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Prediction Method of DOA Characteristics in Microcellular System

Reiko Tsuchihashi, Koichi Tsunekawa, Masaharu Hata
Wireless Laboratories, NTT DoCoMo, Inc.
3-5 Hikarinooka, Yokosuka-shi, Kanagawa, 239-8536, Japan
tsuchi@mlab.yrp.nttdocomo.co.jp

Abstract

This paper proposes a DOA prediction method that extends the ray tracing technique with experimentally-derived data. This method can predict not only the direction, delay, and number of incident waves, but the angle deviation, delay spread and actual path loss of each wave even though it uses a very simple database. Experiments verify this method and some parameters of database objects are derived.

1. Introduction

To realize the 4th generation mobile communication system, the adaptive array antenna is important in increasing the spatial reuse of radio resources. Appropriate adaptive array antenna design requires a directional radio channel model i.e. a DOA (Direction Of Arrival) model. This paper proposes a DOA prediction method based on ray tracing and the use of actual measured data. Experiments verify this method and derive some parameters in the Line Of Sight (LOS) case for a street microcell.

2. Concept of Prediction Method

The DOA characteristics to the base station in an urban environment strongly depend on the local objects, for example, the location and structure of the surrounding buildings, houses, etc. Ray tracing is well known as a method that can predict DOA characteristics for site-specific cases [1]. Unfortunately, the usual ray tracing method can't calculate the angle deviation, time delay spread, and actual path loss for each wave cluster incident to the base station. These parameters are required to design the appropriate adaptive antenna. This problem arises because the accuracy of the information held in the database isn't good enough to calculate these values. It seems infeasible to raise the database accuracy to levels that would permit useful micro, or milli meter wave band simulations. Because the incident wave clusters are generated by the roughness (of the order of half wavelength) of the objects' surfaces. These values can be gained only through experiments and so we extend ray tracing through the use of measured data. Therefore, the general factors of DOA characteristics, i.e. direction, absolute delay, and number of clusters, are simulated by ray trace method by using a simple database and the peculiar factors, i.e. angle deviation, time spread and actual path loss of each cluster, are given through the experiments in typical urban environments.

3. Proposed Method

The proposed prediction method can estimated DOA characteristics using a coarse geometric (position and configuration) database, see Fig. 1, together with the electric parameters of the objects. These electric parameters are determined from actual field measurements.

The proposed method determines the DOA characters of an incident wave cluster as follows.
1) Direction and absolute delay are calculated by ray tracing.
2) Angle deviation and relative delay spread for each path are derived from the electric parameters of the object from which the ray was reflected.
3) Path loss is the sum of free space loss and the reflection loss, which is given by the electric parameter of the object from which the ray was reflected.

4. Experiment

Experiments were made to verify the proposed method and to derive the electric parameters in a simple environment: an LOS in a street microcell. The experiment setup is shown in Fig. 2. Both sides of the street had buildings, whose heights were about 10 m. The width of the street was 32 m. Rx and Tx antenna heights were 3.3 m and 2.2 m, respectively. Measurement frequency was 8.45 GHz.

The measurement equipment system is shown in Fig. 3. Angular-delay profiles were gained using the super resolution method (ESPRIT). They were measured with a sampling step of 10 cm on each course.

5. Experimental Results

DOA characteristics of incident waves were derived from ray tracing and experiments. We used the results to compare ray tracing method and clarify some of the electric parameters.

1) Direction

Figure 4 compares measured (points) and calculated (curves yielded by ray tracing) incident wave directions. The points lie along the curves so the incident wave direction is well estimated by ray tracing.

2) Angle deviation

Figure 5 shows a typical angular power profile of a reflected wave. This is the average of the course, where the direction calculated by ray tracing was set to zero. This resembles a Gaussian distribution. The standard deviations of reflected paths from building A and building B were about 3 degrees and 2 degrees, respectively.

3) Absolute delay

Figure 6 compares measured (points) and calculated (curves yielded by ray tracing) delay times of a reflected wave, where the time of the direct wave was set to zero. Absolute delay is defined as the time at which the maximum of each delay profile arrives. The measurements cluster around the curves, so the absolute delay is well estimated by ray tracing.

4) Delay spread

Figure 7 shows a typical delay profile of a reflected wave. This is the average of the course excluding the effect of absolute delay. It is found that the reflected wave exhibits some relative delay. The average delay and the delay spread of the path reflected from A are about 20 ns and 10 ns, respectively. Those from B were below the measurement limit.

5) Path loss

Path loss is expressed by the sum of free space loss and the reflection loss. Measurements confirm that the loss of a direct path follows the free space loss. The reflection loss measurements are shown in Fig. 8 compared to the calculated values. The reflection loss of A is about -12 dB. This value is much greater than the values calculated with an ideal material parameter. This confirms the necessity of adding the actual reflection coefficients of the buildings to the database.

The above results verify that the proposed method is suitable for street microcellular systems. The electric parameters of a typical building are shown in table 1. However, it should be noted that the data of the table is a typical example of a building in the case of LOS condition, because the experiment was carried out in a specific environment. Adequate electric parameters of each category of object must be decided through more experiments.

6. Conclusion

This paper proposed DOA prediction method which uses a improved ray tracing technique enhanced by employing experiment data. Measurements verified this method and derived some of the typical parameters on Line Of Sight (LOS) case in street microcell. DOA characteristics including deviation of direction, delay spread, and accurate path loss of incident wave cluster can be estimated by this method. It is necessary to study the electric parameters of database objects through more experiments.

References

[1] Y. L. C. de Jong, M. H. A. J. Herben, "Experimental verification of ray-tracing based propagation prediction models for urban microcell environments", VTC '99-Fall, Amsterdam, The Netherlands

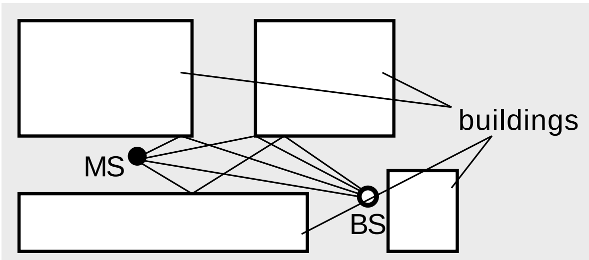

Fig. 1 Database of the surrounding objects

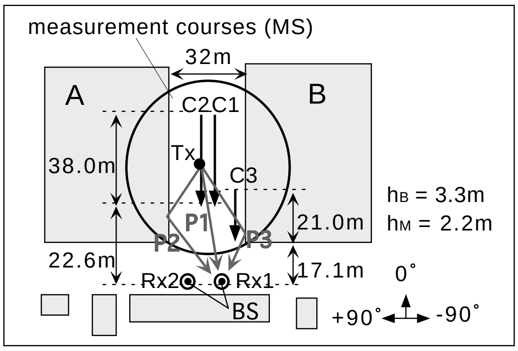

Fig. 2 Experiment setup

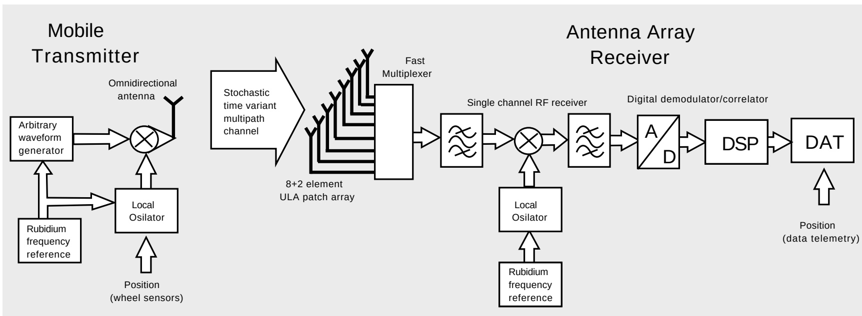

Fig. 3 Measuring equipment system

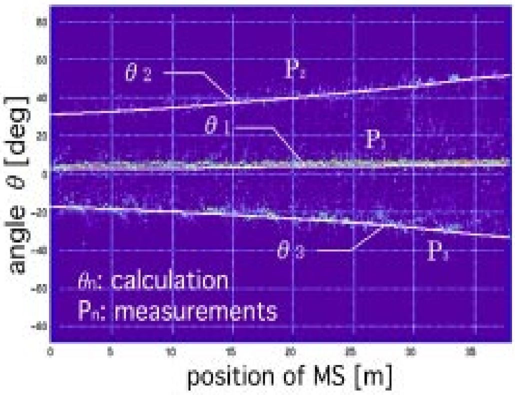

Fig. 4 Direction of incident waves (C1,Rx2)

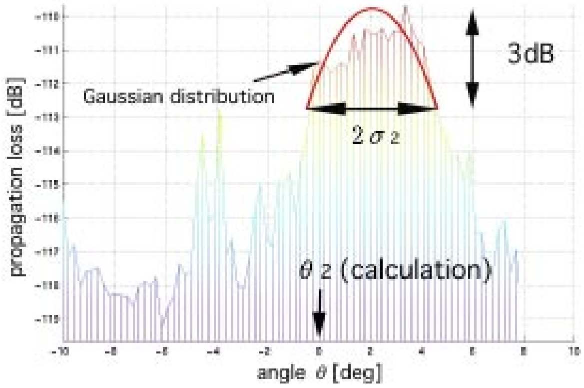

Fig. 5 Average angular power profile (C2,Rx1,P2)

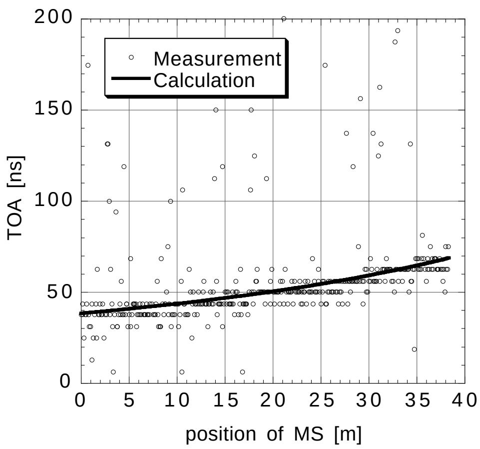

Fig. 6 Delay time of incident waves (C1,Rx1)

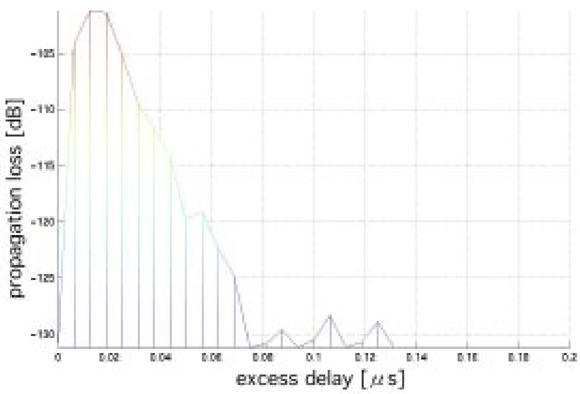

Fig. 7 Average delay profile (C2,Rx1)

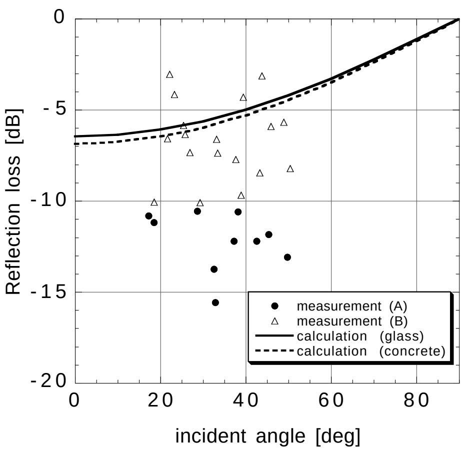

Fig. 8 Reflection loss of buildings

Table 1 Electric parameters of buildings

	σ	(AD, DS)	Γ
A	3 deg	(20ns, 12ns)	-12 dB
B	2 deg	below measurement limit	-6 dB

σ : standard deviation of DOA
AD : average delay
DS : delay spread
Γ : loss