On the Ray Tracing Simulation for NLOS Macrocellular Environment

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1 Introduction

This research focuses on evaluation of Vertical Plane Tracing model and application of single knife-edge diffraction theory for NLOS macro-cell propagation prediction. Vertical Plane Tracing model differentiates itself from other models by applying a slope-diffraction model [1]. This slope-diffraction model addresses the transition zone problem existing in the UTD theory [2]. The second model is based on the diffractions at the top edges of the buildings along the streets. Single knife-edge diffraction theory is implemented with a few special additional methods for its propagation prediction. Both of these methods will be evaluated by comparing with measurement results.

2 Spatio-Temporal Channel-Measuring Approaches

Two channel measurements for Macro-cell areas were performed in Yokosuka-Kanagawa and in Kanda City of Central Tokyo. Unfortunately, during Yokosuka-Kanagawa measurements, some serious errors occurred at mobile station systems side. Then measurement results for all angle was distorted and could not be used in this research anymore. Thus, for this research, all comparisons will use the result from Kanda City of Central Tokyo measurements.

2.1 Central Tokyo Measurements [3]

Measurement was carried out at central Tokyo, near to Kanda Station. In this measurement, the array antenna was placed on the rooftop of an outstanding tall building (70 m), twice higher than height of major buildings around (20 - 25 m), and was about 600 m away from center of the mobile transmitter course. The mobile speed was 10 to 20 km/h. As it is noted in Fig. 1, in this measurement, mobile station (MS) acted as the transmitter, and base station (BS) acted as the receiver. Detail information related to the measurements are listed in Table 1.

Mobile station as the transmitter was moved along courses and receiver was fixed on the rooftop of a building. Three dimensional map of the measurement areas can be seen at Fig. 1. It is clear here that base station (Rx) was located on the rooftop of one of the highest building on that areas, whereas mobile station (Tx) was moved among lower building in an average distance about 600 m. Tx was moved along the courses, started at the start point of course 1, then continue to course 2, course 3, course 4 and finished at the end point of course 4. Rx was set on the building which has 17 floors located on the left side of Fig. 1.

Measurement results can be seen at Fig. 2. Received signal varied from -90 dBm until -70 dBm, and to make it easier, course indices are also given in the lower part of the figure. These course indices refer to the same course indices as in Fig. 1.
Figure 1: Kanda measurement map (3d view)

Figure 2: Kanda measurement results
3 Vertical-Plane Ray-Tracing Approach for Propagation Prediction in Macro-cells

The VPT model traces the waves which propagate over the building rooftops. In this kind of model, diffraction from building rooftops (horizontal edges) is the main consideration. If there is no LOS path, then this diffraction may assumed as the strongest path.

To solve the UTD problem on transition zone, VPT uses the slope diffraction method [1] which is usually neglected as a higher order of term in an asymptotic expansion, is applied. It should be noted that in transition zone diffraction, slope diffraction is of the same order as the ordinary amplitude diffraction terms [4]. The key element of slope diffraction is automatic enforcement of continuity of amplitude and slope at each point by choosing separate values for the distance parameters for amplitude and for slope diffraction.

3.1 Vertical-Plane Ray-Tracing Method

The VPT model consist of multiple absorbing screens those are obtained from building data base, by taking straight vertical plane between Tx and Rx. Each of building walls which is crossed by this vertical plane is assumed as one absorbing screen. The height of all screens is taken from each of its original building height. In VPT model, rays are launched in two dimensional vertical plane from mobile station to base station as can be seen in Fig. 3. To make it simpler, at first it is assume that both mobile station and base station are also act as absorbing screen. These two screen are marked as significants screen and it is assumed that there exists one straight line connecting both tops of these two screens. If there exist one or many other screens break this line, then the screen which is nearest to the mobile station is marked as a significant screen, and the process is repeating with base station as one significant screen, and the screen which break the line as the other significant screen. It should be noted that any screen which might interfere the Fresnel zone between two significant screens will be treated in the same manner as the screen which break the LOS path.

In the diffraction calculation, the basic UTD theory gives the following equation for the total diffracted field for a simple absorbing half plane:

\[ \tilde{E}_d = \left( \tilde{E}_i(0)D + \frac{\partial \tilde{E}(0)}{\partial n} d_s \right) A(s)e^{-jks}, \]  

where
\[ D(\alpha) = -\frac{e^{-j\pi/4}}{2\sqrt{2\pi}k \sin(\alpha/2)} F(2kL_i \sin^2(\alpha)/2) \] (2)

is the diffraction coefficient, \( L \) is a distance factor to be determined from enforcement of amplitude and slope \([1]\), \( \alpha \) is the angle above (positive) or below (negative) the shadow boundary as shown in Fig. 4, and \( A \) is the spreading factor

\[ A(s) = \sqrt{\frac{s_0}{s(s + s_0)}} \] , \hspace{1cm} (3)

where \( s \) is the total length of propagation distance from start point to the present screen, and \( s_0 \) is the propagation distance from the present screen to the next screen.

The slope diffraction coefficient \( d_s \) can be obtained from diffraction coefficient \( D \)

\[ d_s = \frac{1}{jk} \frac{\partial D}{\partial \alpha} = \frac{e^{-j\pi/4}}{\sqrt{2\pi}k} L \cos(\alpha/2)(1 - F(X)) \] . \hspace{1cm} (4)

Here, \( F(X) \) is Fresnel transition function.

4 Validation of VPT for NLOS Macro-cellular Environments

Comparison for measurement results and VPT result in Kanda is shown on Fig. 5. This figure shows that VPT results give good prediction only at some points, those are depicted by some points on course 2 and a few points on course 4. It is interesting because both courses are perpendicular to Tx-Rx line, i.e. transverse course \([5]\). But, in other courses, VPT results give large errors. To analyze this thing, many possibilities should be considered.
5 Single Edge Diffraction Approach for Propagation Prediction in Macro-cells

This section introduces another new prediction methods for macro-cell propagation. According to Fig. 5, the predicted arrival power in vertical plane is not always so strong as total power measured in the experiment. On the other hand, Ikegami et.al [5] pointed out that for the longitudinal course, where the street is parallel to the direction toward BS, the diffractions from edges at the tops of the buildings along the street are dominant. Based on the mechanism, we propose a single edge diffraction approach to consider the diffractions at the tops edges of the buildings along the streets. The reason why knife-edge diffraction methods is chosen because of its calculation simplicity.

5.1 Important steps for knife-edge diffraction application in propagation prediction

In the application of knife-edge diffraction method for propagation prediction, many important steps are needed. Visualization of these steps can be seen at Fig. 6, while the explanation of all steps are given below:

1. Find the top edges of all buildings which are visible by Tx and Rx. For simplicity, we will use term “active edge” to express Tx-Rx visible parts of edges.

2. Find center coordinate of all active edges. Consider the Fresnel zone.

3. After we get the center of the active edge (e.g. point D in Fig. 6), we consider the line connecting Rx and D as the incident ray, and the line connecting D and Tx as the diffracted ray, respectively. Then, the edge direction is modified so that the knife-edge diffraction model is applicable.

To see the difference, here we performed two different assumptions of Fresnel zone relative to the length of active edge. If length of active edge is smaller than the first Fresnel zone then it is assumed that there is no diffraction; else if length of active edge is bigger than the first Fresnel zone then it is assumed that there exists a single diffraction edge. This is assumption 1. However, for assumption 2, if length of active edge is smaller than the first Fresnel zone then it is assumed that there is no diffraction; else if length of active edge is bigger than the first Fresnel zone then it is assumed that there exist n diffraction edges, where the value of n is the integer part of the relative length of active edge with respect to the first Fresnel zone.

Figure 7 shows the proposed prediction result for the NLOS macro-cell areas. It can be seen that both assumptions 1 and 2, give good result at most of areas on courses 1, 2, and 4. Although both assumptions give significant errors of larger than 10 dB for course 3. It is clear that assumption 1 gives better accuracy than assumption 2. It means that, length of the active edge, as long as it is longer than the first Fresnel zone, gives only small effect to the prediction results. Then, rounding of diffraction
Figure 6: Application of single knife-edge diffraction method to NLOS macro-cell propagation prediction

Figure 7: Prediction result of knife-edge diffraction for NLOS macro-cell areas
number for long active edge, when it is the same as 2 or bigger, is no need, at least for our areas case. As is noted above, both assumptions show significant error for course 3 which is located in an open area.

6 Conclusion

VPT approximation gives good result for areas where street are perpendicular to Tx-Rx line. Contrary, for areas where the street are parallel with Tx-Rx line, VPT approximation does not give good approximation.

New propagation prediction method based on single knife-edge diffraction methods is presented. The results show that by using the model, prediction of path loss in NLOS macro-cell areas can be done with small errors for some specific areas.

References


