Mobile Propagation Loss with a Low Base Station Antenna for NLOS Street Microcells in Urban Area

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Abstract

Path loss for non-line-of-sight (NLOS) propagation in urban streets with a low base station antenna is simulated. Typical path loss curves are shown to be characterized by three slopes and two break points. The path loss exponents for each part at different frequency are calculated. The frequency and the road width' s effects on path loss are discussed. And reasonable explanation for the results is also included in this paper.

1.Introduction

In order to increase mobile communication systems' capacity, people made the radio zone radius smaller and smaller, which was realized by using techniques such as a low base station antenna[1].The propagation loss for a low base station antenna on the road has been examined experimentally [2][3][4] and by a geometrical optics method[5][6]. Most of these reports were done for line-of-sight(LOS) street microcells, which means both the base station and the mobile are on the same road. In that case, typical path loss curves along the LOS path are characterized by two slopes and a single breakpoint. The path loss exponent is around two, as in free space propagation, from the transmitter up to the breakpoint. Beyond the breakpoint the loss exponent is around four, implying a faster decrease of the signal strength. However, it is also very common that there is no LOS between the base station and the receiver, especially the base station is low. Hence, the propagation loss with a low base station antenna for NLOS streets is also worth studying.

In this paper, the base station antenna is placed at the street corner and the mobile is on the street with buildings at the both sides. So, there is no LOS between the base station and the mobile. Ray tracing techniques were used to calculate the path loss. The results show the characteristics of the basic propagation loss such as the distance dependence, frequency dependence and effect of the width of the road.

2.Propagation Environment Description

The total environment is shown in Fig.1. The average height of the buildings is 25m. The base antenna is placed on site A, which is 3 meters away from its' right building and 5 meters away from the main road. The mobile was placed on site B, which can be moved on the middle line of the main road in simulation. The main road's width(W_1) is 30m and the width of the cross street(W_2) is 16m. The transmitting antenna is at a height(H_1) of 5m above ground and the received antenna's height (H_2) is 1.5m above ground.

Fig.1

The Dielectric properties used for the buildings'

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wall are shown in Table 1

ε_r (Fm^{-1})	μ_r (Hm^{-1})	σ (Am^{-2})	Reference
9	1	0.1	Lawton[7]

Table 1

3.Simulation Results and Discussion

3.1 Distance Dependence of Propagation Loss

Let the receiver move along the middle line of the main road and the simulation was done at 900MHz, 2GHz and 5GHz, respectively. The curves in Fig.2 show the path loss versus the distance d. The horizontal axis(d) is the distance from the intersection to the mobile.

Fig.2

As shown in Fig.2, There are two BPs(breakpoints) at each curve. The first breakpoint turned out when d is about 10m. When d is smaller than the first BP, the LOS path still exists and the path loss grow very slowly. The second breakpoint, which has been reported widely in LOS case, is also observed. And the distance can be approximately given by[10]

$$d_{bp} = \frac{4H_1H_2}{\lambda} \qquad (1)$$

where H_1 and H_2 are the receiver and transmitter antenna heights, and λ is the wavelength. For 900MHz, 2GHz and 5GHz, we can calculate the second BP's distances are 90m, 200m and 500m, respectively. Now, we can divide the horizontal axis into three parts:[0,first BP], [first BP, second BP] and [second BP,1000m]. For each part, the curve can be approximated by a straight line. From the slope of the line, the path loss exponent can be derived. The path loss exponents for each part are shown in Table 2.

Freq	[0 ,1st BP]	[1stBP,2nd BP]	[2ndBP,1km]
900MHz	0.03	0.9	5.5
2GHz	0.03	1.7	7.0
5GHz	0.04	2.7	12.2

Table 2

The exponent for [0,first BP] is nearly zero. This is because the LOS path still exists and the distance between the Base and the mobile does not change much. In the [first BP, second BP], the exponent is around 2 and this is similar with the LOS case. But in the [second BP, 1000m], the exponent is much larger than 4, which is the average exponent value in LOS case [11].

It is also apparent that there are several peaks in the propagation loss figure, which were verified to be corresponding to the streets cross the main road by analyzing in detail with the specified street map. Other literature[8][9] also gave out similar conclusion that propagation loss along NLOS street does not necessarily increase monotonically with distance.

3.2 Frequency Dependence of Propagation Loss

Still consider Fig.2, for the same d, we can find L at 5GHz is always the largest and L at 900MHz is always the smallest. If the frequency's effect on path loss can be expressed by $20\lg f$, where f stands for the frequency, then we can conclude that

$$L(5GHz) - L(2GHz) = 20\lg(\frac{5}{2}) \approx 8dB \qquad (2)$$

$$L(2GHz) - L(900MHz) = 20\lg(\frac{2}{0.9}) \approx 7dB \qquad (3)$$

(2) and (3) fit the simulation results well before the second BP. We can also see that for the same distance range, the higher the frequency is, the larger the path loss exponents are. This phenomenon is especially apparent in [2ndBP, 1km] and makes the path loss difference between different frequency larger than the value given by (2) and (3). This can be attributed to the fact that waves with higher frequency have stronger diffraction ability, which plays the essential role in NLOS cases.

3.3 Dependence on the Road Width

Fig.3 is the simulation result under different width of the main road. It is obvious that the wider the road is, the farther the break points are. For the first break point, the reason is just geometry relationship. For the second break point, this can be explained by the multiple-ray model which consists of not only the ground-reflected ray but also the rays reflected by the building walls along the main road [4]. For wider road, it is also obvious that the path loss is smaller beyond the second breakpoint.

Fig.3

4.Conclusion

In urban NLOS street environment, we have used Ray tracing techniques to simulate the path loss characteristics. It is found that there are two breakpoints in the path loss curve. The first break point can be explained by the disappearance of the direct wave. And the second is due to the first Fresnel zone obstructed by the ground or the builiding walls. The path loss exponents for each part are shown. Beyond the second breakpoint, the exponent is much larger than that is in the LOS case.

Frequency and the road width's effect on the path loss are also discussed. The results are:

1.For NLOS case, the frequency's effect on path loss can still be expressed by $20\lg f$ before the second BP. And the higher the frequency is , the larger the path loss exponents are;

2.The breakpoints are farther on the wider road. And for wider road, the path loss is smaller beyond the second breakpoint.

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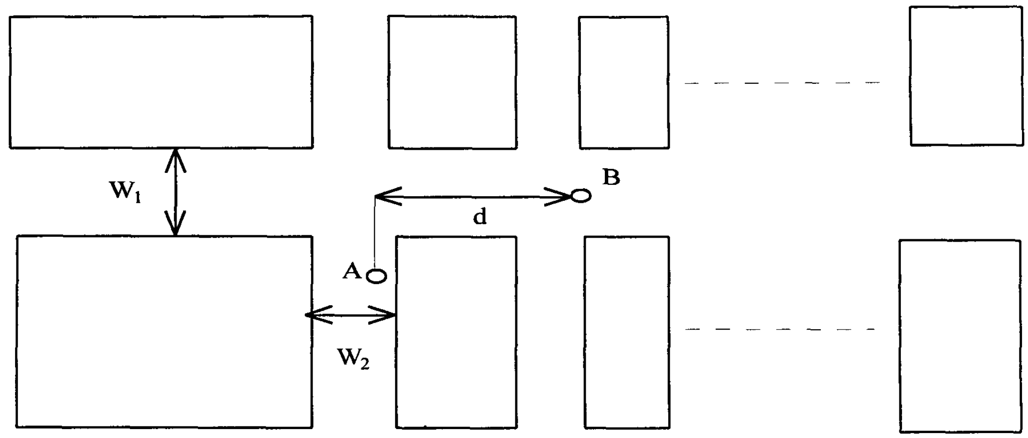

Fig.1 Street environment discription

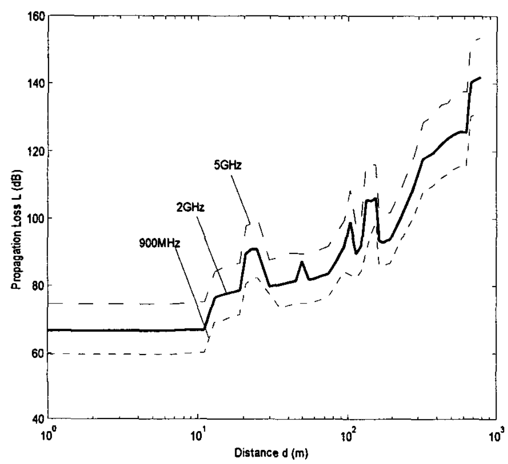

Fig.2 Propagation loss dependence on distance at different frequency (W_1=30m)

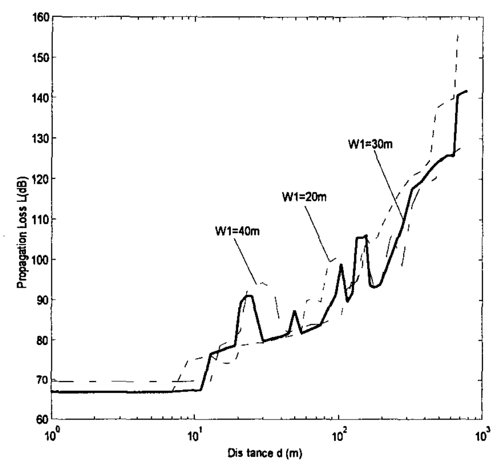

Fig.3 Propagation loss dependence on distance with different road width (2GHz)