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Analysis of Radio Propagation at Intersection Considering Car Antenna Positions for Inter-vehicle Communications

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Abstract—In the development of the inter-vehicle communication systems for the prevention of car crashes, it is important to know the radio propagation characteristics at blind intersections. In experiments and numerical simulations of the radio propagation, a half wavelength dipole antenna is assumed to be the wave source in many cases. However, the directivity of car antenna is changed by the effect of car body. Additionally, the directivity of car antenna is also changed by the effect of antenna position on car body. Therefore, it seems necessary to investigate radio propagation characteristics considering car antenna positions. In this paper, the effect of car antenna positions on propagation loss at different receiving height in a blind intersection for inter-vehicle communications is investigated. Here, the hybrid method using both the FDTD and ray-tracing methods is used for the radio propagation analysis.

Index Terms—inter-vehicle communication, intersection, car antenna position, radio wave propagation, 760MHz.

I. INTRODUCTION

Recently, the inter-vehicle communication systems for the prevention of car crashes have been proposed [1]. Car accidents at blind intersections can be prevented by sending and receiving the information like the location and speed of vehicle by these systems. In the development of the inter-vehicle communication systems, it is important to know characteristics of radio wave propagation at blind intersections. The experiment and numerical simulation have been performed to investigate the radio propagation characteristics at intersections. A half wavelength dipole antenna is assumed to be the wave source in many cases. However, the directivity of car antenna is changed by the effect of car body [2]. Additionally, the directivity of car antenna is also changed by the effect of antenna position on car body. Therefore, it seems necessary to investigate the effect of car antenna positions on radio propagation characteristics [3]-[7].

In [3]-[7], the effect of car antenna positions on the radio propagation characteristics for 5 GHz band has been investigated. However, 700 MHz band is used for the inter-vehicle communications in Japan [1]. Therefore, we have investigated the effect of car antenna positions for 700 MHz band [8], [9]. As a result, it was shown that the radio propagation characteristics change by the effect of antenna positions on car body. However, the effect of car antenna positions on propagation loss at different receiving height in a blind intersection is not well known.

In this paper, the effect of car antenna positions on propagation loss at different receiving height in a blind intersection for 760MHz inter-vehicle communications is investigated. Additionally, the effect of distance from intersection to car on propagation loss at the intersection is also investigated. Here, the hybrid method using both the finite-difference time-domain (FDTD) and ray-tracing methods is used for the radio propagation analysis [9], [10].

II. INTERSECTION AND CAR MODEL

Fig. 1 shows an intersection in urban area used in this simulation. In this paper, a width of road is set to 6 m as an example. A height of building is approximated by infinity.
because the effect of diffraction waves over buildings seems vanishingly small for the inter-vehicle communications. It is assumed that the road and building consist of asphalt and concrete, respectively. These electric constant are shown in Table I [11], [12].

A propagation loss on TCQ path is calculated in this simulation. The transmitter is located at the point T. The transmitting antenna is mounted on car body. In this study, a small sedan type that is typically used in Japan is selected as an example. Antenna positions on car body are shown in Fig. 2. The $\lambda/4$ vertical monopole antenna is used at mounting positions of rooftop center and rooftop rear. The $\lambda/2$ vertical dipole antenna is used at mounting positions of right door mirror, left door mirror and front bumper. In the receiving point on TCQ path, a car body is not considered in this simulation. The receiving height is shown in Fig. 3.

A transmit frequency is 760MHz. The S shows the distance from intersection to car. In this paper, the cases of S = 20 and 30 m are considered. These distance are corresponds to the brake stopping distance of car for about 40 km/h and 50 km/h, respectively.

III. ANALYSIS METHOD

Fig. 4 shows a procedure of hybrid method using both the FDTD and ray-tracing methods for the electromagnetic analysis. In this method, 1) the electromagnetic analysis for car antenna mounted on a car is performed by using the FDTD method. 2) the directivity is calculated by using the FDTD results and the equivalence theorem. 3) the propagation loss on TCQ path is calculated by using the ray-tracing method with the directivity obtained by 2). Table II shows simulation conditions used in this work. Here, in the ray-tracing analysis, a transmitted wave is not considered.

IV. NUMERICAL RESULTS

Fig. 5 shows the directivity of car antenna in the case of front bumper as an example. As shown in this figure, it seems that the directivity is strong in the front side of car.

| TABLE I. ELECTRIC CONSTANT USED IN THIS SIMULATION. |
|-------|-------|-------|
| road (dry asphalt) | $\varepsilon_r$ | 4.9 |
| | $\sigma$ | 0.00761 S/m |
| building (concrete) | $\varepsilon_r$ | 7.0 |
| | $\sigma$ | 0.0473 S/m |

Fig. 3. Receiving height used in this simulation.

Figs. 6 and 7 show the propagation loss at a blind intersection for different receiving height in cases of S = 20m and 30m, respectively. Here, in this paper, the case of front bumper is shown as an example. The $|E_z|$ component is denoted because the vertical polarization is used for the inter-vehicle communications in Japan.

In the case of S = 20 m, it is shown that the propagation loss for h = 1.5 m decreases compared with the case of h = 0.405 m in the non line of sight region. On the other hand, in the case of S = 30 m, the propagation loss for h = 1.5 m denotes the same tendency of that for h = 0.405 m. In the both cases, it is seen that the propagation loss fluctuates at the around of point C. This reason seems to be related to scattered waves at corners of buildings.

V. CONCLUSION

In this paper, the effect of car antenna positions on propagation loss at different receiving height in a blind intersection for 760MHz inter-vehicle communications was investigated. Additionally, the effect of distance from intersection to car on propagation loss in the intersection was also investigated. As a result, in this simulation, it was shown that the propagation loss for different receiving height is changed by the distance from intersection to car for the case of front bumper.

In the near future, the mechanism of radio propagation obtained by this simulation will be investigated in detail. And cases of different antenna positions will be investigated.
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