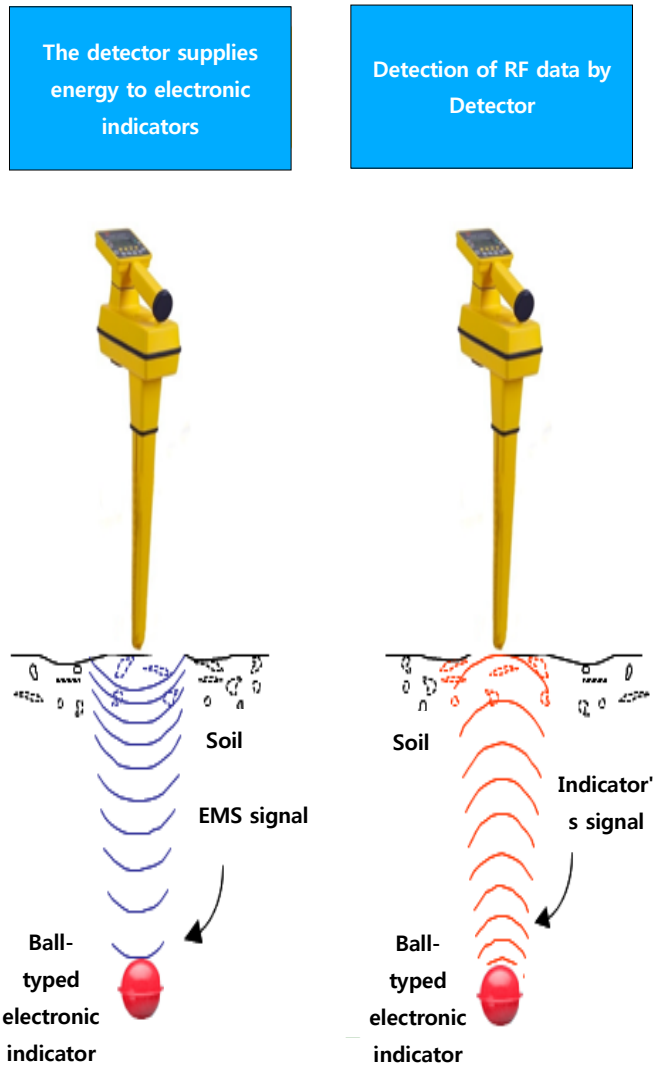

Figure 2: The principle of detecting conduits by using a detector and RF

RF EXPLORATION METHOD AND LOCATION SURVEYING OF UNDERGROUND FACILITIES

RF exploration method

The detection principle is the mutual electromagnetic induction method as shown in Figure 2. As a leader supplies all of electrical energy necessary for making chips of a tag operate, part of powerful magnetic fields released by it generates inductive voltage in a coil antenna of the tag and detects conduit indicators. This method does not supply power to the conduit indicators and special maintenance is not necessary in the future. It is judged to be easy for maintaining conduit facilities.

RF (Radio Frequency) exploration method was carried out as the plan to be able to monitor locations of underground facilities exactly. And the accuracy of locations tries to be verified by installing RF which can monitor locations of conduit facilities in waterworks.

For RF utilized in the study, 134 kHz, the LF band that the recognition speed is low but stable and maintenance of power supply is not necessary in the future, was used. Especially, the products released by two companies in Korea were tested as the security of the safety of underground telecommunications is very important.

However, the response rate of the domestic products was very low as below 30% at the underground depth of 0.6M. The current technical skills in Korea showed the limit of underground communications. In case of Gwangju Metropolitan City, the average depth that water supply facilities

were buried was investigated to be 1.0M and the one that gas facilities were done was done to be about 1.45M. Therefore, RF produced in Korea was excluded from the experiment because the test could not be done. And RF produced 3M located in Naju, Jeonnam was just tested.

Location surveying of underground facilities

The study referred to Article 140 (Exploration) and 142 (Location surveying) of Work Provision for Public Survey. When the pipe size is more than 100 mm and the burial depth is less than or equal to 3.0m, the contents are as follows:

Table 2: Tolerance range of the exploration errors of facilities

Classification	Work Provision for Public Survey		Electronic conduit indication detector
	Metal conduit detector	Non-metal conduit detector	
Error range	Plane ±20cm Depth ±30cm	Location ±20cm Depth ±40cm	Plane ±20cm Depth ±15%, ±5cm

For the location surveying method of underground facilities in the Work Provision of Public Survey, in the locations of facilities newly buried, the separation distance and depth of buried conduits were supposed to be actually measured with the reference point of offset surveying (C) as the center as shown in Figure 3 by using a Staff and a steel ruler before the excavated land is refilled after the facility work is completed. Or the point coordinates (X, Y, Z) can be obtained through total station or GNSS surveying as shown in Figure 4. In the study, the plane coordinates (X, Y) were measured with GNSS and the burial depth was actually measured with a Staff as shown in Figure 5.

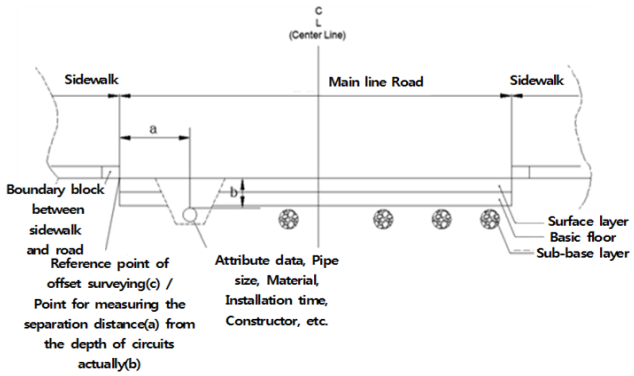

Figure 3: Offset surveying method

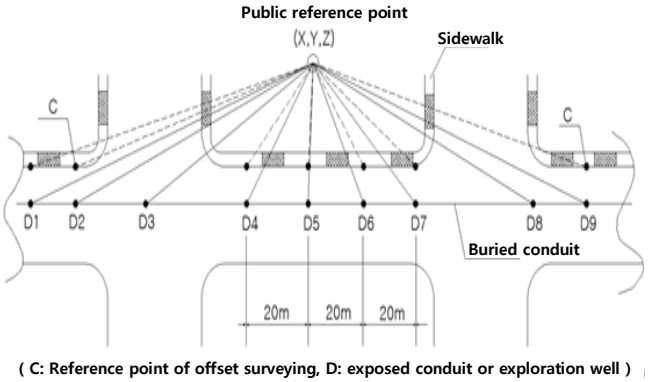

Figure 4: TS, GNSS surveying method

Figure 5: Measurement of the burial depth with a staff

AN ANALYSIS OF THE APPLICABILITY OF THE RF EXPLORATION METHOD

Selection of the site

The subject site for the experiment is the whole area of Gwangju Metropolitan City. The two areas that are is easy to be measured as the construction sites of nonmetallic water pipes were selected. The measurement points of the site are total 40 points of 20 in Samdo-dong, Gwangsan-gu and 20 in Deokrim-dong, Gwangsan-gu.

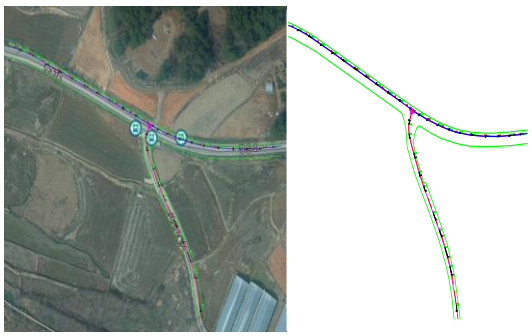

Figure 6 : Location map observed in Samdo-dong

Figure 7 : Location map observed in Deokrim-dong

Observation results of water pipes

First, RF of the LF band, the low frequency band of the passive method, was buried 0.2m higher than the upper part of water pipes. The results that tested and explored 40 RFs buried at an interval of 10.0M has found that the detection rate is 100%. For the following Table 3, the pipe size is 75mm and the pipe type is nonmetallic conduit of HI3P. For the obtained result values, the maximum error of plane location is 0.28m, the minimum error is 0m, and RMSE is ±0.14m. For Table 4, the pipe size is 80㎜, and the pipe type is the nonmetallic conduit of HI3P. For the obtained result values, the maximum error is 0.25m, the minimum error is 0m, and RMSE is ±0.12m. For the obtained depth, the maximum error is 0.21m, the minimum error is 0m, and RMSE is ±0.12m. The areas that the errors are large are judged to be because the recognition rate is low as the indicators' horizontality is misaligned in compaction.

Table 3. The result table of location surveying of RF before being buried and its detection and observation after being done in Sangdo-dong (Unit: m)

Point ID	Variance error of plane location	Real time depth	RF detection depth	Variance error of the depth
1	0.12	0.7	0.90	-0.20
2	0.14	0.8	0.83	-0.03
3	0.02	0.6	0.87	-0.27
4	0.10	0.8	0.98	-0.18
5	0.00	0.8	0.80	0.00
6	0.00	0.8	0.98	-0.18
7	0.04	0.8	0.96	-0.16
8	0.06	0.8	0.92	-0.12
9	0.04	0.8	0.96	-0.16
10	0.10	0.8	1.01	-0.21
11	0.04	0.9	0.86	0.04
12	0.28	0.9	0.95	-0.05
13	0.14	0.9	0.98	-0.08
14	0.13	0.9	1.03	-0.13
15	0.20	0.9	1.04	-0.14
16	0.07	1.0	1.07	-0.07
17	0.24	0.9	1.05	-0.15
18	0.00	0.9	1.09	-0.19
19	0.06	0.9	0.99	-0.09
20	0.03	0.9	0.97	-0.07
Average value		0.84	0.96	
RMSE	±0.12			±0.14

Table 4. The result table of location surveying of RF before being buried and its detection and observation after being done in Sangdo-dong (Unit : m)

Point ID	Variance error of plane location	Real time depth	RF detection depth	Variance error of the depth
21	0.06	1.0	0.94	0.06
22	0.00	0.9	0.70	0.20
23	0.07	0.8	0.91	-0.11
24	0.04	0.9	0.93	-0.03
25	0.04	0.9	1.02	-0.12
26	0.01	0.9	1.02	-0.12
27	0.02	0.8	1.01	-0.21
28	0.00	0.8	0.94	-0.14
29	0.06	0.7	0.74	-0.04
30	0.02	0.8	0.93	-0.13
31	0.08	0.8	0.98	-0.18
32	0.20	0.7	0.90	-0.20
33	0.16	0.8	0.81	-0.01
34	0.10	0.9	0.90	0.00
35	0.01	0.9	0.92	-0.02
16	0.21	0.9	0.90	0.00
37	0.10	1.0	0.95	0.05
38	0.19	1.0	0.85	0.15
39	0.25	0.9	0.84	0.06
40	0.18	0.9	0.85	0.05
Average value		0.87	0.90	
RMSE	±0.12			±0.12

CONCLUSION

The study conducted the accuracy analysis by comparing location surveying values of conduits of water pipes before being buried with the exploration values after being done to check the applicability of RF exploration method. And the results are as follows:

First, the results that tested and explored 40 points have found that the detection rate is 100%. This result shows the possibility that RF can very usefully be utilized in maintenance of underground water pipes.

Second, RMSE of plane location is each ±0.12m and ±0.12m. And RMSE of the depth is each ±0.14m and ±0.12m. They satisfy the allowable limits of error of the Work Provision for Public Survey, but partial plane locations escape from the allowable limits. This is the result that the horizontality cannot be kept in compaction after being installed. It can be very effective for maintaining underground water supply facilities as the allowable limits of error of the Work Provision for Public Survey can be satisfied if horizontal management should be careful when RF is installed However, for the errors of the depth, it showed the limit of measuring the depth as there are a lot of measurement values that escape from the allowable limits of error in equipment.

Third, the fall of the exploration rate can be solved if RF is buried with nonmetallic conduits. And because of fast and simple exploration, prompt response to water pipes can be done by finding the locations as soon as possible when there are all kinds of accidents including the restoration of urgent water leak. And it can be the effective means to be able to prevent damage of water supply facilities in underground excavation due to other construction works.

A physical plan that RF is horizontally installed 0.2m higher than the upper part of water pipes needs to be prepared when it is installed in the future.

REFERENCES

[1] Cheon, Se-yeong, Lee, Yeong-ju, Yang, Sun-yong, “Developement of Detection system of buried Underground Utilities using Magnetic Sensor”, 2005

[2] Kim, I. S., 2009, A Study on the Development of Field Management System for Underground utility using Self-levelling marker and DGPS, Geodesy, Photogrammetry and Cartography, Vol. 27, No. 6, pp. 733~739.

[3] Kim, J. M., Lee, B. W., Yun, S. C. and Yoon, H. S., 2010, Improving the Detection of the Water Mains Underground Facilities, Journal of The Korea Spatial Information Society, Vol. 18, No. 4, pp. 23~32.

[4] Lee, W. J., Lim, S. M., Choi, Y. S. and Min, K. S., 2015, A Study on Applicability of Water Pipe Detecting Using GPR, Journal of Cadastre & Land InformatiX, Vol. 45, No. 2, pp. 131~147.

[5] Lee, Y. W., Heo, M., Lee, J. O. and Bae, K. H., 2007, A Study on Status and Accuracy of Underground Facilities Maps, Journal of The Korean Society of Survey, Geodesy, Photogrammetry and Cartography, Vol. 25, No. 3, pp. 223~230.

[6] Min, Se-il, Kim, Se-yun, Lee, Sang-seol, “Perlimiary Study on the Detection of Plastic Mines by Using Pulse Radar”, 1997

[7] Park, Yeong-jin, Kim, Gwan-ho, Lee, Won-tae, “High resolution groud penetrating image radar using an ultra wideband (UWB) impulse waveform”, 2005