High-Resolution Directional Channel Measurements at 67 GHz and Advanced Analysis of Interactions Using Geometric Information

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Abstract—This paper presents results from a high-resolution channel measurement campaign at 67 GHz in a street canyon in Tokyo, with focus on an extended evaluation method which incorporates map-based side information. Besides being beneficial for validating the results of the path estimation, the analysis allows the identification of main sources of interaction and the differentiation between first and higher order interactions.

I. INTRODUCTION

Fifth generation (5G) mobile networks need to make use of millimeter-wave frequencies to provide ultra-high data rates and capacity. In recent years, huge efforts have been made to develop suitable frequency-agile channel models up to 100 GHz [1], [2]. Besides geometry-based stochastic channel models (GSCMs), deterministic ray tracing models are of particular interest. However, questions remain regarding accurate parameterization and its dependence on the propagation environment. The evaluations in this paper aim to make a contribution towards these issues. They make use of channel virtual array channel sounding data collected during an outdoor measurement campaign at 67 GHz. The advanced path analysis, which is based on the same principle as the environment reconstruction method in [3], makes it possible to identify peculiarities of the propagation environment and draw conclusions about the requirements of map-based simulations.

II. MEASUREMENT SETUP AND SCENARIO

The measurements were performed at 67.25 GHz carrier frequency with a modular channel sounder setup based on Rohde & Schwarz (R&S) test and measurement equipment and dedicated hardware, similar to the setup used in [4]. At the transmitter (Tx) side, an R&S SMW with an integrated baseband generator was used in combination with an external V-band upconverter and a power amplifier (PA) to generate the periodic correlation sounding signal with 2 GHz bandwidth and 15 dBm Tx power. As receiver (Rx), an R&S FSW85 signal and spectrum analyzer was operated along with an external V-Band preamplifier and an R&S RTO digital oscilloscope for wideband data acquisition. On both sides, omnidirectional antennas with vertical polarization were used, with a motor-controlled virtual circular array (VCA) setup at the Rx. It enabled to measure 1000 virtual antenna elements on a circular line (horizontal plane, 100 mm diameter) through full rotation within 50 ms [4]. Synchronization and triggering of Tx and Rx were accomplished with a Fraunhofer HHI Synchronomat device in combination with a commercial caesium clock.

The measurement campaign was carried out in a typical street canyon lined by multi-story buildings in downtown Tokyo, Nihombashi-Kabutocho, representing an urban micro (UMi) scenario. As visible in Fig. 4, a fixed Rx position (coordinates: 35.679098 N, 139.777154 E) was chosen on a lane of the street with an antenna height of 3 m. The Tx (antenna height: 1.5 m) was successively placed to 20 different positions on the sidewalk. Nine line-of-sight (LOS) positions are taken into account for the following evaluations.

III. DATA PROCESSING AND RESULTS

The average power delay profile (APDP) is derived for each Tx position (pos.) by averaging over the set of 1000 channel impulse responses (CIRs) obtained from a full rotation of the VCA antenna. Peaks in the APDP above the noise threshold give an estimate of the channel taps. On each tap, beamspace MUSIC is applied to estimate multiple incorporated propagation paths in polar and azimuth angle [4].

A. Discussion of an Exemplary Result

Fig. 1 shows an exemplary APDP for Tx pos. 4 along with the estimated taps. It exhibits a very high temporal resolution (≈ 0.5 ns) associated with the large measurement bandwidth, and a measurable path loss up to 127 dB. The measurements typically yield around 50 taps, with three paths

Fig. 1. Average power delay profile for Tx pos. 4 with estimated taps.
The overall normalized path power is based on the path estimations, including the differentiation between first order and higher order interactions. They are associated with higher order interactions by a building or are below the ground (rays displayed in cyan color). They are associated with higher order interactions.

From Fig. 2, it is obvious that several virtual first order interaction points (IPs) are the building walls, but other objects like trees and vehicles also induce relevant propagation paths. Main sources of reflection could be identified and the propagation paths could be classified into first and higher order interactions. The presented method is very useful to validate and illustrate direction-resolved measurement results, investigate site-specific propagation in more detail and derive requirements for map-based channel simulations. In the investigated LOS scenario, the LOS path and first order interactions contribute to at least 90% of the received power.

B. Consolidated Result of Multiple Transmitter Positions

To identify main sources of interaction, the individual results of all Tx positions were merged. Fig. 4 displays the estimated LOS paths and first order interactions. The evaluation reveals that most first order interactions are attributed to reflections on the building surfaces and the ground. However, various IPs (see road junction and right side of Figure) arise from trees and vehicles. Furthermore, it is visible that the estimated Tx pos. 8, 14 and 16 slightly deviate from the actual positions and fall into buildings due to small errors in the azimuth angle of arrival which take affect over longer distances.

IV. Conclusion

A channel measurement campaign was conducted in an urban micro scenario in Tokyo to investigate site-specific propagation at 67 GHz. The data captured with the wideband channel sounder setup involving a motor-controlled virtual array antenna allowed an accurate estimation of the propagation paths. By incorporating the building positions, the main sources of interaction could be identified and the propagation paths could be classified into first and higher order interactions. The presented method is very useful to validate and illustrate direction-resolved measurement results, investigate site-specific propagation in more detail and derive requirements for map-based channel simulations. In the investigated LOS scenario, the LOS path and first order interactions contribute to at least 90% of the received power. Main sources of reflection are the building walls, but other objects like trees and vehicles also induce relevant propagation paths.

REFERENCES

[1] 3rd Generation Partnership Project (3GPP), “3GPP TR 38.910 V14.3.0: Study on channel model for frequencies from 0.5 to 100 GHz (Release 14),” Dec. 2017.