Microwave Propagation Characteristics in an Urban Environment with Base Station Antenna on Top of a High Building

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I. INTRODUCTION

In recent years, with the increasing demand for mobile communication and crowding of the radio transmission frequency bands, the use of the microwave band holds the promise of higher bandwidth transmission, so there is vigorous research aimed at clarifying propagation characteristics in the microwave band. In particular, we see many reports of work that is concerned with the propagation characteristics of the configuration in which, assuming the use of microcells to increase system capacity, the installation height of the base station (BS) antenna is lower than the surrounding buildings [1][2]. However, to decrease the hand-over processing load at the switch as well as to reduce the number of station installations, it is effective to use a high BS antenna for the microwave band, so clarification of the propagation characteristics of that configuration is also important. Here, we report the results of propagation experiments in which the propagation loss and delay profile characteristics were evaluated in an urban environment where the transmitting BS was installed on the roof of the highest building within 1-km distance.

II. MEASUREMENT DESCRIPTION

The measurement system consists of a transmitter with its antenna mounted on building at a height of 55 m that transmits at a frequency of 3.35 GHz, and a receiving mobile station (MS) whose antenna is mounted on a vehicle at a height of 2.7 m. Vertical half-wavelength dipole antennas were used for transmission and reception. The propagation loss was measured by using continuous wave at this frequency. The specifications of the delay profile measurement system [4] are summarized in Table 1. The time resolution is 20 ns; the dynamic range of the receiver is around 60 dB ($20\log_{10}2047$ 66 dB) without AGC; and the amplitude uncetainty is 3 dB or less. The automatic gain control (AGC) in the MS operates in 1 dB steps with a 2 μs time constant, and has a dynamic range of 50 dB. For each location, the ensemble average of 32 delay profile data items is taken to serve as the delay profile for that location. The receiver sets the AGC gain between the 32 data.

Table 1 Measurement system

	Transmitter
Frequency	3.35 GHz
Output power	10 W
Modulation	BPSK
Transmission rate	50 Mchip/s
Spreading code	M-sequence, 2,047 bit
	Receiver
Type	Single superhetrodyne
AD conversion	10 bit, 100 Msample/s
AGC range	50 dB in 1-dB step
Data memory	1.6 GB RAM plus a hard disk

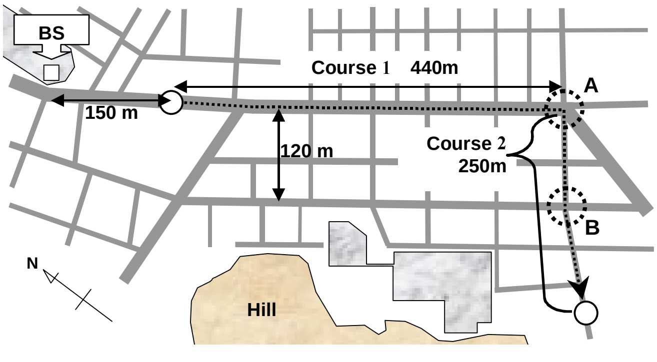

Fig. 1. Location of experiment.

The measurements were made in an urban area in Yokosuka, Japan during the daytime. The BS antenna was installed on the roof of the tallest building within 1-km distance (55 m high; the average height of the other buildings in the area is approximately 25 m). The MS moved along a course in the vicinity of that building, as illustrated in Fig. 1. The course is divided into two parts, course 1 and course 2. Course 1 is a 440-m straight line course that begins at a point that is 150 m from the building on which the BS is installed and is within the line of sight (LOS). Course 2 is a non-line-of-sight (NLOS) course that crosses perpendicularly to the southern end of course 1 at intersection A. The distances that appear in the following description are distances of movement along course 1 and course 2 measured from the origin directly below the BS.

III. MEASUREMENT RESULTS

Path-loss Characteristic

The measured propagation loss characteristic is shown in Fig. 2. The attenuation coefficient α for the distance on course 1 and the distance on course 2 were 3.3 and 4.2. The value 3.3 for course 1 is approximately the same as for the case of a LOS path in another urban environment for a 4-m-high BS antenna configuration [3].

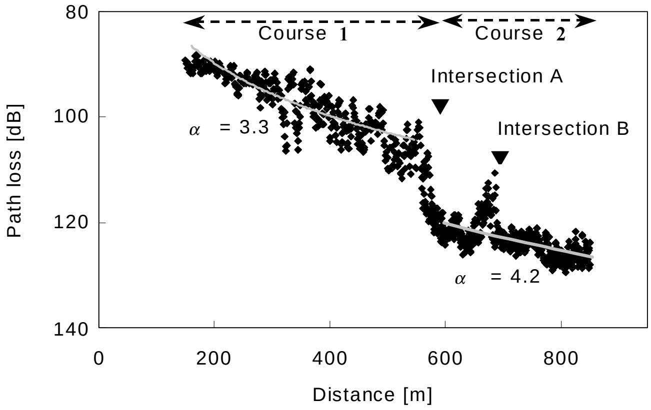

Fig. 2. Path-loss characteristics.

Propagation delay characteristic

Examples of the measured delay profiles are shown in Fig. 3. The delay spreads obtained from the delay profiles is shown in Fig. 4. In the delay spread characteristics, there is a gradual increase at the rate of 0.15 ns/m up to the distance of 300 m and from the distance of 300 m to the near vicinity of intersection A, the value increase at 2.6 ns/m to a maximum of 800 ns. When the MS is moving in the middle of intersection A from course 1, the value drops rapidly to 100 ns, but after the turn at intersection A to course 2 is completed, the value changes to roughly 300 to 400 ns, increasing at the relatively low rate of 1.0 ns/m

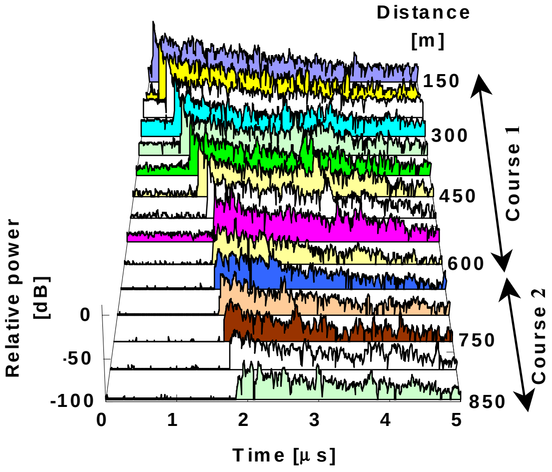

Fig 3. Delay profile characteristics.

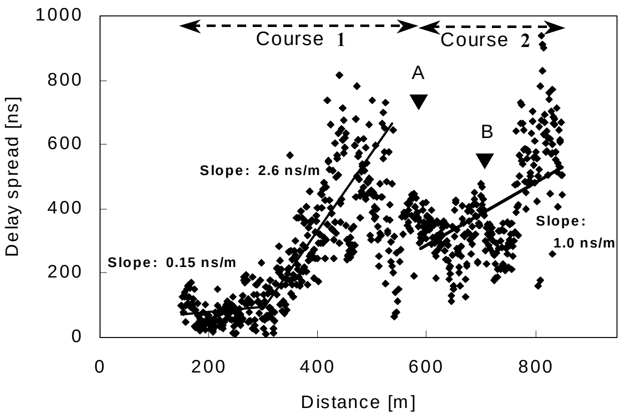

Fig. 4. Delay spread characteristics.

compared to the characteristics for course 1. Up to the distance of 300 m, the delay spread tends to increase slowly, in the same way as for the results for the low BS antenna urban configuration [4], but beyond 300 m a rapid increase that is about 10 times the rate as before that point is seen.

IV. DISCUSSION

Propagation loss characteristic

Here, we consider the difference in the attenuation coefficient α between the LOS path (course 1) and the NLOS path (course 2) for this experimental configuration. For the course 2, the waves that propagate along the course 1 are attenuated at the corner A; hence the waves that have been diffracted by the rooftops in the vicinity of the MS are dominant. Because the transmission antenna is omni-directional in the horizontal plane, the propagation loss in the region where the diffracted waves are dominant is equal at equal straight-line distances from the BS [5]. For course 2, while the distance of movement from intersection A to intersection B is 120 m, difference between the straight-line distances between the BS and the MS between those two intersections is 20 m; thus the direct distance between the BS and the MS varies little during the movement on course 2 compared to the distance that the MS moves. The MS makes a change from a LOS environment to a NLOS environment at intersection A, and therefore cannot receive the direct waves so that the propagation loss sharply increases by what is referred to as corner loss. Because the diffracted waves dominate on course 2, the effect of pedestrians and vehicles is slight in comparison with the low BS antenna configuration. In the NLOS environment along course 2 the factors that affect the change in the propagation loss are essentially the height of the buildings near the MS, the width of the road, and the distance between the BS and the MS. On course 2, except for the areas near the intersections, there is no extreme change in the height of the nearby buildings.

Here, we compare the empirical Sakagami model [6] applicable to below 2.2 GHz and the present results (the results for course 2) in terms of the propagation loss. The frequency range and BS heights that are dealt with by the empirical model were extended to a maximum frequency of 2.6 GHz and MS antenna heights in the range from 1 to 10 m by Fujii et al. [7]. The upper frequency limit for this extended Sakagami model is 2.6 GHz, but there is no exponential increase in the propagation loss as occurs when the original Sakagami model is applied above the 3 GHz band. Therefore, to that extended Sakagami model, we added a further correction (a fixed value of 7 dB) to create a model (referred to as the extended model in the following) that can be applied to the 3.35 GHz transmission frequency and compared the results of that model to the actual measured values. The correction value is obtained by recursive analysis so as to minimize the squared error between the measured data and the extended model values. The extended model (as well as the Sakagami model) is a median estimation method based on the propagation losses in 80 m sections. From the comparison of the extended model predictions and the measured 80-m medians shown in Fig. 5, we can see that the actual measured values and this model agree well within the maximum error range of 3 dB. This results suggests extendability of the Sakagami model to the microwave band in NLOS environments. Further study is needed to verify the full applicability.

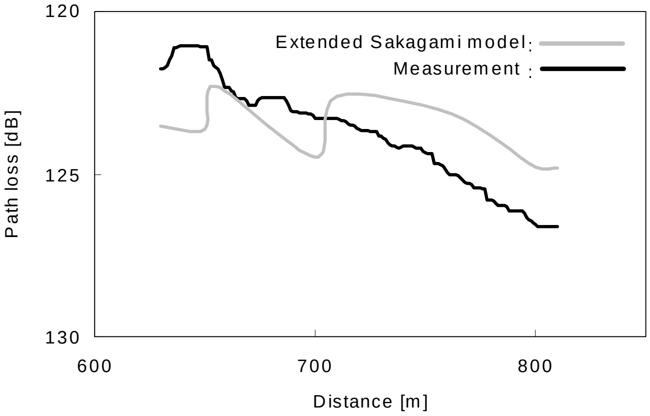

Fig. 5. Comparison of the extended Sakagami model and measured 80-m medians of path loss.

Propagation delay characteristic

The delay spread increases from the movement distance of 300 to 530 m (the near vicinity of intersection A). There are two reasons for that. The first is that the reception level of the direct waves decreases with distance and thus the effect of other delayed waves becomes large. Of those delayed waves, the waves that have a delay time of 1.7 μs and appear almost always in the delay profiles along course 1, become more conspicuous as the MS approaches nearer to intersection A and the delay spread becomes large. These waves whose delay time is 1.7 μs (equivalent to a difference in path length of 510 m) can be identified as the waves that are reflected from an approximately 30-m-high building that is located 270 m to the north of the BS. The second reason for the increase in delay spread is the effect of the environment in which five streets converge at intersection A, with the 23 m wide main road making a turn to the southwest at intersection A. That is to say, as the MS approaches intersection A, the effects of waves from a distance that are reflected into the intersection A by the buildings and connecting roads on the southeast side become large.

V. CONCLUSION

The propagation loss and delay characteristics in the 3.35 GHz microwave-band were measured for a configuration in which the BS antenna is placed in a position that is higher than the surrounding buildings. The main results are as follows:

(1) The attenuation coefficients α are 3.3 and 4.4 for the LOS and NLOS paths in this experiment. These results indicate that the direct wave and the waves reflected from the ground and buildings and propagated along the road dominate on course 1 of LOS, and that the waves diffracted on the roof of buildings dominate on course 2 of NLOS.

(2) By adding a frequency and MS antenna height correction to the Sakagami model, originally developed for the UHF band, the extended model can also be applied to NLOS propagation loss in the microwave band.

(3) The delay spread characteristic exhibits no significant change with distance for the LOS path, but it increases sharply near points at which the path angle changes, such as at curves.

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