Application of a deconvolution technique in a spatio-temporal channel measurement to validate a ray-tracing simulator

Houtao Zhu[1], Jiye Fu[1], Jun-ichi Takada[1], Kiyomichi Araki[2], Hironari Masui[3], Masanori Ishii[3], Kozo Sakawa[3], Hiroyuki Shimizu[3], and Takehiko Kobayashi[3]

[1]International Cooperation Center for Science and Technology, [2]Department of Computer Engineering, Tokyo Institute of Technology 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8550, JAPAN [3]YRP Mobile Telecommunications Key Technology Research Laboratories Co., Ltd

E-mail: tony@icc.titech.ac.jp

I. Introduction

Recently, smart antennas (SA) have been proposed as spatio-temporal signal processing techniques to enhance the qualities of received signals and increase the capacity of mobile systems. In addition, SA is newly proposed as a promising technique for broadband wireless access networks [1]. These networks are supposed to operate at microwave bands (28 GHz for local multipoint distribution service (LMDS) and above 5 GHz for multimedia mobile access communication service (MMAC)).

The fast progress of research on SA has inspired great interests on exploring the spatio-temporal propagation characteristics of wireless channels. Many measurements[2][3] have been carried out for this purpose. However, very few measurements [3] have been done in microcell environments and almost none at microwave bands. There is an urgent need to measure the spatio-temporal channel parameters in microcell environments. Meanwhile, because of the site-specific nature of ray-tracing models, they are promising approaches for the deterministic spatio-temporal channel modeling. However, the validation of ray-tracing models in predicting spatio-temporal parameters has not been fully completed.

Therefore, this paper reports a spatio-temporal measurement at microwave bands in a suburban microcell. This measurement utilized a delay profile measurement system [4] and a rotating parabolic antenna to obtain both angle-of-arrival (AOA) and time-of-arrival (TOA). In order to reduce the influence of antenna pattern and suppress sidelobe effects, the measurement results are processed by a deconvolution-processing technique [6]. Then they are compared with ray-tracing results obtained from a hybrid 2D-3D ray-tracing algorithm [5]. A random phase approach [7] is introduced and extended to obtain the statistical median angular profiles and azimuth-delay profiles. In other words, the approach provides the statistical distribution of spatio-temporal (angle-delay) fading. These predicted profiles are compared with measured data. The good agreement between ray tracing and measurement is observed. The applicability of ray-tracing approaches in spatio-temporal channel modeling is confirmed.

II. 2D-3D Hybrid Ray-Tracing Model

The purpose of this 2D-3D hybrid ray-tracing method is the prediction of spatio-temporal channel parameters in micro- and pico-cellular environments. The details of the ray-tracing algorithm is described in [5]. The tree-attenuation model is described and confirmed with measurement in [8].

A random phase approach (RPA) is extended to account for the narrow-beam fading [6] caused by changes in the partial selection of the angular response by the antenna pattern when sweeping it over the angular domain. The detailed derivation is presented in [8]. With this derivation, a statistical angular profile can be obtained with the deterministic ray tracing result. Similarly, a statistical azimuth-delay profile can also be obtained with a two-step procedure: 1) calculate the statistical delay profile at each azimuth bin with channel impulse response predicted from ray tracing; 2) calculate the statistical azimuth-delay profile along each delay bin by convolving the antenna pattern with the band-limited delay profiles obtained at step 1.

III. Deconvolution Processing

The purpose of deconvolution processing is to obtain unambiguous information of angle-of-arrival (AOA) by reducing the influence of antenna pattern and suppressing the sidelobes. The approach is first to obtain the angular-frequency response $M(\tau, \zeta)$ of the measured azimuth-delay profile, and $A(\zeta)$ of the complex antenna pattern. They are acquired via a Fourier transform from azimuth domain to angular frequency domain. Then the de-convolved response is obtained as follows :

$$H(\tau, \zeta) = \frac{M(\tau, \zeta)}{A(\zeta)} W(\zeta) \tag{1}$$

where τ represents the sampled delay instant, ζ represents the sampling angular frequency, and $W(\zeta)$ is a window function. Hamming window is used in this paper. Finally, the de-convolved response in azimuth domain is obtained by a inverse Fourier transform of $H(\tau, \zeta)$.

IV. Experimental Setup, Analysis and Ray-Tracing Validation

In order to measure the spatio-temporal propagation characteristics, a delay profile measuring system utilizing pseudo noise (PN) code [4] is incorporated with a highly-directional parabolic antenna to obtain TOA and AOA at the same time. A 8.45 GHz spreading-spectrum signal with 50 Mchips/s was transmitted. A resolution of 20 ns and a maximum delay period of 2.54 μs are achieved in the measurement. The parabolic antenna at receiver side is vertically polarized with 32 dBi gain, 4° of beamwidth, front/back ratio (FBR) above 45 dB, and 0.6 m of diameter. The parabolic antenna is rotated to cover the whole azimuth range of 360° in a time period of 70 s, which means that it takes 0.2 ms ($\gg$ 2.54 μs) to cover 1 azimuth degrees. In the measurement, the antenna was rotated twice with an azimuth-angle interval of 4° at each location point. A vertical half-wavelength dipole antenna is used at transmitter side.

A measurement was carried out in a suburban microcellular environment (600 $\times$ 600 square meters) of Yokosuka (shown in Fig. 1). The environment consists of residential buildings with an average height of 8 meter. Note that there are groups of trees at the north side of each road that are not shown in the figure. The heights of receiving and transmitting antennas are set at 4.4 and 2.7 m above the ground. Since the traffic in roads is very small, the effects of random moving scatters can be eliminated. Several location points are selected to do the spatio-temporal measurement with the parabolic antenna. In the spatio-temporal measurement, the observation interval is very short and the propagation process is assumed to be static.

In the ray-tracing simulation, width of trees is set at 1 m. Relative permittivities of walls, the ground, and trees are 4.44, 15, and 1.2 respectively. Conductivities of walls, the ground, and trees are assumed as 0.01, 0.005, and 0.0003 [S/m] respectively. To calculate azimuth-delay profiles, a raised-cosine filter (roll-off factor 0.5) with 100 MHz bandwidth and a parabolic antenna with the measured radiation pattern are utilized in the simulation. Note that in applying RPA, the sampling intervals or the intervals of bins (delay and azimuth) are determined by the specific system conditions, i.e., bandwidth of the system and beamwidth of the antenna.

Due to the limited space of this paper, a typical point in LOS route is selected for comparison. Figure 2, the result without deconvolution processing, shows that the arrived waves are almost concentrated in a small delay interval. The direct waves arrive at around 4 degrees. It is noted that some waves arrive at 180 degrees, which is almost the opposite direction of the direct waves. The azimuth-delay profile after deconvolution processing is depicted in Fig. 3. The de-convolved waves at around 10 degrees is observed. The median azimuth-delay profile obtained from RPA

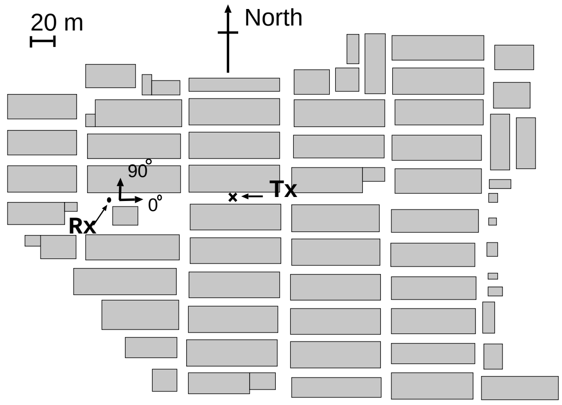

Fig. 1. A microcell environment in Yokosuka.

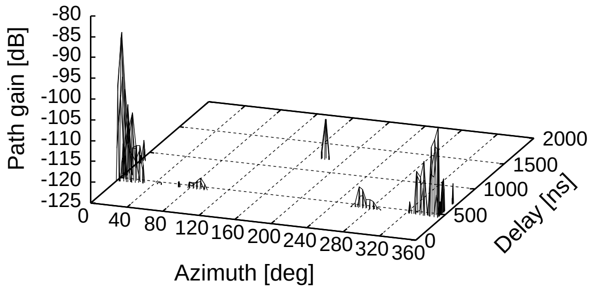

Fig. 2. A measured azimuth-delay profile of a LOS point before deconvolution processing.

is shown in Fig. 4. Those back-scattered waves are not predicted from the ray tracing model. This result indicates that the scattering effects around the receiver may not be neglected in the ray-tracing modeling.

Under uncorrelated scattering conditions, the angular profile is obtained from measurement data by using a power-summing approach. The measured azimuth-delay profile is incoherently summed up at each azimuth bin to get the angular profile. The normalized angular profiles (with and without deconvolution processing) at this LOS point are shown in Fig. 5 and 6. The impulse-type ray-tracing result is also depicted in Fig. 6. A median angular profile by using RPA is illustrated in Fig. 7. The general agreement between ray tracing and measurement is observed.

V. Conclusion

This paper reports a spatio-temporal measurement carried out in a suburban microcell environment. The spatio-temporal channel parameters are obtained by a wideband delay-profile-measuring channel sounder and a directional parabolic antenna. A hybrid 2D-3D ray-tracing model is used to validate the application of ray-tracing approaches for spatio-temporal channel modeling. The focus of this paper is to describe a random phase approach incorporated into the ray-tracing model and present a de-convolved measurement result. The improved accuracy is observed. The results indicate that 1) ray-tracing approaches can predict the spatio-temporal channel parameters in microcell environments; 2) the scattering model nearby the receiver is important in microcell environments; 3) the arrived waves are concentrated in a small delay interval in LOS.

References

[1] K. Sheikh, D. Gesbert, D. Gore, and A. Paulraj, IEEE Communications Magazine, vol. 37, no. 11, pp. 100–105, Nov., 1999.
[2] J. Fuhl, J. Rossi, and E. Bonek, IEEE Trans. Antennas and Propagtation, vol. 45, no. 45, pp. 672–682, April, 1997.
[3] M. Mizuno, S. Sekizawa, and K. Taira, IEEE Vehicular Technology Conference (VTC'99 fall), pp. 2263–2267, Sept. 1999.
[4] H. Masui, K. Takahashi, S. Takahashi, K. Kage, and T. Kobayashi, IEICE Trans. Electron., vol.E82-C, no.7, pp.1287–1292, July 1999.
[5] H. Zhu, J. Takada, and K. Araki, Int. Symp. on Personal, Indoor and Mobile Radio Comm. (PIMRC'99), pp. 116–120, Sept. 1999.
[6] P. C. F. Eggers, Wireless Personal Communications, no. 11, pp. 3–29, 1999.
[7] S. Takahashi and Y. Yamada, IEICE Trans. Fundamentals, vol. E81-A, no.7, pp.1445–1451, July 1998.
[8] H. Zhu, J. Fu, J. Takada, K. Araki, H. Masui, M. Ishii, K. Sakawa, H. Shimizu, and T. Kobayashi, IEICE Tech. Rep., vol.99, no. 628, pp. 83–90, Feb. 2000.

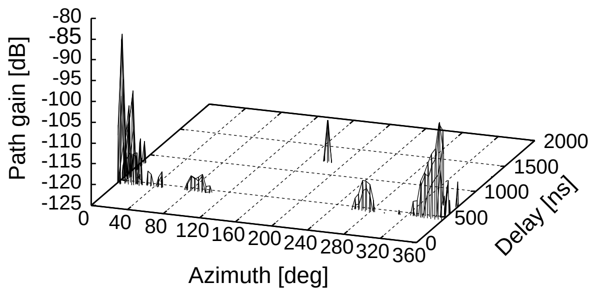

Fig. 3. An azimuth-delay profile of a LOS point after deconvolution processing

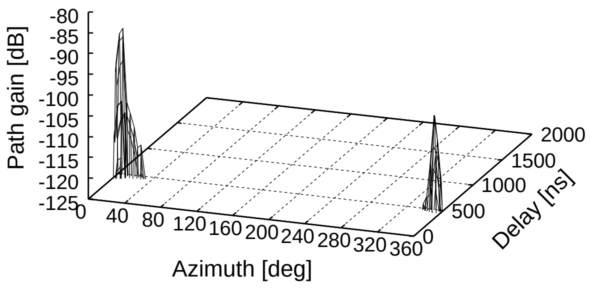

Fig. 4. An azimuth-delay profile of a LOS point from random-phase ray tracing .

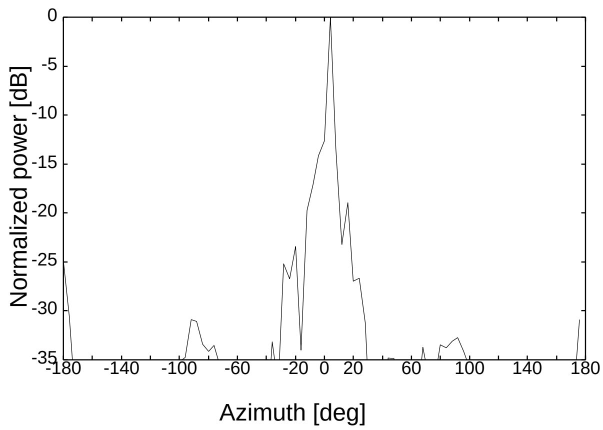

Fig. 5. A measured angular profile of a LOS point before deconvolution processing.

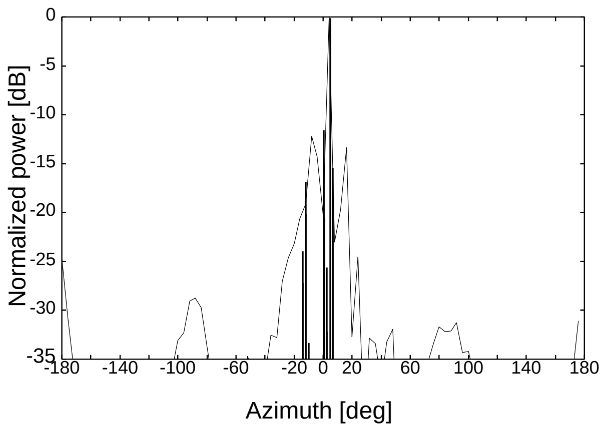

Fig. 6. An angular profile of a LOS point after deconvolution processing.

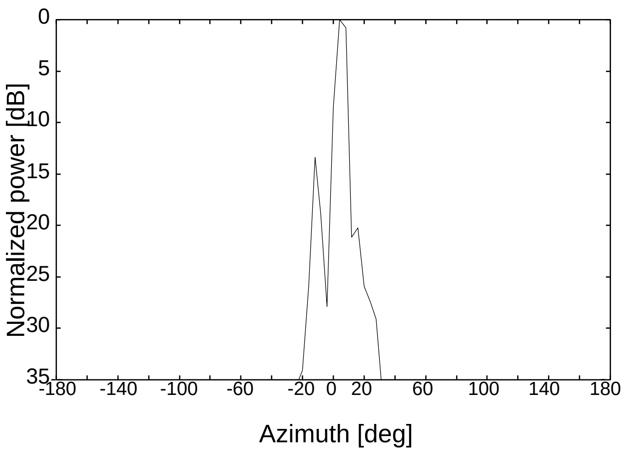

Fig. 7. An angular profile of a LOS point by random-phase ray tracing.