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Simplified Prediction of Propagation Loss over Non Line-of-Sight Intersections in V2V

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Abstract **– A simplified prediction scheme of averaged propagation loss over an NLOS intersection in V2V is proposed. In the scheme, the propagation loss is calculated by accounting only the dominant paths in the ray-tracing calculation. In this paper, the calculation method is presented and its accuracy is evaluated by comparing the predicted results with those by the ray-tracing method. As the result, we show the proposed method effectively estimates the propagation loss close to that by the ray-tracing.**

Index Terms **— Propagation loss, Ray-tracing, ITS, V2V**

I. Introduction

Research and development on ITS (Intelligent Transport System) has actively been advanced aiming at reduction of traffic accidents. Particularly, attentions are paid to V2V (Vehicle to vehicle communications) to achieve the support of safety driving [1]. In Japan, the DSRC band at the 5.8GHz has primarily been used for ITS and the development of V2V using the band have been studied [2]. On the other hand, 700MHz band was allocated to ITS to realize a wider and stable service area particularly in Non Line-of-Sight (NLOS) situations. To design a reliable service area of V2V, study of propagation characteristics is indispensable. The ray-tracing method is often used for the prediction of the propagation loss in various wireless systems. But the calculation load of the ray-tracing is generally heavy and it takes a long time to complete the calculation. In this paper, we therefore consider a simplified prediction method of the propagation loss over an NLOS intersection in V2V environments. We present the theory of the simplification used in the method and evaluate the prediction accuracy in comparison with the ray-tracing. In the evaluation, the carrier frequency at 720MHz and 5.8GHz is assumed.

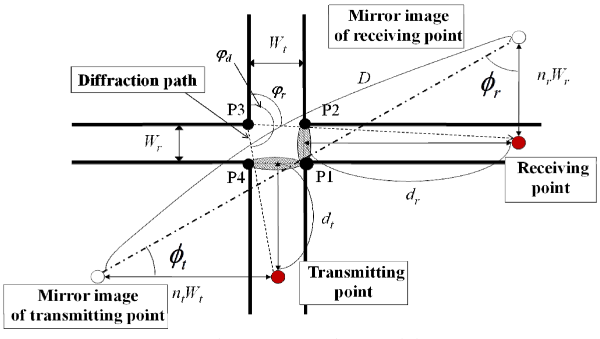


Fig. 1 Intersection model.

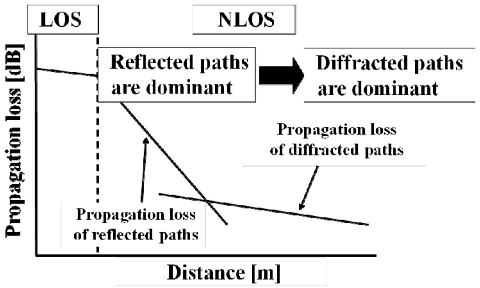


Fig. 2 Propagation loss characteristics in NLOS environments.

II. Simplified Prediction Method

The intersection model assumed in this paper is shown in Fig. 1. It is considerably a simple model where the lengths of the buildings are semi-infinite and the surfaces are perfectly flat. In this analysis, we assume a two-dimensional space.

Figure 2 shows the general characteristics of the variation of the propagation loss in NLOS situations [3]. In NLOS, the reflected paths are dominant near the intersection and, in contrast, the diffracted paths become dominant in the far area from the intersection. In this paper, we define “reflected path” as a propagation path experiencing only reflection by buildings’ surface. We also express “diffracted path” as a path experiencing both reflection and diffraction. The diffraction is made by the buildings’ edge at the intersection. As shown in Fig. 2, the propagation loss in the NLOS situation can be presented by two lines of the reflected and diffracted paths. Considering the characteristics, our method of the simplified estimation of the propagation loss is to estimate the two losses separately and merge them in the received power domain. This approach is generally found in path loss prediction formula for V2V and street canyon environments [4].

The followings are the description of the simplified prediction method. For simplicity of the model development, we assume the transmitting and receiving points are on the center of the roads.

Reflected paths: Considering multiple reflections in each road, the propagation paths can be expressed by connecting the mirror images of the transmitting and receiving points as shown in Fig. 1. We assume the strongest reflected path is given when the reflection count by the walls is the smallest and the propagation loss of the total reflected paths is approximately represented by some of the strong paths among all possible reflected paths. Considering the above assumption, we calculate the propagation loss of the reflected paths by the sum of the following three paths. (1) the strongest path, (2) the two paths where the reflection is one count larger than that of (1) in the roads of the transmitter and the receiver. Based on the above assumptions, the propagation loss of the reflected paths, L_R [dB], is given by the following expression:

$$L_R = 20\log\left(\frac{4\pi}{\lambda}\right) - 10\log\left[\left(\frac{R(\phi_t)^n R(\phi_r)^n}{D_0}\right)^2 + \left(\frac{(R(\phi_{t+}))^{n+}(R(\phi_{r-}))^{n-}}{D_{t+}}\right)^2 + \left(\frac{(R(\phi_{r+}))^{n+}(R(\phi_{t-}))^{n-}}{D_{r+}}\right)^2\right] \quad (1)$$

$$n = A - 1/2,\ \ n^+ = A + 1/2,\ \ n^- = A^2/(A+1) - 1/2\ \ \left(A = \sqrt{d_t d_r / W_t W_r}\right)$$

$$\phi_{(t,r)+} = \arctan\left(\frac{d_{(t,r)}}{(A+1)W_{(t,r)}}\right),\ \ \phi_{(r,t)-} = \pi/2 - \phi_{(t,r)+}$$

$$D_0 = \sqrt{(AW_t + d_r)^2 + (AW_r + d_t)^2},\ \ D_{(t,r)+} = \sqrt{((A+1)W_{(t,r)} + d_{(r,t)})^2 + \left(\frac{A^2}{A+1}W_{(r,t)} + d_{(t,r)}\right)^2}$$

$R(\theta)$ represents a reflection coefficient when the incoming angle to the wall is θ.

Diffracted paths: For the diffracted paths, there are four possible cases of the diffraction edge at the corner P1-P4 as shown in Fig. 1. From ray-tracing analysis assuming various intersection environments, we found the diffracted paths at P3 are dominant and become close to the total at the large distance area where the diffracted paths become dominant as indicated in Fig. 2. So we focus only on the diffracted paths at the edge P3. The strongest path diffracted at the edge is the path experiencing only diffraction without any reflections by the walls of the roads.

As mentioned before, the diffracted path is dominant in the far area from the intersection. Therefore by assuming d_t and d_r in Fig. 1 are large enough, we can well approximate the incident and diffracted angles of the path at the edge P3 as $\varphi_d=\pi$, $\varphi_r=\pi/2$. In this case, the diffraction coefficient C_d is approximately given as $C_d=19\sqrt{3\lambda}/60\pi$ by UTD (Uniform Theory of Diffraction) calculation where λ is the wavelength.

Adding the diffraction loss to the distance loss which can easily be determined by the geometrical parameters, the propagation loss of the strongest diffracted path is estimated. However only by the strongest diffracted path we could not obtain sufficient prediction accuracy. So we consider more number of the diffracted paths. Here the reflections before and after the diffraction at the edge P3 are taken into account. We consider the additional reflection counts up to 4. In the case, the propagation loss of the diffracted paths, L_D [dB], is shown below.

$$L_D = 20\log\left(\frac{4\pi}{\lambda}\right) + 20\log\left(\frac{60\pi}{19\sqrt{3\lambda}}\right) - 10\log\left(\sum_{n_t=0}^{4}\left(\sum_{n_r=0}^{4-n_t}\frac{\left(R^{n_t}(\theta_{n_t})R^{n_r}(\theta_{n_r})\right)^2}{s_{1,n_t}s_{2,n_r}(s_{1,n_t}+s_{2,n_r})}\right)\right) \quad (2)$$

$$s_{1,n_t} = \sqrt{((n_t+1/2)W_t)^2 + (W_r + d_t)^2},\ \ s_{2,n_r} = \sqrt{((n_r+1/2)W_r)^2 + (W_t + d_r)^2}$$

$$\theta_{n_t} = \arctan\left(\frac{W_r/2 + d_t}{(n_t+1/2)W_t}\right),\ \ \theta_{n_r} = \arctan\left(\frac{W_t/2 + d_r}{(n_r+1/2)W_r}\right)$$

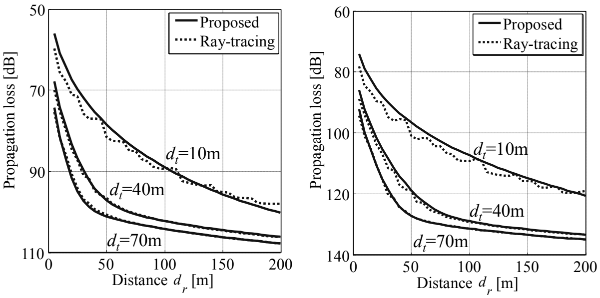
The overall propagation loss including both reflected and diffracted paths, L [dB], is presented by combining formulae (1) and (2) in the received power domain as:

$$L = -10\log\left(10^{-L_R/10} + 10^{-L_D/10}\right) \quad (3)$$

We evaluate the accuracy of proposed method. The assumed parameters are shown in Table 1. The predicted propagation loss is compared with that by the ray-tracing in Fig. 3. Note that, in the ray-tracing, the sum of multiple rays is calculated in the power domain in order to obtain the average propagation loss excluding the fading effect. The figure shows that the proposed scheme realizes good agreement with the ray-tracing. Considering the simplicity of the proposed method in comparison with the ray-tracing, the proposed scheme is useful to predict the propagation loss at an NLOS intersection in V2V environments.

Table 1 Calculation parameters.

Frequency	720MHz, 5.815GHz
Polarization	Vertical
W_t	8m
W_r	16m
Maximum reflection count	30
Maximum diffraction count	1
Material of walls	Concrete



(a)720MHz (b)5.815GHz

Fig. 3 Comparison of proposed scheme with ray-tracing.

III. CONCLUSION

We proposed a method by which the average propagation loss over an NLOS intersection in V2V can be simply estimated. The reflected and diffracted paths are approximated by accounting only the dominant paths. Comparing with ray-tracing, we show the proposed method provides the close estimation of the propagation loss to that by the ray-tracing.

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