Analysis of Propagation Channel in Urban Street Microcell Environment

We identified dominant scattering objects in an urban street microcell environment through analysis of time-space data obtained by actual measurement and clarified their effects on the reception characteristics. This research was conducted jointly with the Takada laboratory (Associate Professor Jun-ichi Takada), Graduate School of Science and Engineering, Tokyo Institute of Technology.

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1. Introduction

In station site selection, i.e., the process of determining locations for installing base stations in mobile communication systems, it is highly advantageous to be able to estimate the propagation loss in a manner that allows accurate modeling of interference from surrounding geographical features and objects on the ground. Moreover, active application of time-space signal processing, represented by Adaptive Antenna Array (AAA) and Multiple Input Multiple Output (MIMO) technologies, has recently been investigated in order to achieve large-capacity and high-speed transmission. In the future, estimation of propagation delays and angles of emission/arrival of radio waves is considered to become important [1]-[6].

Ray tracing is a method for unitary estimation of various propagation characteristics. The ray tracing method regards radio waves emitted from a transmission point as individual rays and traces each ray geometrically as it propagates, going through repeated reflection, diffraction and transmission by surrounding structures until it finally arrives at the reception point. Various propagation characteristics at the reception point can be obtained based on the propagation distance, angles of arrival/emission and electric field (complex amplitude) of the traced ray [7]. Since the processing demands tend to be very heavy compared to the computing power available, it has so far been considered difficult to use the ray tracing method for estimation of mobile propagation environments in urban areas (macrocell environments, in particular). However, with the current exponential growth in processing power of modern computers along with recent advances in studies on high-speed algorithms for ray tracing, it has lately become possible to perform accurate large-scale ray tracing-based simulations of mobile propagation environments in urban areas [8]-[12]. For example, the authors compared the simulation results generated by our previously developed "Urban Macrocell Area Prediction (UMAP)" system with a series of actual measurements. The prediction values matched relatively well with the actual measurements; the errors (cumulative 50% value) were found to be 6 dB for received power, 0.2 μs for delay spread and 3 degrees for angular spread (within a horizontal plane on the base station side) [10]. We also evaluated Cross Polarization Discrimination (XPD), which is one of the significant polarized wave characteristics in urban areas [11] [12]. The value predicted by the simulation was 13 dB for the cumulative 50% value, which is approximately 6 dB larger than the actual measurement result.

It should be noted that, in ray tracing targeted at urban areas, the only structures that need to be taken into consideration under normal circumstances are walls of buildings. Signboards, traffic lights, signs and similar objects that exist in large quantities in urban areas are not taken into consideration because the scattering caused by such objects is mainly non-normal scattering (in other words, not geometrical-optical reflection and diffraction) and thus considered not to have significant impact on the propagation characteristics. It has not been fully investigated yet whether this assumption actually holds for real-life applications, however. Consequently, if such non-normal scattered waves are taken into consideration in the ray tracing simulation, there is a possibility that the prediction accuracy can be further improved [13] [14].

This article examines the impact of non-normal scattered waves on the propagation characteristics experimentally, as a preliminary step toward examination of the ray tracing method taking non-normal scattered waves into consideration. Specifically, we conducted time-space measurements in an urban area (i.e., measurements where arrival waves are separated by delay time and arrival direction), analyzed the data to identify scattering objects, and clarified the impact of waves scattered by structures other than building wall surfaces on the received power as a whole. The propagation environment used in the examination is a so-called street microcell environment where both the receiving and transmitting antennas are placed at locations below the surrounding buildings, so that scattering objects can easily be identified.

2. Propagation Measurement

2.1 Measurement Specification and Configuration

We used a delay measuring instrument based on sliding correlation for the measurement. The transmission frequency was 3.35 GHz and the chip rate was 50 Mcps (the propagation distance resolution was 6 m). A sleeve antenna was used for the transmitting antenna and a patch array antenna with a half width of 10° in both the horizontal and the vertical plane was used for the receiving antenna. The transmitting and receiving antennas were mounted on rotating platforms, such that each of them could rotate within the horizontal plane, and placed on measuring vehicles (one each for the transmission and the receiving sides) using these rotating platforms. The height of both the transmitting and the receiving antennas was 3 m. **Table 1** shows the measurement specification and **Figure 1** shows the measurement configuration.

2.2 Overview of Measurement

We conducted the measurements by stopping the measuring vehicles on shoulder of Kannai Ohdori in Yokohama, as shown in **Figure 2**. The distance between the transmission and reception points was 60 m. The measurements were conducted at midnight in order to avoid disturbances from vehicles in the vicinity as much as possible. **Photo 1** shows the surrounding conditions at the transmission and reception points. As can be seen from the photos, there are many street lamps, traffic lights, signboards, traffic signs and other objects in the vicinity.

On the transmission side, radio waves were transmitted while rotating the sleeve antenna at 5 rpm. On the reception side, the patch antenna acquired data while rotating the main beam direction at 3° intervals. Here, the data acquisition time for each measurement direction was set to 30 seconds. The reason for rotating the transmitting antenna while acquiring the measurements was to eliminate the influence of instantaneous fluctuations due to multipath interference caused by averaging in the subsequent data processing.

2.3 Data Processing

In the data processing, we first averaged the instantaneous delay profiles for each reception direction and obtained average delay profiles for 120 directions in total. Next, we overlaid the delay profiles to obtain two-dimensional delay/angle profiles.

Table 1 Measurement specification

Frequency		3.35 GHz
Trans-mission	Transmitted power	35 dBm
	Chip rate	50 Mcps
	Antenna	Sleeve antenna (2.2 dBi)
	Antenna height	3 m
Recep-tion	Antenna	Patch array antenna (24 dBi) Half width: 10° in both horizontal and vertical directions
	Antenna height	3 m

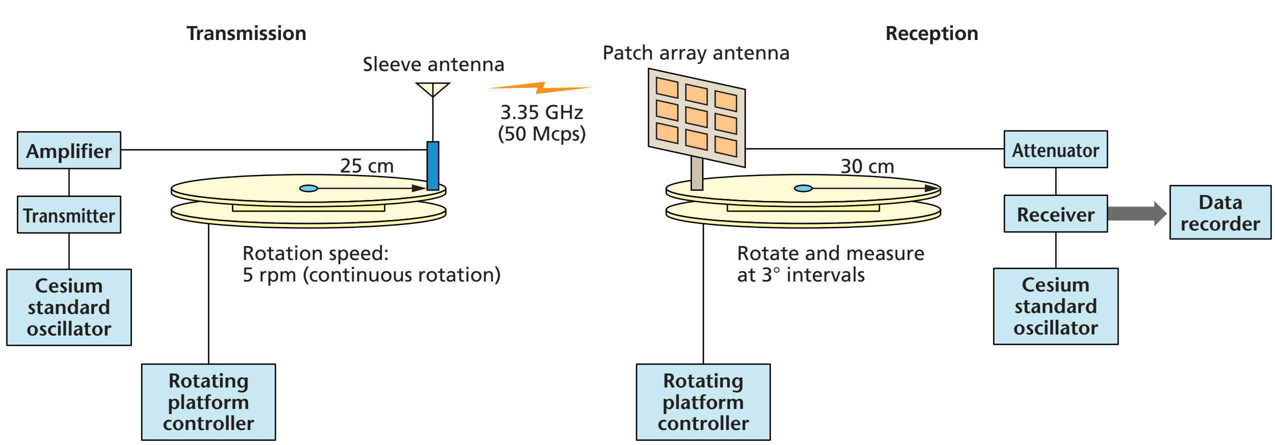

Figure 1 Measurement configuration

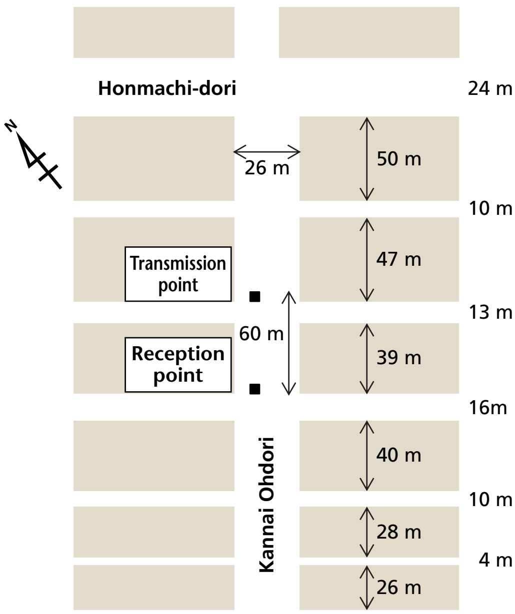

Figure 2 Measurement location

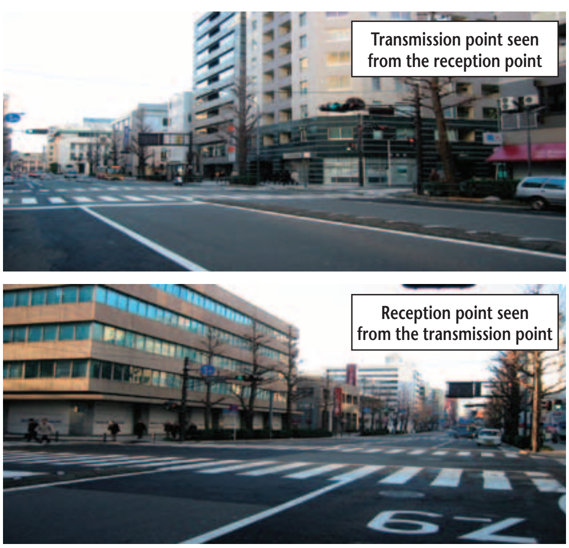

Photo 1 Surroundings of the measurement site

At this point, the delay times in the delay profiles were converted to absolute delay times based on the relationship between arrival time of direct waves and distance between the transmission and reception points. After that, we obtained a spatial distribution of the received power from the delay/angle profiles by assuming that scattering occurred once between the transmission and reception points and identified scattering objects based on comparison between the analysis result and the corresponding map information.

3. Analysis Result

Figure 3 shows the spatial distribution of received power obtained from the acquired data. In the figure, the areas where peaks of the received power indicate the positions of scattering objects. One would expect all scattering objects to be found on the roads, but in fact there are many cases where scattering objects are identified within buildings, such as A in the figure; this is attributed to the assumption that each ray only scatters once between the transmission and reception points. In other words, it is concluded that waves for which a scattering object was identified in such a position must in fact have arrived at the reception position after being scattered twice or more from the transmission position.

The main scattering objects that we were able to identify by comparing the result shown in Fig. 3 and map information include signboards, street lamps, traffic signs and traffic lights; the quantity of each type is shown in **Table 2**. Next, we analyzed the ratio of power contributed by scattered waves whose scattering objects could be identified to the total received power. As a result, it was found that 6% of the total received power came from scattered waves for which scattering objects could be identified, while direct waves and waves reflected

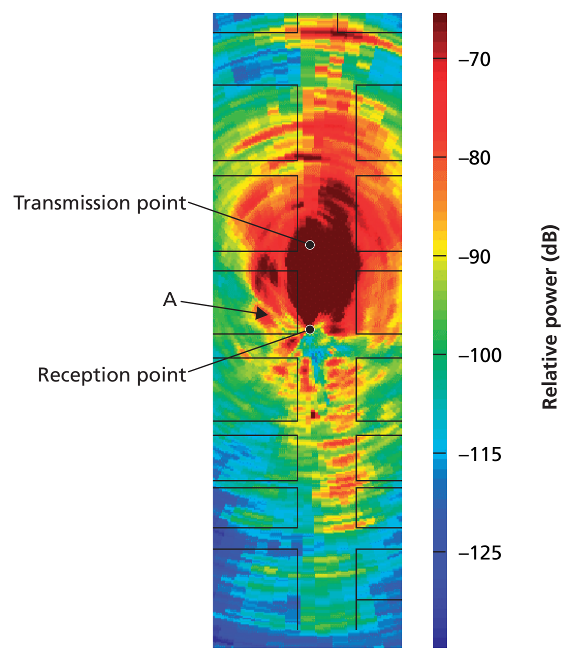

Figure 3 Spatial distribution of received power

Table 2 Types and quantities of identified scattering objects

Identified scattering objects	Quantity
Signboard	15
Street lamp	7
Traffic sign	10
Traffic light	10
Others	4

from wall surfaces (including waves diffracted from wall surfaces) accounted for 70% and 14%, respectively. This corresponds to approximately half of the amount of waves reflected from wall surfaces; it can thus be said that the impact of signboards and similar on the propagation characteristics is greater than what has been considered so far.

4. Conclusion

In this article, we conducted time-space measurements of 3 GHz radio wave propagation in an urban street microcell environment with good visibility between the transmission and reception points, and analyzed the data. In particular, we examined the impact of waves scattered by signboards, traffic lights and similar on the propagation characteristics. As a result, it became clear that such scattered waves have a relatively significant impact on the received power. The result shown in this article is only a part of the analysis, and for further information, refer to [15] and [18].

In the future, we intend to conduct similar measurements and analyses for urban macro cell environments, and examine how to handle non-normal scattered waves using the ray tracing method.

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Abbreviations

AAA: Adaptive Antenna Array
MIMO: Multiple Input Multiple Output
UMAP: Urban Macrocell Area Prediction system
XPD: Cross Polarization Discrimination