24/60-GHz Dual-Band Double-Directional Channel Measurements in Urban Cellular Access Environments

Hibiki Tsukada[†], Naoya Suzuki,
Riku Takahashi and Minseok Kim
Graduate School of Science and Technology,
Niigata University, Niigata, Japan
Email[†]: f21c087a@mail.cc.niigata-u.ac.jp

Hirokazu Sawada and Takeshi Matsumura
Wireless Network Research Center,
National Institute of Information and
Communications Technology (NICT),
Yokosuka, Japan

***Abstract*—This paper reports the results of propagation channel measurements simultaneously performed at 24 and 60 GHz in an urban cellular access environment. A channel sounder with a phased-array antenna capable of high-speed beam steering was used to achieve double-directional full-azimuth scan measurements at the same position and at the same time at both frequencies. Statistical properties of the delay time of arrival, and the azimuth angles of departure and arrival, called large-scale parameters (LSPs), were obtained from the measured data. The results improve the accuracy of the currently widely used cluster-based millimeter-wave channel models for site-specific channel prediction.**

***Index Terms*—millimeter-wave, channel sounding, channel model, 3GPP, large scale parameters, small parametars**

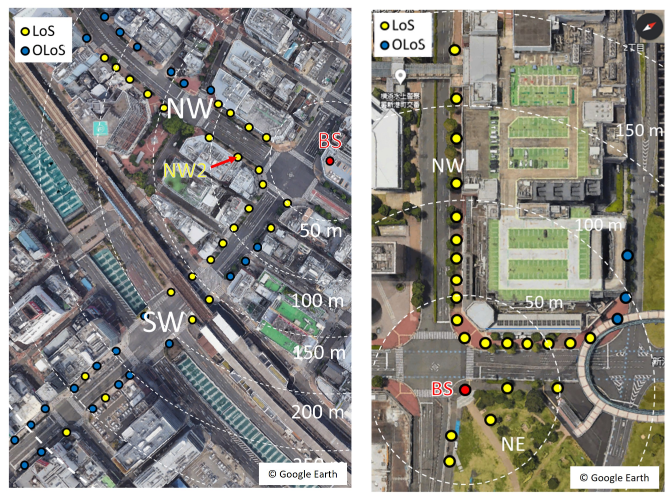
I. Introduction

The use of the millimeter-wave (mm-wave) band, which offers wide bandwidth, is expanding in order to cope with the rapidly accelerating increase in communication traffic each year. The mm-wave is known for its high environmental dependence, with small objects being the primary propagation mechanism due to their short wavelength [1]. The channel model that well reflects the characteristics of mm-wave is indispensable for the development of new wireless communication systems using mm-wave. However, the site-general cluster-based channel models that are widely used today do not reflect the strong environmental dependence of mm-wave [2]. Therefore, further experiment-based propagation channel analysis is required to improve the accuracy of these channel models. This paper reports on the results of simultaneous spatio-temporal propagation channel measurements in the 24 and 60 GHz bands in an urban cellular access environment, and the channel statistics calculated from the measured data.

II. Measurement campaign

A. Channel sounder

The channel sounder used for this measurement consists of custom baseband processing units and custom-off-the-shelf (COTS) phased array antenna beamforming transceivers [3]. The transmitter side baseband processing unit is mainly responsible for sounding signal generation. The sounding signal

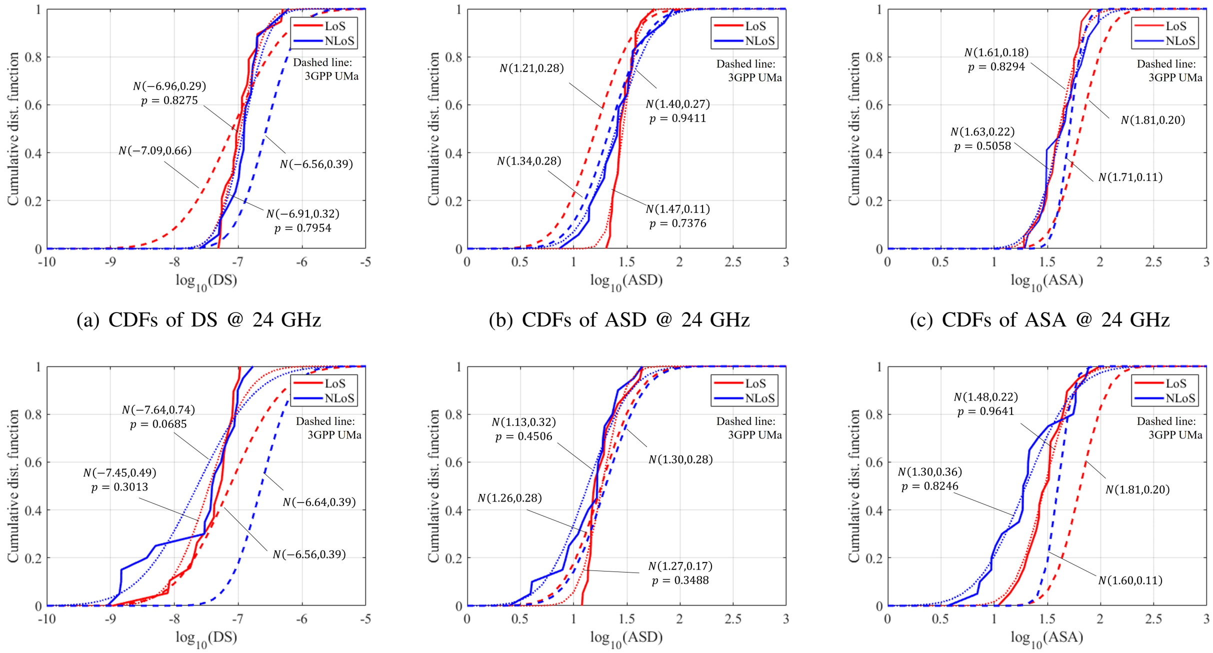


(a) Urban macro-cell (UMa) (b) Urban micro-cell (UMi)

Fig. 1. Measurement environment

was the unmodulated Neumann phase multitone (NPM). The number of samples for a single waveform is 2,048 for both frequencies, and the numbers of tones are 512 in 200 MHz and 1,024 in 400 MHz for the 24-GHz and 60-GHz bands, respectively. The sounding signals are up-converted to the center frequencies of 24.15 GHz and 58.32 GHz, respectively, by the local oscillator of the transceivers.

In each transceiver, a narrow beam in the azimuth plane is synthesized using a planar array and a uniform linear array for the 24-GHz and 60-GHz bands, respectively, at both Tx and Rx. The half-power beam width (HPBWs) of the broadside beam patterns are approximately 15° and 6° for the 24 and 60 GHz, respectively, in the azimuth plane. Further, those in the elevation plane are 45° for the 24 GHz phased arrays, and 18° for Rx and 45° for Tx for the 60 GHz phased arrays, respectively. The scanning range of 90° is covered by 5 Tx and 5 Rx beams and 11 Tx and 12 Rx beams for 24 and 60 GHz, respectively. By using four phased array antennas directing toward -135°, -45°, +45° and +135°, this system is extended to the 360° azimuth angle sweep.



(a) CDFs of DS @ 24 GHz (b) CDFs of ASD @ 24 GHz (c) CDFs of ASA @ 24 GHz

(d) CDFs of DS @ 60 GHz (e) CDFs of ASD @ 60 GHz (f) CDFs of ASA @ 60 GHz

Fig. 2. Largescale parameters

Employing a dual 4×4 MIMO time division multiplexing (TDM) scheme can measure 32 channels simultaneously for rapid acquisition of full azimuth angle range. The complete measurement consists of 132 MIMO measurement blocks for angle scanning with 11 Tx and 12 Rx beams for both bands, which takes approximately 5 minutes.

B. Measurement environment

A measurement campaign was carried out in a typical urban environment around JR Kannai Station and Yokohama World Porters, Yokohama, Kanagawa, Japan. The aerial maps of two measurement environments are shown in Fig. 1. The channel measurement was conducted in downlink (BS: Tx, MS: Rx). Regarding the UMa scenario, the BS was installed on the roof of an 8-story building (BS antenna height: 31.0 m), and the MS was moved along 49 points on the sidewalk (MS antenna height: 1.5 m). The distance between the BS and MS antennas ranged from 40–350 m. On the other hand, in the UMi scenario, the height of the BS antenna installed on the sidewalk was 3.0 m, and the MS was moved along 25 points on the sidewalk (MS antenna height: 1.5 m). The distance between the BS and MS antennas ranged from 27–200 m. The measurement data might include some influence of cars and pedestrians running around the MS.

III. Channel parameters

The delay spread (DS) and angular spread (ASD/ASA) were calculated based on the 3GPP model and compared with values used in the 3GPP model (UMa) [4].

Fig. 2 shows the cumulative probability distribution of each parameter. The solid lines denote the distribution obtained in this measurement, and the dashed line is the distribution obtained in the reference model. The figure also shows the p-value of the KS test under the null hypothesis that the measured distribution follows the Gaussian distribution.

Comparing the measured distributions with those of the reference model, we see that the distributions are quite different, especially for DS. In other words, we can infer that DS is a parameter with strong site-specific nature. Comparing the two frequency bands, we can also see that the distribution at 60 GHz is smaller for all parameters. This can be attributed to the fact that 60 GHz is more strongly affected by diffuse scattering by small objects and larger attenuation by oxygen than 24 GHz.

Acknowledgment

This research has been conducted under the contract “R&D for the realization of high-precision radio wave emulator in cyberspace” (JPJ000254) made with the Ministry of Internal Affairs and Communications of Japan.

References

[1] C. Gentile, P. B. Papazian, R. Sun, J. Senic, and J. Wang, “Quasi-Deterministic Channel Model Parameters for a Data Center at 60 GHz,” *IEEE Antennas Wireless Propag. Lett.*, vol. 17, no. 5, pp. 808–812, May. 2018.

[2] H. Tsukada, K. Kumakura, S. Tang and M. Kim, “Millimeter-Wave Channel Model Parameters for Various Office Environments,” *IEEE Access*, Vol.10, pp. 60387-60396, Jun. 2022.

[3] M. Kim, H. Tsukada, K. Kumakura, R. Takahashi, N. Suzuki, H. Sawada, T. Matsumura, “A 24/60-GHz dual-band double-directional channel sounder using COTS phased arrays”, Proc. *IEEE International Conference on Communications*, May 2022.

[4] ETSI TR, 138 901 V16.1.0, “Study on Channel Model for Frequencies From 0.5 to 100 GHz”, Nov. 2020.