Cost-Effective ETC System using RFID Tag

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Abstract: While many countries have introduced ETC (Electronic Toll Collection system) for reducing the cost of toll collection, improving service time and environmental burden, some countries that have not yet introduced ETC accelerate to innovate this system actively. In each country, the communication method for ETC is different, for example passive DSRC (Dedicated Short Range Communication) and active DSRC etc. Some countries need not only high performance but also cost-effective, a variety of installation methods and easy maintenance. In this situation, we have developed "ETC system using RFID tag" of 900MHz frequency band that fulfills these requirements. And we have evaluated performance of our ETC system based RFID tag on actual roads in Asian countries. As a result, performance of our system is as high as other ETC systems. In this paper we report the characteristics of this system and evaluation results on actual roads.

Keywords: Electronic Toll Collection system (ETC), RFID tag, Road Side Equipment (RSE), Dedicated Short Range Communication (DSRC)

1. Introduction

Some countries have studied to innovate ETC (Electronic Toll Collection system) actively, but there are a variety of requirements by the road operators, such as high performance, cost-effective, a variety of installation methods and easy maintenance. As a result of our research and studies for these requirements, we have developed "ETC system using RFID tag" [5] that fulfills these requirements. And we have evaluated the system behavior and radio characteristics of 900MHz frequency band. In comparison to 5.8GHz DSRC (Dedicated Short Range Communication), the influence of fading is large at 900MHz frequency band, as 900MHz frequency band is easier to diffract than 5.8GHz. We have tested our system on actual roads in Asian countries. In this paper, we report features of our ETC system, specification overview and evaluation results on actual roads as followings.

2. Related Studies

As for ICT (Information Communication Technology) practical deployment for vehicle, telematics integrated the cellular phone and the navigation system and the safe driving assistance system using V2I (Vehicle-to-Infrastructure) communication have been put to practical use. For telematics mobile WiMAX (Worldwide Interoperability for Microwave Access) in addition to 3.5G cellular phone system is used. For the safe driving assistance system, “ITS (Intelligent Transport Systems) spot services” adopting 5.8GHz DSRC of V2I communication deliver the road traffic situation and the preventive safety information to the OBU (On-Board Unit) with ETC function.

3. Problem Setting and Requirements

3.1. DSRC Communication

5.8GHz DSRC is used for ETC in Japan as a V2I communication. DSRC is compliant with ARIB STD-T75 [1], STD-T88 [2], and composes a steady communication zone that has a range of 30m from the center of the base station. One base station communicates simultaneously with multiple mobile stations. Wide communication area and high transmission speed (4Mbps) is realized by active communication method.

3.2. Requirements of the System

The ETC system using RFID tag we propose in this paper is expected to apply to ETC systems, where high-speed and high-quality means of communication is required as V2I systems. Here, the requirements that the system should meet are as follows.

- Communication zone is a dedicated short range of about 6.5m × 4m. In this system, since the running vehicle is related with the camera image, it should be possible to identify which lane the vehicle is running by communicating with one antenna on the lane of the vehicle running.
- At the vehicle speed of 120km/h, application data of about 400 bytes should be transmitted and received twice both side between roadside equipment (RSE) and OBU.
- One RSE communicates with minimum two OBUs simultaneously.

4. Features of ETC System and Specification Overview

To apply to the ETC system that satisfies the requirements, we consider to use RFID tags as OBUs. Heretofore, ID tags have developed for the fleet management, and a various types of ID tags have been spread in the market. We have developed OBUs by using RFID tag chip in ID tags of the fleet management, and have developed RFID readers to read and write information in ID tags. The following descriptions are features of our ETC system and specification overview of OBU and RSE.

4.1. Features of ETC System

Table 1 shows features of our ETC system. Though our RFID tags and RSE have a variety of installation methods, accuracy of our system is equivalent to the proven ETC systems based DSRC compared with our systems.

Table 1. Features of two types ETC systems.

Items	ETC using RFID tag	ETC based DSRC
Toll collection type	Flat rate type (Open system), Distance based rate type (Close system)	Same as ETC using RFID tag
Lane condition	Single lane with barrier	Same as ETC using RFID tag
Accuracy	Equivalent to ETC based DSRC	Over 99.99%
Communication protocol	ISO/IEC 18000-6C [3] EPC global Class-1 Gen2 [4]	ISO15628, ITU-R M.1453, ARIB STD-T75
Installation of RSE	Side-fire mount, Overhead mount	Overhead mount
Installation of OBU	Front-glass or Dashboard	Front-glass

We have developed two types of optimized installation configurations to comply with various antenna installation positions. One is side-fire mount installation as shown in Fig.1 and the other is overhead mount installation as shown in Fig.2.

- Side-fire mount installation is available to be accepted under the canopy, but formation of communication zone is difficult.
- Overhead mount installation is difficult to be accepted under the canopy, but formation of communication zone is easy.

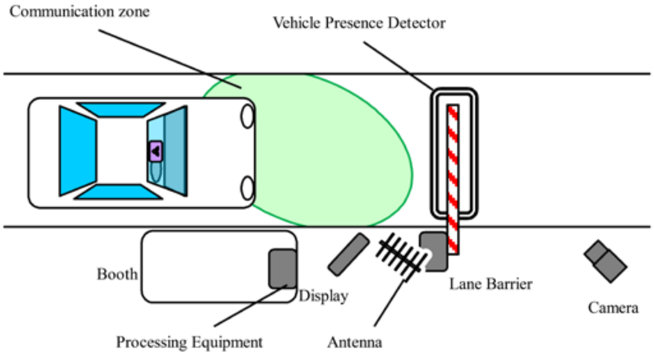

Fig.1. Lane layout image of Side-fire mount.

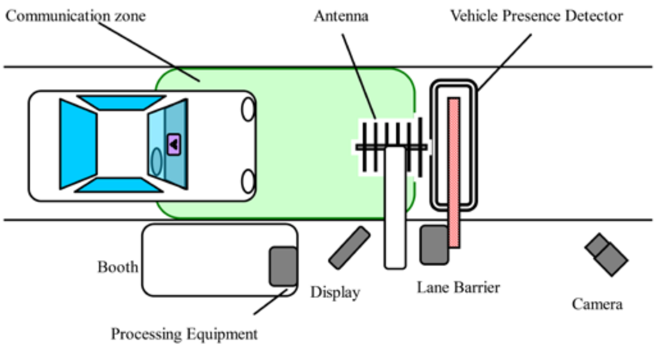

Fig.2. Lane layout image of Overhead mount.

4.2. Features of ID Tag for ETC System

We have developed two types of RFID tags with considering about permittivity for installation methods. One is front-glass stuck RFID tag, the other is dashboard stuck RFID tag. These ID tags are compliant with a various requests how to stick ID tag directly to the object. Fig.3 shows the image figure of ID tag. Table 2 shows the specification of RFID tags.

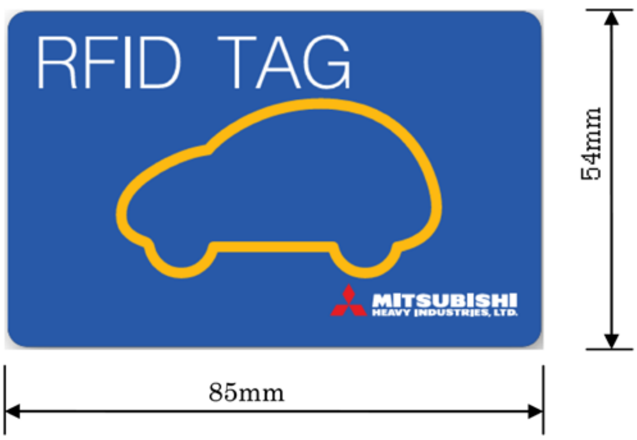

Fig.3. Image figure of RFID tag.

Table 2. Specification of RFID tag.

Items	Specification
Data retention period	10 years or more
Anti-collision	Supported
Operating temperature	-40-85℃
Storage temperature	-40-85℃
Humidity	95%RH or less
Weight	Less than 2g

4.3. Specification of RSE

RSE is separated for maintenance operations and consists of antenna and processing equipment. Table 3 shows the specification of processing equipment.

Table 3. Specification of processing equipment.

Items	Specification
Operating temperature	-20-60℃
Storage temperature	-30-80℃
Humidity	95%RH or less
Weight	3.5±0.5kg

5. Evaluation on Actual Roads

We have evaluated performance of our ETC system at toll plaza in Asian countries. As a result, performance of our "ETC system using RFID tag" is as high as other ETC systems of us. Fig.4 shows the figure of toll plaza in the Asian county and Fig.5 shows the image of field tests. Moreover, in our internal field tests we have tested a lot of cases including abnormal cases, such as the effect of fading by tandem driving, multiple driving and various types of vehicles.

Fig.4. Toll plaza in Asian country.

Fig.5. Image of field tests.

5.1. Test Conditions

We have confirmed two objects in these tests. One is the system behavior on actual roads and the other is that we will confirm whether there is any effect of radio characteristics at 900MHz that radio fading affects the reliability of radio communications on actual roads.

We have confirmed the system behavior and the effect of radio characteristics for communications under the following conditions.

Tests are running by using the following types of vehicles.

1) Heavy Vehicle

2) Compact size passenger cars

3) Normal size passenger cars

5.2. Test Cases

a) Two or more test vehicles, to confirm communication results (read out ID tag information) are properly notified to Lane Controller (LC) by using vehicle types of 1), 2), 3) at 30 times driving.

b) Two or more column running cars with tag, to confirm communication results for all test vehicles are properly notified to LC by using vehicle types of 1), 2), 3) at 30 times driving.

c) Test vehicle running through adjacent lanes, to check microwave leakage to those lanes by using vehicle types of 1), 2), 3) at 30 times driving.

d) Change the tag sticking position, and test cases of a), b), c).

e) Test vehicle which briefly stops abreast on the tollbooth by using vehicle types of 1), 2), 3) at 30 times driving (one-stop).

f) Test vehicle which passes through the lane as fast as possible by using vehicle types of 1), 2), 3) at 30 times driving (non-stop).

5.3. Test Results

As a result of these tests, all tests (from a) to f)) are completely successful, there is no communication error and processing error in communication transactions within communication area of the antenna. Moreover, in the installation conditions and the road environment, we have found out that the effect of radio characteristics at 900MHz affects the reliability of radio communications.

6. Conclusions

As a result of actual roads in Asian countries and the internal field tests, we have achieved that performance of our ETC system based

RFID tag is as high as other ETC systems of us. Though there is no error affecting the system under the test environment in this time, there is possibility to affect impact of radio fading if installation conditions and road environment are changed. Furthermore, we will continue to evaluate quantitatively robust communications by using 900MHz frequency, and also conduct test runs in a variety of test environments.

And then, in the future, we will study and develop toward the system adaptation to multi-lane ETC systems based on the current system.

References

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