Analysis of the Effect of Antenna Beamwidth on Received Power in Large Indoor Environments Based on Millimeter-Wave Channel Measurements

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Abstract—When a narrow-beamwidth antenna is employed, all the multipath components from arbitrary directions may not be received due to the spatial filtering of the antenna. In this paper, we study the effect of antenna beamwidth on received power, based on millimeter-wave narrow-beamwidth directional antenna measurements. Unlike our prior work on outdoor environments, this paper focuses on large indoor environments, such as passenger terminals of a railway and an airport, which are potential hot-spot candidates for 5G millimeter-wave systems.

Index Terms—Propagation, channel model, millimeter-wave system, beamforming

1. Introduction
Owing to the consideration of millimeter-wave frequency allocation for 5G networks, beamforming techniques have been developed to overcome the associated propagation losses. One fundamental challenge relevant to the beamforming is the determination of the beamwidth to maximize the signal reception while balancing the directivity gain. When there are numerous multipaths from various directions, the solution becomes complicated since the signal reception is dependent on both the beamwidth and the surrounding multipath environments. Based on millimeter-wave measurements that were collected in multipath-rich indoor environments such as passenger terminals of a railway station and an airport, we investigate the effects of antenna beamwidth on received power. Note that we conducted a similar study for multipath-rich outdoor environments as in [1]. This paper focuses on indoor propagation environments in which scatterers are typically located close to the transmit and receive antennas.

2. Measurement Overview
We conducted measurement campaigns with 28 GHz and 38 GHz millimeter-wave channel sounder (detail specifications can be found in [2]). Measurement data were collected not only with omnidirectional antennas but also with 10° HPBW horn antennas. Other beamwidth data were synthesized with the algorithm introduced in [1].

Fig. 1 shows two large indoor measurement sites in which locations of TX and RX are marked: passenger terminals of Seoul railway station and Incheon International Airport.

(a) Site: Seoul Railway Station passenger terminal
(b) Site: Incheon International Airport passenger terminal

Fig. 1: Large indoor environment measurement layout

These two sites can be considered as hotspot areas. At TX, we installed a wide-beamwidth (30° HPBW) antenna and positioned it to cover the entire range of interest (shown in a grey shaded area in the figures). At every RX point in the figures, we collected measurements with both an omnidirectional antenna and a narrow-beamwidth horn antenna (10° HPBW). The horn antennas were rotated in 10° steps.

3. Measurement Results and Analysis
Fig. 2 shows the comparison between the omnidirectional and the 10° horn directional antenna measurements. Although the data were collected at similar positions, the path loss measurements show different behaviors, especially for the NLOS (non-line-of-sight) situations. This is because, in NLOS, no dominant propagation path is established and only a small portion of the multipath components is
captured with the narrow-beamwidth antenna. Note that we observed that the synthesized omnidirectional data from the narrow-beamwidth antenna measurement data was gotten by following the procedure in [1] and have a good agreement, although we did not show the plot here due to the space limitation.

TABLE I: Constant \( \eta \) for the directional-antenna shaping loss for large indoor environments

<table>
<thead>
<tr>
<th>Freq</th>
<th>Link type</th>
<th>( \eta )</th>
<th>RMSE (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 GHz</td>
<td>LOS</td>
<td>28.46</td>
<td>0.26</td>
</tr>
<tr>
<td>NLOS</td>
<td>70.54</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>38 GHz</td>
<td>LOS</td>
<td>26.66</td>
<td>0.36</td>
</tr>
<tr>
<td>NLOS</td>
<td>76.77</td>
<td>1.34</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2: Omnidirectional vs \( 10^9 \) directional ant. measurements

Fig. 3: Additional loss \( \Delta L \) as a function of beamwidth \( W_\phi \) terminals of a railway station and an airport. We have shown that the total received power (or propagation loss) can be obtained by adding an additional loss term to the existing omnidirectional propagation loss, which is an inverse function of the antenna beamwidth.

4. Conclusion

We have investigated empirically the antenna beamwidth effects on the received power for multipath-rich indoor environments. This study was conducted by examining millimeter-wave measurement data collected in passenger

References


[3] 3GPP TR 38.901, Study on channel model for frequencies from 0.5 to 100 GHz (Release 14), Mar. 2017.