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건물 내의 위치기반 서비스를 위한 RFID 시스템

(Evaluation of RFID System for Location Based Services in the Building)

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요 약

본 논문에서는 UHF RFID 시스템을 콘크리트 블록에 매립하기 위해 다양한 종류의 RFID tag를 선택하여 실험한다. 매립된 tag의 수신율을 측정하기 위해 매립 깊이를 달리하고, 재질을 바꿔가며 감쇄율을 측정한다. 실험결과에서 콘크리트의 혼합비율은 성능에 큰 영향을 주지 않는 것을 알 수 있다. 본 연구는 GPS 신호를 사용할 수 없는 유비쿼터스 환경의 실내에서 위치기반의 서비스를 위해서 필요한 위치정보를 얻어 내는 방법인 RFID 시스템의 기반시설 매립에 초점을 맞춰 진행한다.

Abstract

In this paper, different RFID tag types compliant with UHF frequency based RFID system were chosen to build RFID tag embedded concrete blocks. Then, by placing the tags in systematically varied depths of a concrete block, we could measure the RF signal attenuation pattern as the performance indicator of a specific concrete embedded RFID system. Experiments show that the concrete mixing ratio makes no significant difference in tag detection performance level. The significance of the developed RFID system lies in its capability of eliminating GPS's error and shadow area as well as providing smart infrastructure for supporting truly pervasive ubiquitous computing applications especially in outdoor environment.

Keywords : RFID, Location, Read range, UHF, Metal tag, Dog bone tag.

I. 서 론

RFID[1~3] increases productivity and convenience. RFID is used for hundreds of applications such as preventing theft of automobiles, collecting tolls without stopping, managing traffic, gaining entrance to buildings, automating parking, controlling access of vehicles to gated communities, corporate campuses and airports, dispensing goods, providing ski lift access, tracking library books, buying hamburgers, and the growing opportunity to track a wealth of assets in supply chain management[4~7]. The 1990's were a significant decade for RFID since it saw the wide scale deployment of electronic toll collection in the United States. Important deployments included several innovations in electronic tolling. The world's first open highway electronic tolling system opened in Oklahoma in 1991, where vehicles could pass toll collection points at highway speeds, unimpeded by a

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toll plaza or barriers and with video cameras for enforcement.

Recently introduced RFID antenna integrated electronic cane system that uses street floor embedded RFID tags for path findings of visually handicapped population is another exemplary case utilizing concrete embedded RFID technology even though it only works almost on the surface of the street because of the limited read range of 13.56MHz frequency RFID system[8~13].

In general, 13.56MHz frequency radio wave shows high penetration rate with various materials including concrete but has only limited read range, therefore, is not a proper choice for this research. On the other hand, 2.45GHz frequency radio wave is highly influenced by the surrounding environment, therefore, is again not adequate to embed in concrete.

In this research, two types of 900MHz UHF radio frequency compliant RFID tags are selected to be buried in concrete. Detection experiment with concrete embedded RFID tag that complies with UHF frequency range radio wave is a novel attempt since existing approaches utilized in most cases, HF frequency range RFID tag that only works within only a short distance.

Ⅱ. Concrete Embedded UHF RFID System

1. Making of concrete embedded RFID systems

This research focuses on a concrete embedded RFID installation technology. It includes a research that analyzes the relationship between RFID signal and concrete and that looks for a way of enhancing the read range of the concrete embedded RFID system. The performed research also provides methods for installing RFID tag in concrete, securing RFID tag buried in concrete as well as testing the developed technology in a simulated circumstance representing the actual field. This research experiments UHF (900MHz) frequency range bone type tag or similar plate pattern tags to be buried in

그림 1. 콘크리트 블럭에 매립 중인 RFID 태그
Fig. 1. Placement of RFID tag in a wooden concrete frame.

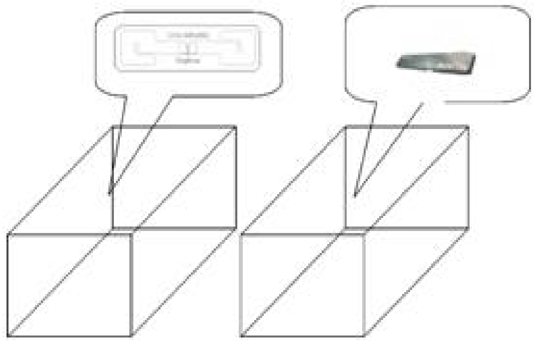

그림 2. 콘크리트 블럭에 RFID 태그 매립한 상태
Fig. 2. Embedding RFID tags in separate concrete blocks

concrete.

To avoid RFID detection interference due to conductive material or residue, cared examination of ingredients in concrete before starting curing process was needed. To measure the RF signal attenuation caused by embedding RFID tag in concrete, a special experiment setting has been established. Concrete mixing ratios tried in the experiment were both 5:5 and 3:7 (sand: cement) in Figure 1.

Instead of burying RFID tags directly into wide area of concrete, we created modularized concrete block and varied depths of embedding RFID tag below the surface of such a block as shown in Figure 1 and 2 to test RF signal penetration intensity changes.

2. Tested RFID tags and their characteristics

We tested two types of RFID tags for our research purpose. Concrete covering depth of RFID tags were between 0.5cm and 3cm.

Dog bone type RFID tag in Figure 3 needs to

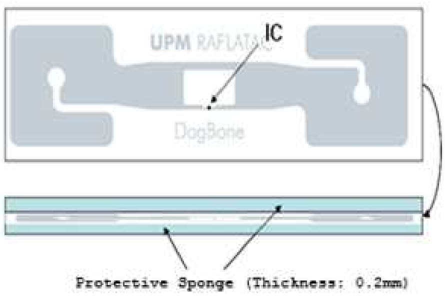

그림 3. Dog bone 타입의 태그와 보호 스펀지 케이스
Fig. 3. Dog bone tag and protective sponge casing.

표 1. UPM dog bone 타입의 RFID 태그 특성
Table 1. Characteristics of UPM dog bone type RFID tag.

Attributes	Description
Protocol	EPC Class 1 Gen 2
Operation Frequency	860 ~ 960MHz
Antenna Size	93 x 23 mm
Memory	240bit EPC / 64bit TID(Tag ID)

표 2. Metal 타입의 RFID 태그 특성
Table 2. Characteristics of metal typed RFID tag.

Attributes	Description
Protocol	EPC Class 1 Gen 2
Operation Frequency	900MHz frequency range
Antenna Size	148 x 24 x 4mm
Memory	240bit EPC / 64bit TID(Tag ID)

make small sized space for protecting IC part of RFID tag. On the other hand, metal RFID tag does not require such kind of protective skin. Table 1 and 2 show the characteristics of each RFID tag, a dog bone type and a metal type.

As for a mathematical modelling, concrete embedded RFID tag's concrete covering depth (D), read range (L) and read area(A) have the following relationship.

Equation (1) and Figure 4 show the relationship between concrete covering depth and read area

$$A = \Pi * (\frac{L}{\tan\theta})^2, \quad (1)$$

$$L = \frac{K}{D}, \text{ K: constant}$$

To acquire high precision location readings, street or road can have an array of concentrate embedded RFID tags each of which has either absolute latitude and longitude or other forms of coordinates depending on the target applications' software development specification (Figure 5).

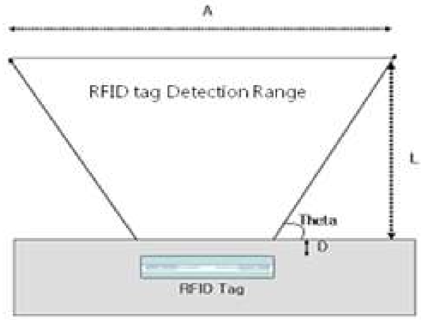

그림 4. 매립 깊이와 통신 가능영역의 관계
Fig. 4. Concrete covering depth vs. read area configuration.

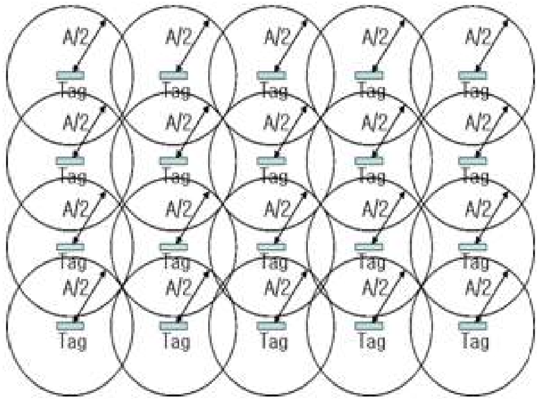

그림 5. 매립 RFID 태그의 배열
Fig. 5. Structure of a concrete embedded RFID tag array.

In this array, the inter-tag distance could be flexibly controlled according to the required location resolution. Ratio between cement and sand could be varied from 1:1 to 1:3 since it does not influence too much on the read performance.

Ⅲ. Performance Evaluation

1. Performance evaluation for the concrete embedded RFID system in dry environment

As was expected, the performed experiments show that the dog bone type RFID tag's read range is significantly decreased according to its depth of being buried in a concrete block. Figure 6 shows the

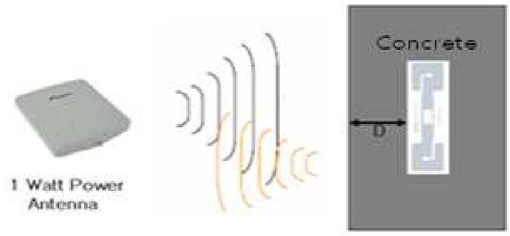

그림 6. 콘크리트 매립 RFID 시스템 구조
Fig. 6. Concrete embedded RFID system Architecture.

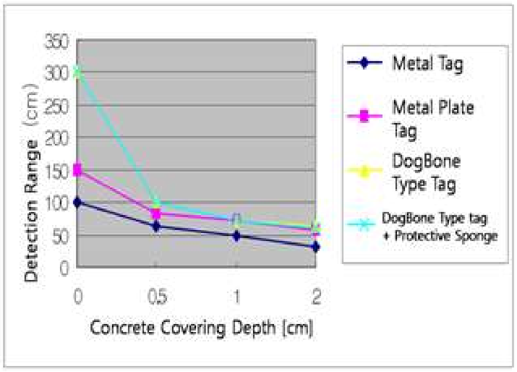

그림 7. 매립 깊이와 통신 높이
Fig. 7. Concrete covering depth vs. read range.

표 3. 다양한 RFID 태그의 매립깊이와 통신 높이
Table 3. Performance measurements for various concrete embedded RFID tag options.

RFID Tag Type	RFID Tag Covering Depth(D)	Detection Range
Metal Tag	0cm	1m
	0.5cm	63cm
	1cm	48cm
	2cm	31cm
Metal Tag + Metal Plate	0cm	1.5m
	0.5cm	82cm
	1cm	71cm
	2cm	57cm
DogBone Type Tag	0cm	3m
	0.5cm	1m
	1cm	73cm
	2cm	62cm
DogBone Type Tag+ Protective Sponge	0cm	3m
	0.5cm	1m
	1cm	72cm
	2cm	61cm

experimental setup. In this paper, 1 watt power antenna is used.

The buried RFID tag shows 1m reading range when the tag is placed 0.5cm beneath the surface of a concrete block and concrete mixing ratio turns out to make little difference for read range changes in Figure 7.

In metal tag's case, typical 1m read range limit in open air environment was dropped down to 0.63m when the RFID tag is buried 0.5cm below the surface of a concentrate block.

This is because metal type RFID tag's antenna has almost no change whereas the dog bone type tag is sensitive to the orientation and antenna impedance changes due to the morphological change of its antenna, which triggers the read range decrease.

As a result, dog bone type RFID tag shows relatively higher and more stable read range profile regardless of the concrete covering depth. Metal type RFID tag gets better signal propagation by being contacted with metal plate, therefore, shows good read range when it is buried in shallow depth (0.5cm ~ 1cm) while it is attached to a metallic plate.

This test case would be a good choice especially when a RFID tag needs to be attached to a steel structural member. But even in this case, limitation still prevails since the tag should be placed in shallow depth.

Dog born type tag does not have this limitation in relation with the concrete covering depth, therefore, could be a better selection in general circumstances. Protective sponge cover of a RFID tag made out of a special class of plastic material turns out to be a reliable choice for safe and stable installation of the tag in concrete because it does not significantly decrease the reading performance of the tag.

2. Performance evaluation for the concrete embedded RFID system in wet environment

Another test for evaluating the influence of rain, snow or water on the surface of concrete block that has embedded RFID tag inside reveals that the read range of the tag drops significantly.

To test this phenomenon, we developed a special

표 4. 물의 영향으로 인한 RFID 태그의 매립깊이와 통신 높이
Table 4. Performance measurements of the concrete embedded RFID tag options under the influence of water.

RFID Tag Type	RFID Tag Covering Depth(D)	Detection Range
Metal Tag	0cm	51cm
	0.5cm	33cm
	1cm	25cm
	2cm	16cm
Metal Tag + Metal Plate	0cm	74cm
	0.5cm	40cm
	1cm	33cm
	2cm	22cm
DogBone Type Tag	0cm	2m
	0.5cm	53cm
	1cm	41cm
	2cm	31cm
DogBone Type Tag+ Protective Sponge	0cm	1.8m
	0.5cm	54cm
	1cm	44cm
	2cm	28cm

test setting in which various RFID tag embedded concrete blocks are separately placed at 1 cm beneath the water surface to experiment its read range changes.

The consequence of such experiments show almost 45%-50% read range drops across all tested RFID tag types. It turns out to be that the metal tag gets better performance when it is attached to a metallic plate even when the concrete block is placed under the water.

Ⅳ. Conclusion & Future Works

The ways for covering RFID tags with concrete and the impacts of such operation in relation with RFID tag read range changes are still remained as important research issues. Among many remaining issues, embedding tags directly into on-site casting concrete instead of the modular concrete blocks adopted in our research is a crucial research topic calling for further studies. In case concrete embedded RFID system is used as an essential smart infrastructure of a typical region, the concrete embedded RFID tag array needs to be further investigated for enhancing precision of location identification by analyzing direction and read ranges of multiple RFID tags.

This research focused on UHF frequency range RFID tag for its placement in concrete. Next step would include developing the ways to make concrete embedded RFID reader and antenna in addition to special RFID operating system targeting this special type of RFID hardware packaging practice.

Development of a concrete embedded RFID system plays crucial role for various outdoor location based services not to mention its potential use for managing and monitoring the buildings or street furniture items made out of concrete or similar materials.

Unlike most of HF frequency concrete embedded RFID systems, UHF type concrete embedded RFID system investigated in through this study can extend the applicability of RFID technology for an invisibly labelled built environment that could dramatically change our everyday interactions with surrounding environment as was vividly envisioned by the late Mark Wieser when he ignited the explosive idea of the ubiquitous computing units vanishing into our living environment.

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