Outdoor-to-Indoor Channel Characteristics at 20 GHz

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***Abstract* - The next generation (5G) mobile communication system has been the focus of studies recently. One of the approaches to enable this system is utilizing the high-SHF band (over 6 GHz) and the EHF band (mainly 30 – 100 GHz). To design radio links with high accuracy and evaluate 5G system performances for various scenarios, channel characteristics must be clarified. In this paper, we clarify the channel characteristics of Outdoor-to-Indoor (O2I) propagation scenario at 20 GHz band based on the measurement using a channel sounder with a 50 MHz bandwidth. The propagation mechanism is also analyzed based on estimating single scattering positions of multipath.**

***Index Terms* — 5G, High-SHF, EHF, Outdoor-to-indoor channel characteristics.**

1. Introduction

In recent years, the next generation (5G) mobile communication system with a very high data transmission rate has been the focus of studies. One of the approaches to enable this system is utilizing the high-SHF band (over 6 GHz) and EHF band (mainly 30 – 100 GHz) [1, 2] because these bands provide wider bandwidths. Considering scenarios using high-SHF and EHF bands for small cells, to design radio links with high accuracy and evaluate 5G system performance for various scenarios, the channel characteristics such as path loss, delay spread, and angle spread etc. must be clarified.

Up to now, the path loss characteristics of the high-SHF and EHF bands have been reported [2-7]. However, channel characteristics of "Outdoor-to-Indoor (O2I) propagation", especially delay spread and angle spread are still not clarified enough. In this paper, we present the O2I channel characteristics at 20 GHz band based on the measurement using a channel sounder with a 50 MHz bandwidth and by rotating a horn antenna. We also analyze the propagation mechanism by estimating single scattering (scattering just once) positions of multipath.

2. Measurement of Channel Characteristics

In measurements, we used a channel sounder with the specifications as shown in Table 1. On the transmitter (Tx) side, orthogonal frequency-division multiplexing (OFDM) signals with a 50 MHz bandwidth at the 20 GHz band were generated and propagated into the air using a 2.4 dBi sleeve antenna. The transmission power was 30 dBm. On the receiver (Rx) side, a 19.1 dBi horn antenna with a 20 degree half-power beamwidth was used to receive the radio frequency (RF) signals. After down-converting the RF signals to an intermediate frequency (IF) band, the complex amplitudes of the subcarriers (transfer functions) were converted into channel impulse responses and obtained power delay profiles.

Measurements were conducted in the campus of Niigata University, Japan. Fig. 1 shows the measurement environment. We located the Tx of the channel sounder at points A1 with at the antenna height of 2.5 m. On the other hand, in side measurement building B0, we located the Rx in corridors of 1st , 2nd, 4th, 6th, 8th floors (namely, 1F, 2F, 4F, 6Fand 8F) with the positions of 2 m, 9 m, 16 m from glass window W0. The height of the horn antenna was 1.5 m. Here, at each Rx position, we rotated the horn antenna and measured power delay profiles. The ranges of rotation were from -180 degrees to +180 degrees in 1 degree steps for azimuth angle, and from -50 degrees to +50 degrees in 10 degree steps for elevation angle.

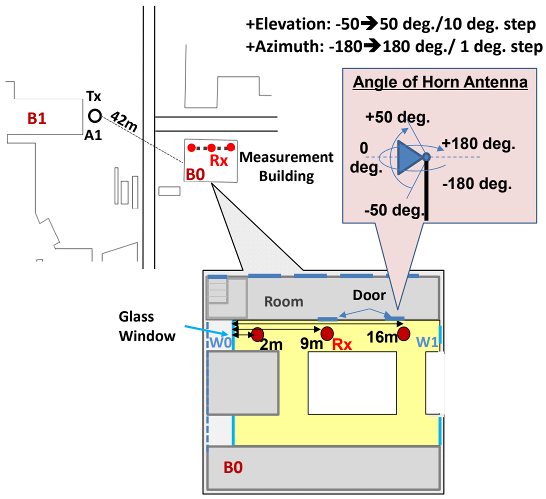

Fig. 1. Measurement environment

TABLE I
Channel Sounder Specifications

Center frequency	19.85 GHz
Bandwidth	50 MHz
Transmission signal	OFDM
Number of subcarriers	449
Transmission power	30 dBm
Tx antenna	Sleeve (2.4 dBi)
Rx antenna	Horn (19.1dBi: 20 deg. HPBW)

3. Measurement and Analysis Results

Fig. 2 shows the measurement results of number of paths, delay spread, azimuth spread (ASA) and elevation angle spread (ZSA), obtained at each Rx position. From the results, it is verified that there are not strong dependences of the number of paths and the ASA on the positions of the Rx and floor number. On the other hand, we also verify that the delay spreads are become larger when the distances from window are further, and the ZSAs at the positions near by windows are become larger when the floor number increases.

To analyze the propagation mechanisms of multipath, we assume that all arrival paths (multipath) scatter just once (single scattering). Based on this assumption and from the measurement results of delay times and arrival angles of multipath, the single scattering positions of multipath can be estimated as shown in Fig.3. In this figure, the star marks are the single scattering positions of multipath which have relative powers over -20 dB. From the estimated results, the single scattering position of path #1 is quite matched with the wall of the building B0, so the path #1 with single scattering is appropriate with the assumption. For the other paths, the single scattering positions are not quite match with the walls of any buildings, so these paths have multiple scattering positions. The path #2 is one example of paths with two scattering positions can be predicted. Moreover, based on the estimated results, the scattered areas can be also predicted as shown in Fig.3a. Group 1 is scattered by the building B0 and group 2 is scattered by the building B2. On the other hand, group 3 is scattered between the building B0 and the building B1. From the comparison results between Fig.3b and Fig.3c, it is verified that when the Rx was at the position of 16m from the window W0, there are some arrival paths scattered at the building B2 with long delay resulting in larger delay spread than the case of the Rx was at the position of 2m from the window W0 (shown in Fig.2b). And from the comparison results between Fig.3c and Fig.3d, the difference in ZSA of Fig.2d is also verified.

4. Conclusion

In this paper, we measured the Outdoor-to-Indoor (O2I) channel characteristics at the 20 GHz band by using a channel sounder and by rotating a horn antenna. From measurements results, the basic characteristics of number of paths, delay spread, ASA, ZSA are clarified. The propagation mechanisms of multipath are also analyzed. In future work, we plan to compare measurements results with ray tracing results and analyze the clustering characteristics of O2I channel.

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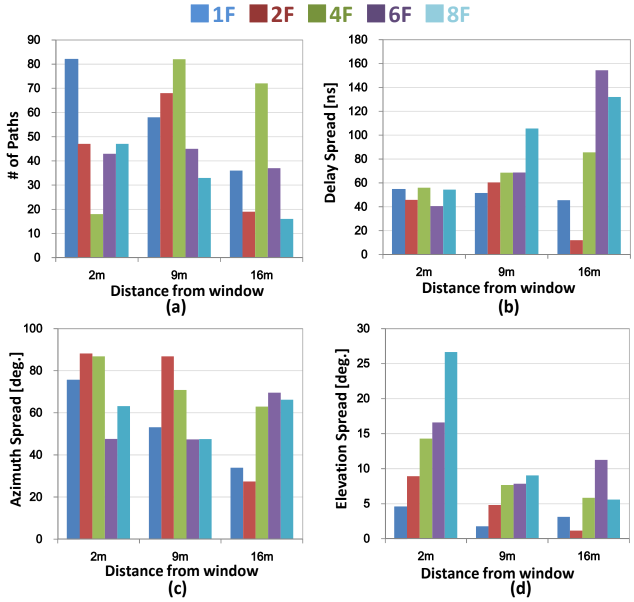

Fig.2. O2I channel characteristics

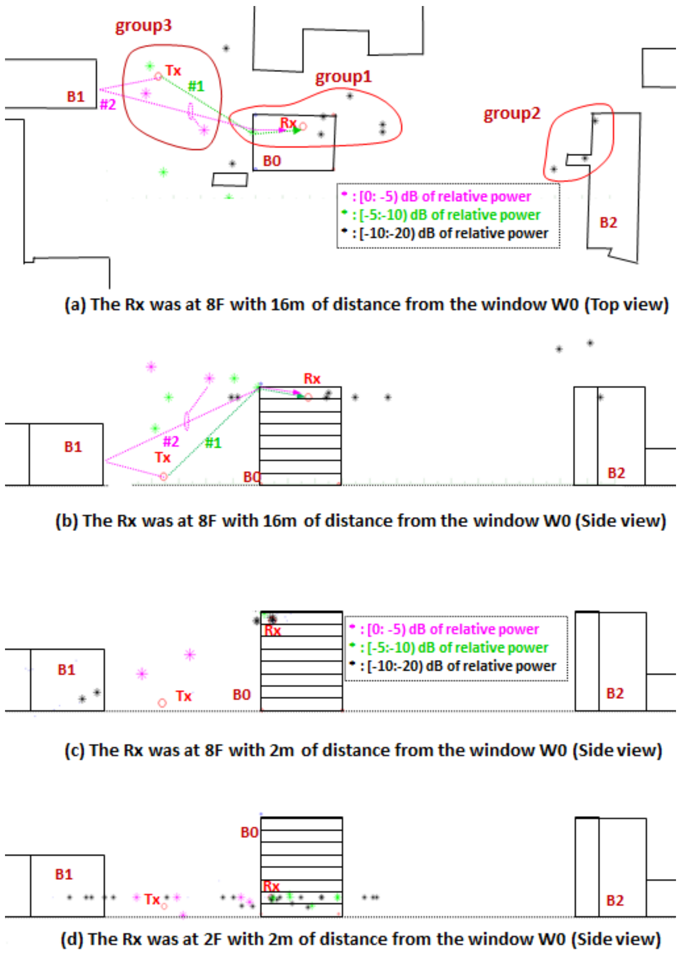

Fig.3. Single scattering positions of multipath