POS1-19

An Analysis of Propagation Loss Characteristics for Inter-Vehicle Communications in Non Line-of-Sight Intersections Using Ray-Tracing Technique

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1. Introduction

Research and development on ITS (Intelligent Transport System) have actively been advanced aiming at reduction of traffic accidents. Especially, great attentions are paid to inter-vehicle communications (Vehicle to vehicle communications : V2V) to achieve the support of safety driving. In Japan, the DSRC band at 5.8GHz has primarily been used for wireless communications of ITS and the development of V2V using the band have been studied [1-3]. On the other hand, a new idea on the frequency for ITS applications has been considered to cover wider area using relatively lower frequency band. In order to study the feasibility of V2V in such new frequency band in various environments, the study of the propagation characteristics is indispensable. In this paper, by modelling the buildings and intersections by a relatively simple configuration, we study the propagation characteristics in V2V assuming non line-of-sight intersections using the ray-tracing technique [4,5]. The main focus of the study is to obtain the general dependency of the propagation characteristics on various system and environmental parameters such as carrier frequency, road width, materials of surrounding buildings, etc. Among various propagation characteristics, we investigate propagation loss characteristics because it is the most essential property in general wireless communications. As the carrier frequency, 5.8GHz band is mainly assumed while the propagation characteristics in the other frequency bands are also evaluated and the frequency characteristics of the propagation loss are clearly presented.

2. Intersection Model

We assume a relatively simple intersection model shown in Fig. 1 for the evaluation of the propagation loss characteristics. The surface of the buildings is perfectly flat and the length and the height of the buildings are assumed semi-infinite. The widths of the roads are expressed by W1 and W2 and the propagation characteristics are evaluated when these values are changed. The both antenna heights are set at 1.5m from the ground level assuming a V2V environment. The parameters used in the ray-tracing calculations are listed in Table 1. The material constants of the buildings are also presented in Table 2. In the calculation of the propagation characteristics, the average propagation loss is estimated using the following formula :

$$P = \sum_i | E_i |^2$$

where P is the average received power and E_i is the amplitude of the i-th traced path. The calculation method of the above equation is based on the assumption that each component of the multipath waves are independently fluctuating.

In the following chapters, the average propagation loss are shown when the transmitter distance is varied from 5m to 85m and the receiver distance is from 0m to 200m.

3. Evaluation Results

3.1 Propagation characteristics when building materials and road widths are changed

Assuming the material constants and the road widths in urban and suburban areas presented in Table 3, the propagation loss characteristics are calculated. The results are shown in Fig. 2. The

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characteristics are roughly divided into two propagation conditions : (i) at least one of the two vehicles are in the neighbourhood area of the intersection, and (ii) both vehicles are far from the intersection. In the area (i), the dominant paths between the two vehicles are multi-reflected waves by walls, while, in (ii) the paths are composed mainly by diffracted waves. When the both transmitter and the receiver are located far from the intersection, the reflected paths have to experience many reflections and long travelling distance. As the results, the attenuation of the reflected paths becomes great and the dominant mode of the propagation is by the diffracted paths. On the dependence on the road width, the loss becomes large when the width is narrower. It is explained as the reflection count and the travelling distance of the reflected paths become larger when the road is narrower. It is conceptually shown in Fig. 3. When the characteristics are examined by the viewpoint of the materials of the buildings, it can be seen from the figure that the propagation loss of the urban area is smaller than that of the suburban. It is because, when the materials of the buildings are concrete, the magnitude of both reflection and the diffraction coefficients are larger than those of wooden materials. Moreover, it is seen that the inflection points of the curves depend on the materials. It indicates that the dominant mode (reflection or diffraction) depends on the materials.

3.2 Frequency characteristics

Figure 4 shows the propagation loss characteristics when the carrier frequency is changed as 200MHz, 740MHz, 2.45GHz and 5.815GHz. From the figure, it is seen that the frequency characteristics are relatively small when either transmitter or receiver are in the intersection neighbourhood while they become larger when the both are far from the intersection. Figure 5 summarizes the difference of the propagation loss between 740MHz and 5.815GHz to show the characteristics more clearly. The difference of the free space propagation loss at the two frequencies is also shown in the figure for the comparison. It should be noted from the figure that, when either is in the intersection neighbourhood, the characteristics are close to that of free space propagation. On the other hand, when the both are far from the intersection, it is understood from the figure that there is more propagation loss difference than that generated by the frequency difference. The frequency characteristics of the diffraction coefficients are significant while those of the reflection coefficients are negligible between 740MHz and 5.815GHz [6], therefore the additional frequency characteristics to those of the free space path loss (square-law characteristics) exist in the region where the diffracted paths are dominant mode of the propagation channel.

As the results of the frequency characteristics, if we assume the frequency band used in V2V is changed from the higher frequency such as 5.8GHz band to the lower frequency as 700MHz band, the reduction of propagation loss more than the effect of the frequency characteristics of the free space path loss will be expected. Moreover, because the reduction effect occurs particularly in the non line-of-sight and remote area, which is usually the edge of the coverage of V2V, the service area extension effect brought by the frequency shift from the higher to the lower is remarkable.

4. Evaluation of simplified model

In this paper, we evaluate propagation characteristics in V2V environments using considerably simple intersection model. In order to examine the validity of the simple model, the following three cases are considered here :

- Finite building height case
- When a space like a passage exists on the building surfaces along the road (Case (a), Fig. 6)
- When transparent waves through the building blocks exit (Case (b), Fig. 7)

The propagation loss characteristics assuming the above models are compared with those by the reference model shown in Fig. 1. The results of the finite building height case is not presented here due to the space limitation of the paper, but, from the results of the simulation of the finite height case, it is made clear that the received power of the propagation paths experiencing the diffraction at the edge of the building top is at least 30dB below the received power of the reference model. Therefore we conclude that the effect of the finite building height can be negligible.

4.1 Case (a) : Effect of space on building surface

In order to evaluate the situation where a space like a passage exists on the building surfaces, we assume the intersection model shown in Fig. 6. In the model, because we focus on the evaluation of the effect of the space, we assume there exist no passing waves through the building block. The comparison with the reference model is presented in Fig. 8. It can be seen from the figure that, in any positions of the transmitter and the receiver, the difference from the reference model is negligibly small. The number of the reflected paths becomes smaller because of the less reflection area while the number of the diffracted grows due to the more building edges. It seems that, as the results of these effects, the resultant propagation loss remains almost the same.

4.2 Case (b) : Effect of transparent waves

The effect of the passing paths through the building blocks is studied. We assume the intersection model shown in Fig. 7. Because the number of the reflection surfaces and the diffraction edges of the model are great and it takes very long period to calculate 3-dimensional ray-tracing, we adopt 2-dimesinoal ray-tracing technique, here. The transmitter distances are set at 47.5m and 60.0m where the inside of the block is line-of-sight and non line-of-sight conditions through the entrance of the small passages, respectively. The evaluation results are shown in Fig. 9. From the figure we see that the transparent paths exist and, around the exits of the transparent paths at the other side of the building blocks, emissions of the radio wave are found. However, the amount of the emissions is not significant in comparison with the results by the reference model. Therefore we can conclude that the effect of the transparent paths is not so great and the results evaluated by the simple reference model are valid.

5. Summary

Propagation loss characteristics in the V2V environments are evaluated using ray-tracing technique. In the calculations, various system and environmental parameters are changed to obtain the general characteristics of the V2V. Although all of the results are not shown in the paper due to the limitation of the space, we presented the following characteristics of V2V in the paper.

As the general property of the propagation characteristics, the propagation mode is roughly classified into two regions : (i) reflection is dominant where either transmitter or receiver is in the intersection neighbourhood and (ii) diffraction is dominant where the both stations are remote from the intersection. Also in the area where the both stations are far from the intersection, the propagation loss has more frequency dependency than that of the free space path loss because of the significant frequency characteristics of the diffracted paths. Also we show that the non-line of sight propagation characteristics over intersections can be analyzed by a considerably simple model.

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References

[1] S. Kato, et.al., IEICE Technical Report, ITS2005-5, 2005.
[2] K. Seki, IPSJ 19th meeting of ITS Special Interest Group, 11, 2004.
[3] K. Sugai, et.al., IEICE Communications Society Conference, A-17-10, 2006.
[4] T. Imai, et.al., Proc. AP-S'97, pp.2572-2575.
[5] R. J. Luebbers, IEEE Trans. Antennas Propagt., AP-32, 1, 1984.
[6] S. Kawai, et.al., IEICE Technical Report, AP2005-163, 2006.

Table1. Reference parameters.

Frequency	5.815GHz	Polarization	Vertical polarization
Building material	Concrete	Antenna height	1.5m
W1	8m	W2	16m
Maximum number of reflection	5 times	Maximum number of diffraction	2 times

Table2. Material constants.

	Relative permittivity	Electric conductivity
Concrete	7.0	0.0023S/m
Architecture in wood	2.0	0.029S/m
Earth	3.0	0.0001S/m

Table 3. Materials and road widths.

Name	Material	W1	W2
Urban 1	Concrete	8m	16m
Urban 2		16m	16m
Suburban 1	Architecture in wood	8m	16m
Suburban 2		8m	8m

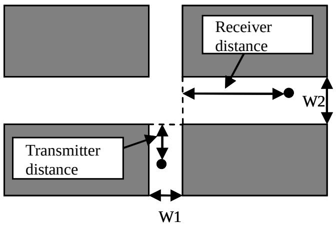
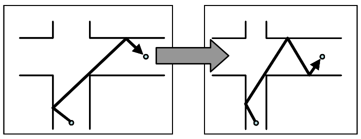


Fig1. Intersection model (reference model).



(a) Wide road (b) Narrow road

Fig3. Reflected paths in non line-of-sight condition.

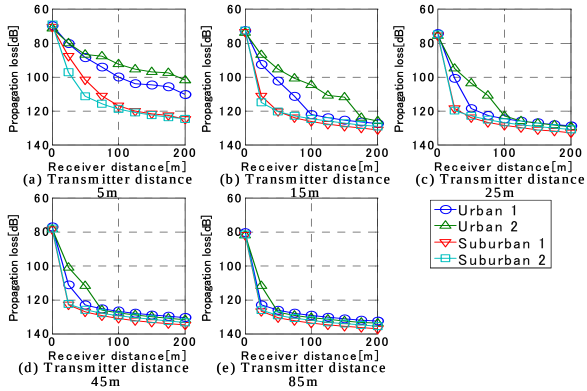


Fig2. Propagation loss when materials and road widths are varied.

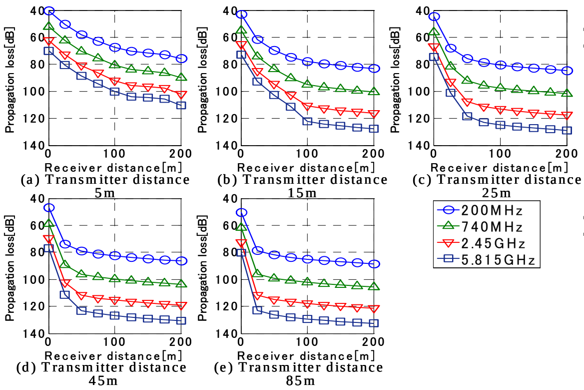


Fig.4 Frequency characteristics of propagation loss.

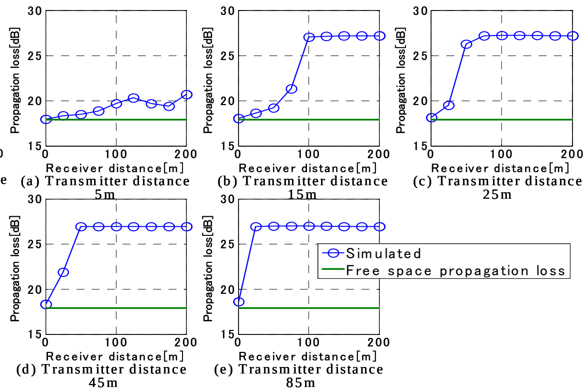


Fig.5 Difference of propagation loss between 740MHz and 5.815GHz.

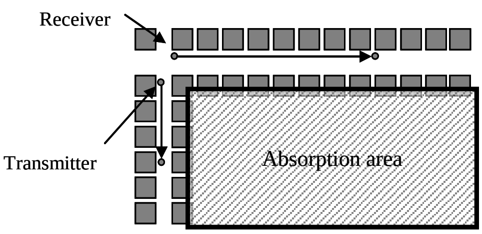


Fig.6 Case (a).

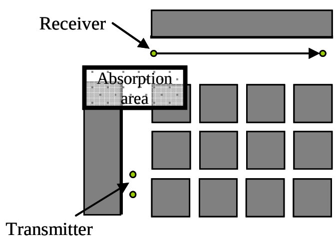


Fig.7 Case (b).

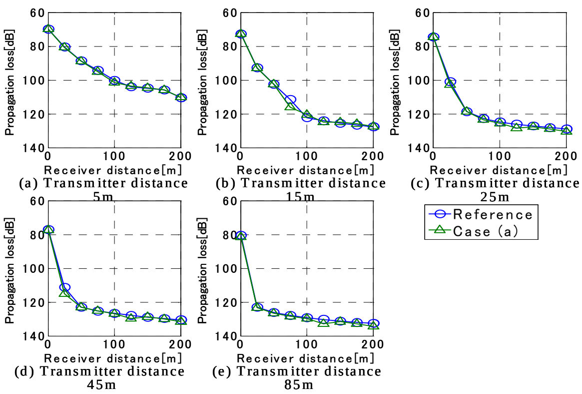


Fig.8 Propagation loss in Case (a).

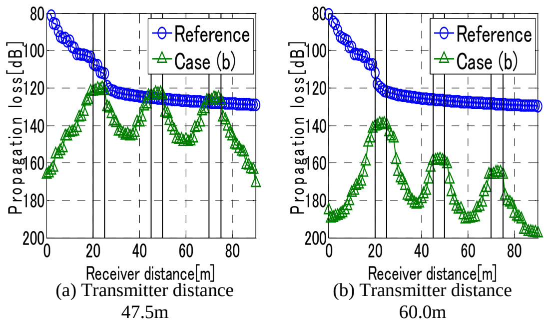


Fig.9 Propagation loss in Case (b).