

Impact of Antenna Beamwidth and Obstructions on 400 GHz Inter-Rack THz Links

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Abstract— This paper investigates the R.M.S. delay spread characteristics of inter-rack wireless communication in a data center environment at 400 GHz. Measurements were conducted using 10°, 30°, and 60° horn antennas with and without mesh-type obstructions. Results show that narrower beamwidths lead to lower delay spreads, while wider beams capture more multipath components. The presence of mesh obstacles, particularly rack back covers, significantly reduces delay dispersion. These findings provide practical insight into the impact of antenna design and environmental structures on terahertz propagation, supporting efficient THz wireless link design for future data centers.

Keywords—R.M.S. delay spread, Rack, Measurement

I. INTRODUCTION (HEADING 1)

The explosive growth of data traffic and the rising demand for ultra-high-speed wireless communication have increased interest in the terahertz (THz) frequency band, especially for dense indoor environments like data centers. According to Shannon's theory, expanding bandwidth is key to enhancing channel capacity. However, conventional frequency bands are congested, and mmWave systems face limitations due to interference and spectrum scarcity. To address this, the International Telecommunication Union (ITU) has extended the frequency range in Recommendation ITU-R P.1238-11 [1] from 100 GHz to 450 GHz, while WRC-19 [2] updated the allocation table to support active services between 275 and 450 GHz. These changes are reflected in ITU-R Report M.2417 [3], which outlines THz applications such as kiosk data downloads, intra-chip wireless links, and inter-rack communication in data centers. THz wireless interconnects offer a compelling solution for data centers requiring low-latency, high-throughput, and interference-free communication. Although prior studies have examined propagation characteristics in the 275–295 GHz range using horn antennas with varying beamwidths, further investigation at higher frequencies near 400 GHz is needed to generalize findings and support future deployment. This paper analyzes delay spread and relative received power in a 400 GHz inter-rack environment, focusing on the effects of antenna beamwidth and obstructions like mesh panels and cabling. High-resolution time-domain measurements using a vector network analyzer and frequency extenders are used to characterize multipath propagation and provide a modeling basis for next-generation THz wireless systems in data centers.

II. MEASUREMENT CAMPAIGN

To evaluate the propagation characteristics of the 400 GHz band in a data center environment, a measurement campaign

was conducted at the Space Radio Research Center of the National Radio Research Agency (NRRA) in Jeju, Korea. The environment emulates realistic inter-rack communication scenarios with and without obstructions, reflecting practical deployment conditions in future THz-based data centers.

A. Measurement Setup

The measurement system comprises a vector network analyzer (VNA, Keysight N5222A) and a WR2.2-band frequency extender (VDI WM-570 VNAX), enabling wideband measurements in the 410–420 GHz range with 1200 frequency points, corresponding to a step size of 8.333 MHz and time-domain resolution of 0.1 ns. The intermediate frequency (IF) bandwidth was set to 1 kHz to ensure high dynamic range. Three horn-type directional antennas with half-power beamwidths of 10°, 30°, and 60°, as well as an omnidirectional antenna, were used. Both transmitter and receiver antennas were vertically polarized. For each measurement configuration, the same beamwidth was applied to both the transmitting and receiving antennas to maintain consistency in angular resolution.

B. Measurement Scenario

The transmitter antenna was fixed during all measurements, while the receiver antenna was moved along two orthogonal directions—Back (B) and Horizontal (H)—relative to the rack. The receiver was moved from 0 mm to 300 mm in 3 mm increments, capturing fine-grained spatial variation in received signal characteristics. Measurements were repeated using 10°, 30°, and 60° horn antennas for each configuration, with the omni antenna used as a reference.

1) No Obstruction

In this baseline setup, no objects were placed between the transmitter and receiver. The objective was to measure the direct propagation channel and its reflection from nearby surfaces. Measurements were performed for each antenna beamwidth and along both B and H axes. This configuration provides the reference for delay spread and received power analysis.

2) Obstructed Environment with Mesh Panels

To study the influence of partial obstructions commonly found in data centers (e.g., metal structures, cabling), three different sizes of metal mesh panels—referred to as Big Mesh, Small Mesh, and Rack Mesh—were installed between the transmitter and receiver. These mesh panels simulate real-world obstacles such as server chassis, vertical rack mounts, or structured LAN wiring trays. The measurement protocol

(antenna types, moving distances, and directions) was identical to the no-obstruction scenario, allowing direct comparison.

III. MEASUREMENT RESULTS

Figures 1 to 4 present the CDFs of R.M.S. delay spread for various antenna beamwidths (10° , 30° , 60°) under four environmental conditions: no mesh, small mesh, large mesh, and rack back cover mesh. Measurements were taken by fixing the transmitter and moving the receiver in 3 mm steps up to 300 mm along back and horizontal directions. In the no-obstruction case, wider beamwidths exhibit larger delay spreads due to their broader angular reception. The 10° antenna shows compact delay values mostly below 1 ns, whereas the 60° antenna reaches up to 3 ns, capturing more multipath components. With small and large mesh obstacles, the delay spreads of the 10° and 30° antennas remain tightly grouped under 0.6 ns and 0.4 ns respectively, while the 60° antenna still records values up to 1.6–1.8 ns. This suggests that mesh panels partially block or scatter NLoS paths, reducing temporal dispersion, especially for narrow beams. In the rack back cover mesh case, all beamwidths show reduced delay spreads. The 10° and 30° antennas are mostly below 1 ns, and the 60° antenna remains under 2.5 ns, indicating effective suppression of reflections. Overall, narrower beamwidths consistently yield lower delay spreads, and the presence of mesh obstacles reduces multipath delay, particularly when combined with directional antennas. These results highlight the importance of beamwidth and obstruction type in shaping delay characteristics in THz intra-data center environments.

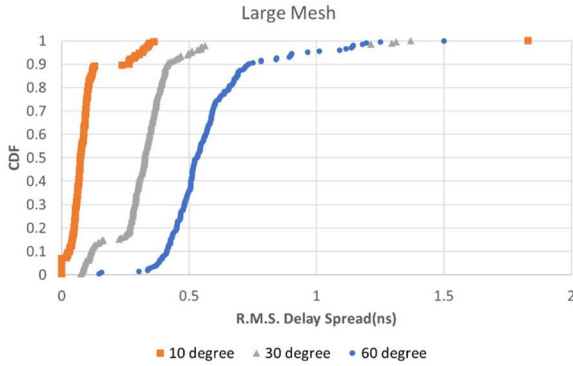


Fig. 1. CDF graph for R.M.S. delay spread of large mesh

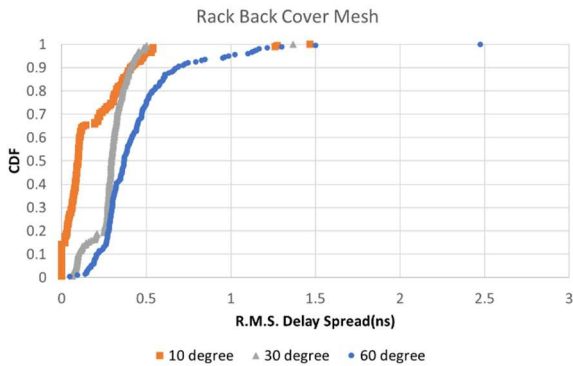


Fig. 2. CDF graph for R.M.S. delay spread of rack back cover mesh

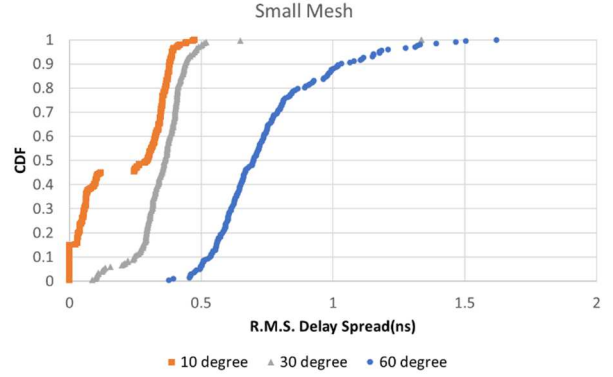


Fig. 3. CDF graph for R.M.S. delay spread of small mesh

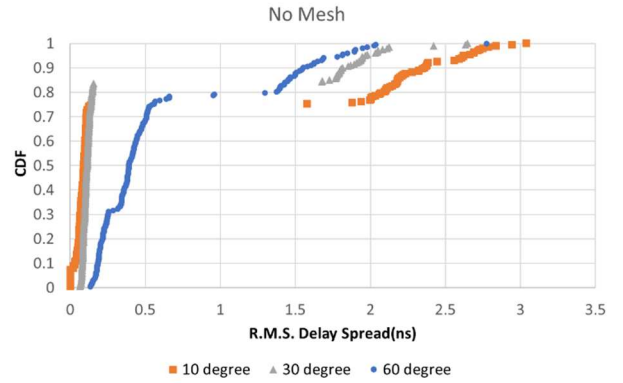


Fig. 4. CDF graph for R.M.S. delay spread of no mesh

IV. CONCLUSION

This study examined R.M.S. delay spread characteristics at 400 GHz in a data center inter-rack environment using horn antennas with 10° , 30° , and 60° beamwidths under various obstruction scenarios. Results show that narrower beamwidths yield lower delay spreads, while wider beams capture more multipath components, especially without obstructions.

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