**한국ITS학회논문지**
제8권, 제1호 (2009년 2월)
pp. 30～36

# Coverage Extension of the Highway Dedicated Short Range Communication System based on a Fixed Relay

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## 요　약

도심지역에서 사용되는 DSRC 통신시스템은 노변기지국과 차량간 100미터의 통신거리를 갖고 있으며, 이 특성을 이용하여 DSRC시스템에서 RSE(Road Side Equipment)는 차량으로부터 교통정보를 수집하거나 차량에 교통정보를 제공한다. 그러나 고속도로상에서 100미터 통신범위를 갖는 RSE를 사용하는 것은 장비가격 및 설치비가 고가이어서 현실적으로 많은 어려움이 있다. 본 논문에서는 RSE의 표준 셀 범위를 100미터에서 300미터로 확장하고 차량단말기가 RSE와 통신할 수 없는 불감지역을 Cover 하기 위하여 Fixed Relay를 도입하였으며, 이로 인해 Fixed Relay를 사용하는 것이 RSE 만을 사용하는 것 보다 더 경제적인 것을 보인다.

## Abstract

Dedicated Short Range Communication (DSRC) systems in urban areas are used to collect traffic information from vehicles and to provide vehicles with information received from Roadside Equipment (RSE) having a range of 100 meters (m). However, it is not practical to use RSE with a range of 100 m for express highways. In this paper, we expand the standard cell coverage of RSE to 300 m, and adopt fixed relays to cover sites that cannot communicate with the RSE. We demonstrate that the system using the fixed relays is more economical than using only RSE.

**Key words:** ITS, DSRC, fixed relay, coverage extension, express highway

## Ⅰ. Introduction

Intelligent Transportation Systems (ITS) may be broadly categorized into vehicle-to-vehicle and vehicle-to-infrastructure communications [1, 2]. Vehicle-to-vehicle communications are being studied through ad hoc networks and Differential Global Positioning System (DGPS) [3-5]. ITS is used to manage factors affecting vehicles and the routes they use. Since drivers cannot know all of the conditions of the routes, such as traffic, road and weather information, Vehicle-to-Infrastructure communications are used to inform the drivers of such

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† 논문접수일 : 2009년 1월 23일
† 논문심사일 : 2009년 2월 23일
† 게재확정일 : 2009년 2월 24일

information. However, because of the short communication range, the DSRC system cannot be applied directly to express highways.

In this paper, a system is proposed to expand the communication distance by using fixed relays so as to reduce service limits derived from short communication distances and to make various services available. The rest of this paper is organized as follows. Section 2 discusses the parameters required for the system using fixed relays as a transmitting role. Section 3 proposes a simulation model based on these parameters, and then analyzes the simulation results. Finally, in Section 4, our work is briefly summarized as a conclusion.

# Ⅱ. The DSRC System based on a Fixed Relay

The DSRC system currently used in Korea has a communication radius of up to 10 m for Class 1 and 100 m for Class 2 [6]. Even though a short communication radius (e.g., 10 m or 100 m) can provide such services as Electronic Toll Collection System (ETCS), Advanced Traveler Information System (ATIS), and Bus Information System (BIS), it cannot accommodate all of the DSRC application services. In particular, the Cooperative Vehicle and Highway System (CVHS) of the DSRC application services is suitable for express highways. In order to provide medium and long distance services such as CVHS, a communication distance of 300 m is minimally required in Continuous Air interface for Long and Medium distance(CALM), which is our motivation for expanding the communication distance of the existing standard DSRC to 300 m. In addition, in order to provide the DSRC service on a road outside the existing communication range of RSE, it is necessary to install fixed relays. This section examines the parameters that are required to be applied to the DSRC system based on a fixed relay.

## 1. Output Power of the DSRC System

The output power of the existing standard DSRC system is the Equivalent Isotropically Radiated Power (EIRP) as specified in the DSRC standards: in the case of Class 1 (i.e., within 10 m), power impressed on the antenna is less than 10 dBm, antenna gain is 22 dBi, and EIRP is less than 32 dBm; and in the case of Class 2 (i.e., within 100 m), power impressed on the antenna is less than 15 dBm, antenna gain is 11 dBi, and EIRP is less than 26 dBm [6].

Since the communication radius for the output of the standard DSRC system is 100 m, only a limited number of services are possible. Therefore, the U.S. DSRC standards instituted by the American Society of Testing and Materials (ASTM) set the maximum output power as follows [7]. Table 1 below shows that the maximum output power of a device is classified according to device class and <Table 2> below shows that the maximum range is classified according to the maximum transmitter power.

By compounding Classes A, B, C, and D in <Table 1>

<Table 1> The maximum output power of a device

| Device Class | Maximum Device Output Power |
|---|---|
| A | 0 dBm |
| B | 10 dBm |
| C | 20 dBm |
| D | 28.8 dBm |

<Table 2> The maximum range according to transmitter power

| Class | Maximum Transmitter Power | Maximum Range |
|---|---|---|
| 1 | 10 dBm EIRP | Up to15 m |
| 2 | 20 dBm EIRP | Up to 100 m |
| 3 | 33 dBm EIRP | Up to 400 m |
| 4 | 44.8 dBm EIRP | Up to 1000 m |

and Classes 1, 2, 3, and 4 in <Table 2>, adequate communication areas are secured. Based on the tables above, the proposed system adjusts the maximum power defined in the South Korea RF-DSRC standards to expand the communication distance up to 300 m. When a power of Device Class C with 20 dBm and an antenna with an antenna gain of 10 dBi is used, EIRP becomes 30 dBm and electric waves can be transmitted up to 300 m.

## 2. Standoff Distance between Roadside Equipment

Standoff distance is needed between Roadside Equipments (RSEs) because RSEs using the 5.8 GHz band, which is allocated for the ITS services, generate co-channel interference [8]. If RSEs are installed densely without cell planning, the bit error rate (BER) increases due to either channel interference or output imbalance between RSE and OBE, causing performance degradation. Another problem associated with increased BER is that unwanted communications occur because of the characteristics of electric waves (e.g., multi-path fading).

To avoid the aforementioned problems, the proposed system uses the cell planning method which has been used in building the ITS system of Korea. The standoff distance for the cell planning, denoted by D, is expressed below in Equation 1 as

$$D = 4 \times R \quad (1)$$

where R is the communication radius of RSE.

Since the communication radius of the proposed system is 300 m, the distance between RSEs should be 4 × 300 = 1,200 m.

## 3. Output Power of a Fixed Relay

The output power of a fixed relay follows the output power design procedure of the relay station used in a cellular system. The output power design in a cellular system involves the following procedure: first, provided that there is a line of sight between a base station and a fixed relay, path loss from output power of a base station to a relay station is calculated to obtain link budget. Then, a relay station gain is set according to the communication radius covered by a relay station.

If the fixed relay covers an entire road outside the existing communication region of RSEs within the standoff distance of 1,200 m, it has to have a communication distance of 200 m at the 450 and 750-meter points. The design parameters should be set as shown in <Table 3> below.

RSE output power is 30 dBm and path loss between RSE and a relay is 104 dBm, so the reception level of the signals received at the relay is 30-104= -74 dBm. This becomes 66 dBm when reception antenna gain is added, and EIRP becomes 26 dBm in consideration of power to cover 200 m. Thus, after subtracting 8 dBi of the antenna gain from 26 dBm of output power, 18 dBm becomes power impressed on the relay and relay gain is 66 + 18 = 84 dBm.

<Table 3> Design parameter of a fixed relay

| RSE Character | |
|---|---|
| RSE Output (dBm) | 20 |
| Antenna Gain (dBi) | 10 |
| RSE EIRP (dBm) | 30 |
| Relay Character | |
| Path Loss between RSE and Relay (dB) | 104 |
| Reception Level of Donor Antenna (dBm) | -74 |
| Donor Antenna Gain (dBi) | 8 |
| Relay Input (dBm) | -66 |
| Relay Gain (dB) | 84 |
| Relay Output (dBm) | 18 |
| Relay Antenna Gain (dBi) | 8 |
| Relay EIRP (dBm) | 26 |

# Ⅲ. Simulation Result

## 1. Simulation Model

The simulation model compares and analyzes the system including only RSEs in <Fig. 1> and the system including RSEs and fixed relays in <Fig. 2> For simulations, first, RSEs are set apart by a standoff distance of 1,200 m. Then, in order to dissolve the shadow area between them, a system is simulated using an additional RSE at a point 600 m from the

base station, and the other system is simulated using two fixed relays at 450-meter and 750-meter points. Each system calculates a carrier to interference and noise ratio (CINR) value, and the communication channel status can be determined according to this value.

Equations 2 and 3 needed to calculate CINR values for each location are shown below. Equation 2 is for the path loss. The path loss in the free space can be expressed as

$$P_{LOSS} = 32.44 + 20\log_{10}(f_c) + 20\log_{10}(d) \quad (2)$$

where $f_c$ is a carrier frequency in units of MHz, $d$ indicates the distance between a vehicle and a RSE or a relay, in units of km [9].

Equation 3 below is used to calculate CINR

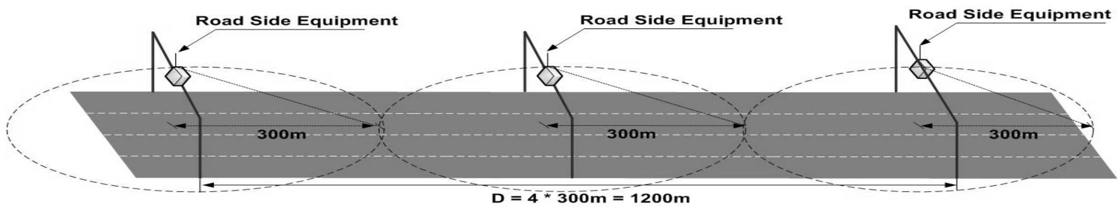
$$CINR = \frac{P_S}{N + \sum I_{other\ RSE}} \quad (3)$$

where $P_S$ is the received power when signals sent from a designated RSE or relay reach a vehicle, $N$ is noise power, and $I_{ohter RSE}$ is the received power reaching a vehicle from other RSEs in the form of interference.

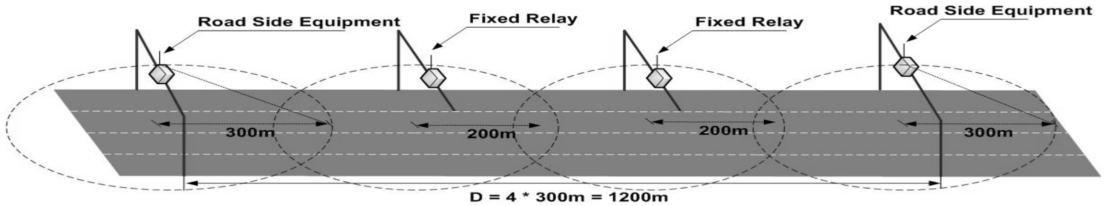
## 2. Simulation Results and Analysis

The system with RSEs only and the system with RSEs and fixed relays are compared and analyzed based on the parameters explained above in order to examine which system can best dissolve a shadow area and to analyze the change of channel conditions by RSE locations so as to determine RSE installation locations.

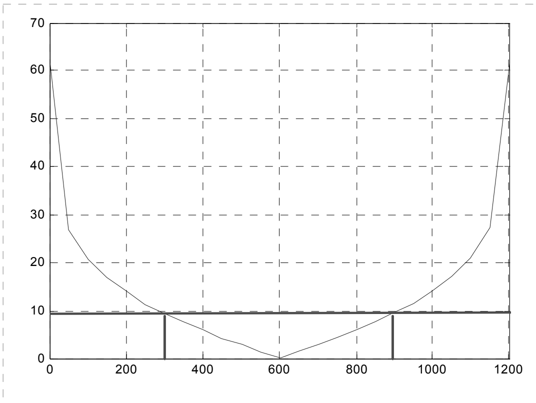
<Fig. 3> shows a case when nothing exists between two RSEs set apart four times the communication



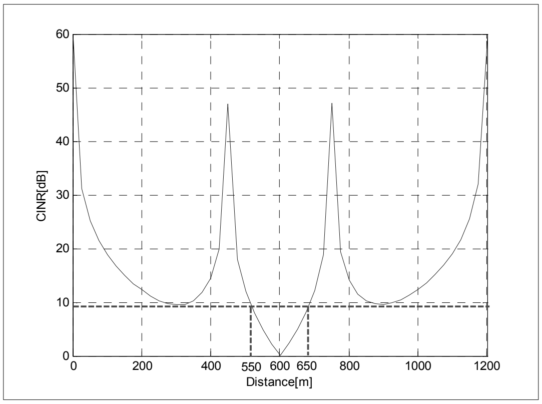

<Fig. 1> System including only RSEs




<Fig. 2> System including RSEs and fixed relays



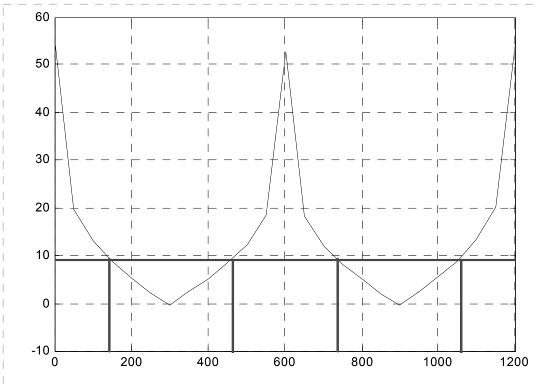

<Fig. 3> Nothing between RSEs




<Fig. 5> Using two fixed relays between RSEs

radius of the RSEs. A CINR value at any point less than the CINR value at a point with the minimum threshold value of incident power, corresponds to an area where communication is impossible. The CINR value at a point with the minimum threshold value incident power is 9.5 dB. Thus, locations with this value or higher are considered as areas where communication is possible, and the shadow area excluding the areas where communication is possible between two RSEs is 600 m long.

In <Fig. 4>, a RSE is added between two RSEs. The additionally installed RSE seems to solve the shadow areas shown in Fig. 3, but when analyzing the area with a value of 9.5 dB or less where




<Fig. 4> RSE added between other RSEs

communication is impossible, the 600-meter shadow area is found, which is similar to the case where nothing exists between two RSEs because of the effect of co-channel interference.

When fixed relay is not used, the total of 600 m shadow area is formed between 300m and 900 m. <Fig. 5> shows a case in which shadow area is formed only in the 100 m area between 550 m and 650 m points, when two fixed relays are used at 450 m and 750 m points, respectively.

The costs of the system consisting of fixed relays and the system consisting of RSEs only should be reviewed. According to RSE cost data received from Daejeon city in Korea and fixed relay cost data received from a mobile company, the installation costs of the two systems are shown in <Table 4> and <Table 5> below.

<Table 4> Installation cost of RSE

| | | |
|---|---|---|
| RSE / 1EA | US$2,500 | US$2,593 |
| Maintenance / 1EA | US$75 | |
| IP rent | US$18 | |

<Table 5> Installation cost of a fixed relay

| | | |
|---|---|---|
| Fixed Relay / 1EA | US$800 | US$824 |
| Maintenance / 1EA | US$24 | |

The installation cost per unit sector is US$7,779 for the system using fixed relays, while the installation cost per unit sector for the other system is US$6,834. The farther the distance is expanded, the more economical the installation cost is.

## Ⅳ. Conclusions

In this paper, a DSRC system using a fixed relay has been proposed to dissolve shadow areas on express highways. The proposed system extends the communication radius of the standard DSRC from 10 m or 100 m to 300m by adjusting output power, and covers the shadow area between RSEs set apart four times the communication radius of the RSEs by using fixed relays.

The simulation results show that the proposed system using fixed relays is better than the system composed of RSEs only, because it can dissolve more shadow areas. Additionally, how channel conditions change by RSE location is examined, and it is recognized that it is more effective to install the RSE in the middle of the road.

In addition to the currently operated ETCS, BIS, and ATIS, the application of the proposed system enables various services as well as highway CVHS. The application of this CVHS secures safety as information on the state of traffic accidents or road conditions can be received from RSEs.

In order to guarantee better safety on highways, more research is needed not only about dedicated short-range communication but also about dedicated medium- and long-range communication. Also, more efforts should be made to make communication between vehicles available.

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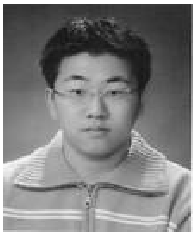

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