1 Introduction

Spectrum sharing remains one of the most important goals for wireless communication systems. Exclusive use of spectrum has been a long-standing principle; it forces different systems or operators to use appropriate spectrum masks to avoid imposing harmful interference on each other. To decide the mask, an accurate prediction model of path loss is required.

A lot of channel models have been proposed and roughly speaking, there are two categories. One covers the models such as Cost 231-hata [1] and Recommendation ITU-R M.1225 [2], which are appropriate for evaluating the capacities of wireless communication systems [3]. The other covers those proposed for evaluating inter-system interference [4, 5]. The former predict average path loss under a given environment; typical parameters include distance between transmitter and receiver, antenna heights, center frequency, and surrounding building heights. These models are not suitable for inter-system interference studies since some paths in the field may have smaller loss than predicted, which results in harmful interference effects such as smaller coverage areas and lower achievable throughputs.

In this paper, we focus on the prediction model of path loss given in Recommendation ITU-R P.452 [4]. This model uses a path profile for calculating the path loss between two points. To determine path status such as LOS or NLOS and to calculate diffraction losses and some other loss components, this method utilizes a uniform ground level, and so does not consider the heights of surrounding objects such as buildings and trees. The model lumps the effect of objects around the transmitter and receiver into the term of clutter loss. Clutter loss values are calculated from clutter heights, distances to clutters, and base station (BS) heights. In Recommendation ITU-R P.452, these parameters except BS heights are specified for area types such as dense urban, urban, and suburban.

The following two points need to be investigated in detail to confirm the validity of the method.

- Clutter height for dense urban areas is 25m, but present urban areas contain many buildings much higher than 25m.
- Local fluctuations in ground height are not considered in defining clutter losses.

The ITU-R model was originally developed for studies on inter-system interference, so the losses calculated from the model should include some additional margin. However, too much margin results in inefficient use of the spectrum; it is clear that the margin should be set high enough to suppress harmful interference but as low as possible.

In this paper, we investigate the validity of the clutter-loss calculation specified in Recommendation ITU-R P.452 by comparing the distributions obtained using the default fixed parameters and those obtained using parameters extracted from 3D maps. As the areas to be investigated, two dense-urban areas in Tokyo and two suburban areas in Yokosuka are selected.

2 Clutter loss prediction in Recommendation ITU-R P.452

In Recommendation ITU-R P.452, clutter losses are calculated by the following equation:

\[
A_h = 10.25 \times e^{-d_i} (1 - \tanh(h/h_a - 0.625)) - 0.33
\]  

(1)
where \( d_k \) is the distance between BS and clutter [km], \( h \) [m] is the antenna height of BS, and \( h_a \) [m] is the height of the clutter. In Recommendation ITU-R P.452, \( h \) and \( h_a \) are defined according to area categories, i.e. \( h = 9 \) m and \( h_a = 25 \) m for suburban area and \( h = 25 \) m and \( h_a = 20 \) m for urban area. Equation (1) is used as is shown in this paper. Please note that this equation has been validated and accepted for Recommendation ITU-R P.452, and our intention is not to modify this relation.

3 Validation of clutter loss using 3D-maps

In our validation method, \( d_k \) and \( h_a \) are defined according to the following steps. Here, height at position \((x,y)\) is denoted as \(d(x,y)\).

**Step 1**

Ground level \(g(x,y)\) at the point of \((x,y)\) is set by steps 1.1 and 1.2 below. The ground level is used for calculating nominal BS and clutter heights.

**Step 1.1**
The map is divided into 100m×100m square blocks.

**Step 1.2**
For each block, the lowest level with \(d(x,y) > 0\) is selected as the ground level of the points in the “100m×100m square block”.

**Step 2**
The positions are searched to find where the nominal heights \(d(x,y) - g(x,y)\) meet a given condition. These positions are regarded as the points at which a BS is placed. This search is done in 20m steps on both x and y directions.

**Step 3**
For four directions on the x and y axis from each BS point selected in step 2, steps 3.1 and 3.2 are applied. Let us denote BS position as \((x_b,y_b)\).

**Step 3.1**
On each direction from a BS position, objects with 1m separation are regarded as clutter candidates and the losses of all clutter candidates are calculated. Note that the ground level used here is not the ground level at the clutter position but the level at the corresponding BS position. Thus the height of a clutter candidate at position \((x,y)\) is \(d(x,y) - g(x_b,y_b)\).

**Step 3.2**
The clutter candidate that yields the largest clutter loss on each direction path is selected as the clutter on that direction. The data of clutter loss, clutter height and BS-clutter distance are stored.

**Step 4**
For each point selected in step 2, the clutter losses with default P.452 parameters are obtained. In this case, the clutter height and BS-clutter distance are set to the default values defined in Recommendation ITU-R P.452; the only data used from the 3D maps is BS height.

**Step 5**
Make histogram using data stored in step 3.2.

4 Results and discussions

This section uses the method given in Section 3 to examine the validity of the clutter loss calculation specified in Recommendation ITU-R P.452. In this examination, we use a 3D map [6]. As the areas to be investigated, two dense-urban areas in Tokyo and two suburban areas in Yokosuka were selected.

4.1 Dense urban

It is expected that the parameters defined in ITU-R Recommendation P.452 are not suitable for some of advanced urban areas where the city structure is changing due to development, e.g. construction of tall buildings. Accordingly, we selected Tokyo as one such advanced urban area. Fig. 1 (a) shows the
distributions of clutter losses obtained from the 3D map of “Tokyo 1 (Nihonbashi)”; BS height ranged from 0 m to 100 m. Two distributions are shown in the figure: one was obtained using the default fixed parameters and the other from clutter parameters obtained by the 3D Map. The two curves in Fig. 1 (a) show similar distributions in general, but the numbers of clutters with loss of 0 dB differ significantly. The default fixed parameters yielded three times as many clutters with clutter loss = 0 dB than the parameters from the 3D Map.

To further investigate the difference, we show the distributions of clutters for BS heights of 0-19 m, 20-39 m and 40-60 m, shown in Figs. 1 (b)-(d). For “BS height=0-19 m” and “BS height=40-60 m”, the default P.452 parameters and our validation methods yield basically the same distribution. The key difference occurs at the BS heights of 20-39m.

If default fixed-parameters are used, the clutter height of 25 m is used regardless of the surrounding environment. Thus almost all clutter losses are calculated to be zero if BS height is 20-39 m because the clutter heights are around the antenna height. On the other hand, the clutter parameters extracted from the 3D map yield clutter loss values from 0 dB to 20 dB, because, according to the 3D map, many clutter heights are much higher than 25 m in the area.

Figs. 2 (a)-(d) show the distributions of clutter losses with various sets of BS heights obtained from the map of “Tokyo 2 (Kodenma-cho)”. These results match those shown in Figs 2 (a)-(d), which indicates that the above discussion is widely applicable to dense urban areas.

4.2 Suburban

As explained in a previous section, ITU-R Recommendation P. 452 does not consider the effect of fluctuation of local ground level when calculating clutter losses. We selected Yokosuka to investigate this effect since its topology exhibits large fluctuations of local ground level. Maps “Yokosuka 1 (Nagasawa)” and “Yokosuka 2 (Nobi)” were used to obtain the results shown in Figs. 3 and 4, both are categorized as “suburban” areas. The plots show the distribution of clutter losses obtained with BS heights of 0-6 m, 7-17 m, 18-35 m, and 36-72 m. They show that there are noticeable differences between the distributions obtained using P.452 default parameters and those obtained from the 3D map even for BS heights of 18-35m. Both areas are mostly residential and most houses are two story buildings i.e. there are few buildings higher than 9 m, which is the clutter height defined for suburban areas in Recommendation ITU-R P.452. Then reason for the differences is thought to be the fluctuation in ground level.
5 Conclusion

In this paper we examined the validity of the method specified in Recommendation ITU-R P.452 for calculating clutter losses. Recommendation ITU-R P.452 employs fixed values for the parameters of clutter height and BS-clutter distances in area categories such as “dense urban” and “suburban”. We used the parameters extracted from 3D maps to calculate clutter loss distributions which were then compared to the distributions obtained by using the default (fixed) parameters.

The results for two “dense urban” areas revealed that the parameter values defined in Recommendation ITU-R P.452 yields lower propagation losses in these areas. Thus it is desirable that new clutter parameters be added to the Recommendation to enable more accurate interference estimation in advanced urban areas. The results for two “suburban” areas show that local fluctuations in ground level may significantly affect the resultant clutter losses; these fluctuations are not considered in current area categories. Thus the local fluctuation in ground level should be taken into consideration by extending the clutter height to include an additional height term.

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References

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